DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

BULLETIN 520

MINERAL RESOURCES OF ALASKA

REPORT ON PROGRESS OF INVESTIGATIONS IN 1911

BY

ALFRED H. BROOKS AND OTHERS

WASHINGTON
GOVERNMENT PRINTING OFFICE
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PREFACE.

By Alfred H. Brooks.

The mineral industry of Alaska is, for the most part, in a stage of development where the results of even preliminary surveys and examinations have their maximum value to the miner and prospector. This value is much increased by making the results of investigations available at the earliest date possible to those who are developing this new land. As the complete reports and maps can not be prepared and printed for a year or a year and a half after the field work is completed the Survey, in 1905, began the practice of issuing an annual bulletin containing abstracts of the more important economic conclusions reached by its geologists as a result of their explorations. The present volume is the eighth[1] of this series to be published. Such advance publication of results necessitates more or less haste in preparation, and the conclusions set forth may therefore be somewhat modified when the more exhaustive office study has been completed. Hence, those interested in any particular district are urged to procure a copy of the complete report as soon as it is available.

In addition to presenting preliminary statements on investigations made during the year, this volume, like those previously issued, summarizes the conditions of the mining industry and presents statistics of production and other data. It is intended that this series of reports shall serve as condensed statements of the progress of the mining industry for the years which they cover. The fund available for Alaskan exploration is too small to permit a visit to every mining district each year by a member of the Survey. Therefore the data

[1] Report on progress of investigation of the mineral resources of Alaska, 1904: Bull. U. S. Geol. Survey No. 259, 1905; Idem, 1905: Bull. 284, 1906; Idem, 1906: Bull. 314, 1907; Idem, 1907: Bull. 345, 1908; Idem, 1908: Bull. 379, 1909; Idem, 1909: Bull. 442, 1910; Idem, 1910: Bull. 480, 1911.

used in the preparation of the summaries contained in this volume are, in part, based on information gleaned from various sources.

Again, as in previous years, the writer is under great obligations to many residents of the Territory for valuable data furnished. Those who have thus aided include many mine operators, engineers, prospectors, Federal officials, and officers of banks and of transportation and commercial companies. It is impossible to enumerate all who have contributed information, but special acknowledgment should be made to the following: The Director of the Mint; Chas. D. Garfield, of Juneau; Alaska Mexican Gold Mining Co., Alaska United Gold Mining Co., and Alaska Treadwell Gold Mining Co., of Treadwell; R. M. Odell, of Haines; C. C. Noughton, of Katalla; Geo. M. Esterly, of Nizina; Stephen Birch, of Kennecott; Melvin Dempsey, of Dempsey; H. E. Ellsworth, of Seward; W. H. Hammer, of Sunrise; M. M. Reese, of Valdez; Henry S. Tibbey, of Chignik; Thos. H. Hanmore, of Iliamna; R. W. J. Reed, of Nome; John A. Dexter, of Golovin; Geo. W. Woodruff, of Fortymile; A. M. Allma, of Miller House; John L. Abrams, of Eagle; Frank Slaver, of Woodchopper Creek; Edw. H. Boyer, Jos. R. Mathews, Wells Fargo Co., American Bank, and First National Bank, of Fairbanks; T. M. Thurston, Geo. Y. Kilroy, and Cyril P. Wood, of Iditarod; John D. Leedy, of Quinhagak; H. W. Reeth, of Seattle; and W. E. Thorpe, of the Yuba Construction Co. Besides these many mine operators have furnished information in regard to mineral production.

The arrangement and manner of treatment in this volume is the same as in those previously issued. First, papers of a general character are presented, followed by those treating of special districts, treated geographically from south to north. This bulletin contains 19 papers by 12 authors. One of these papers deals with administrative matters, eight are summaries of particular features of the mining industry, and the remainder deal more specifically with the economic geology of special districts. In the geologic papers emphasis is laid on the conclusions having immediate interest to the miner, which will, however, be discussed here briefly but will be more fully treated in reports now in preparation. The need of prompt publication requires that the illustrations in this volume be of the simplest kind.

ADMINISTRATIVE REPORT.

By Alfred H. Brooks.

INTRODUCTION.

Thirteen parties were engaged during 1911 in Alaskan surveys and investigations. The length of the field season varied from three to six months, being determined by the climatic conditions prevailing in different parts of the Territory. The parties included 12 geologists, 4 topographers, 2 engineers, and 30 packers, cooks, and other auxiliaries. In addition to these, some gage readers were employed, who gave only part of their time to the work. Seven of the parties were engaged in geologic work, one in both geologic and topographic surveys, three in topographic surveys, and two in investigating water resources.

The areas covered by geologic exploratory surveys, on a scale of 1:500,000 or 1:1,000,000 (8 or 16 miles to inch), amount to 8,000 square miles; by geologic reconnaissance surveys, on a scale of 1:250,000 (4 miles to the inch), 10,550 square miles; by detailed geologic surveys, on a scale of 1:62,500 (1 mile to the inch), 496 square miles. Much of the time of the geologists was devoted to the investigation of special field problems in the important mining districts, the results of which can not be presented areally. About 14,460 square miles of topographic reconnaissance surveys, on a scale of 1:250,000 (4 miles to the inch), and 246 square miles of detailed topographic surveys, on a scale of 1:62,500 (1 mile to the inch), were completed.

Sixty-eight gaging stations were maintained in the Yukon-Tanana region in 1911 for an average of 15 weeks each, furnishing data on the water resources of the Fortymile, Eagle, Seventymile, Birch Creek, and Fairbanks districts.

To state the work geographically, two parties were in the Copper River basin, one on Prince William Sound (later transferred to Kenai Peninsula), three on Kenai Peninsula, one in the Susitna basin, four in the Yukon-Tanana region, one in northeastern Alaska, and one in northwestern Alaska.

Among the important results of the year were the completion of a detailed topographic survey of the most important part of the Port Valdez mining district and of a reconnaissance topographic survey of the northern part of Kenai Peninsula. Geologic and topographic reconnaissance surveys of the Hanagita Valley and Bremner River regions were also completed. A geologic and topographic exploration of the Noatak Valley was made, and the geologic reconnaissance mapping of the Circle and Rampart quadrangles was completed.

The following table shows allotment, including both field and office expenses, of the total appropriation of $100,000 to the districts investigated. In preparing this table the general office expenses were divided among the districts in proportions determined by the cost of the surveys in each district, allowance being made for variations in the character of the work. The results are expressed in round numbers. The item "General investigations" includes the cost of working up field data on districts that were not under survey during the year and the cost of collecting the statistics of production.

Allotment to Alaskan surveys and investigations in 1911.

Copper River region	$18,500
Prince William Sound	4,800
Kenai Peninsula	24,500
Susitna basin	5,100
Yukon basin	23,700
Noatak region	11,700
Northeastern Alaska	5,500
General investigations	6,200
	100,000

In the following table the approximate amount of money devoted to each class of investigations and surveys is indicated. It is not possible to give the exact figures, as the same party or even the same man may have carried on two different kinds of work, but this statement will help to elucidate a later table, which will summarize the complete areal surveys:

Approximate allotments to different kinds of surveys and investigations in 1911.

Geologic exploration	$5,200
Geologic reconnaissance surveys	37,600
Special geologic investigations	7,500
Topographic reconnaissance surveys	25,500
Detailed topographic surveys	4,700
Investigation of water resources	6,500
Collection of statistics of mineral production	1,100
Miscellaneous, including clerical salaries, administration, inspection instruments, office supplies, and equipment	11,900
	100,000

Allotments for salaries and field expenses, 1911.

Scientific and technical salaries	$34,860
Field expenses	55,440
Clerical and other office salaries	9,700
	100,000

The following table exhibits the progress of investigations in Alaska and the annual grant of funds since systematic surveys were begun in 1898. It should be noted that a varying amount is expended each year on special investigations, yielding results which can not be expressed areally.

Progress of surveys in Alaska, 1898–1911.[a]

Year.	Appropriation.	Areas covered by geologic surveys.			Areas covered by topographic surveys.[b]					Water-resources investigations.	
		Exploratory (scale 1 : 625,000 or 1 : 1,000,000).	Reconnaissance (scale 1 : 250,000).	Detailed (scale 1 : 62,500).	Exploratory (scale 1 : 625,000 or 1 : 1,000,000).	Reconnaissance (scale 1 : 250,000; 200-foot contours).	Detailed (scale 1 : 62,500; 25, 50, or 100 foot contours).	Lines of levels.	Bench marks set.	Gaging stations maintained part of year.	Stream volume measurements.
		Sq. m.	Sq. m.	Sq. m.	Sq. m.	Sq. m.	Sq. m.	Miles.			
1898	$46,189.60	9,500			12,840	2,070					
1899	25,000.00	6,000			8,690						
1900	60,000.00	3,300	6,700		630	11,150					
1901	60,000.00	6,200	5,800		10,200	5,450					
1902	60,000.00	6,950	10,050		8,330	11,970	96				
1903	60,000.00	5,000	8,000	96		15,000					
1904	60,000.00	4,050	3,500		800	3,480	480	86	19		
1905	80,000.00	4,000	4,100	536		4,880	787	202	28		
1906	80,000.00	5,000	4,000	421		13,500	40			14	286
1907	80,000.00	2,600	1,400	442		6,120	501	95	16	48	457
1908	80,000.00	2,000	2,850	604		3,980	427	76	9	53	556
1909	90,000.00	6,100	5,500	450	6,190	5,170	444			81	703
1910	90,000.00		8,635	321		13,815	36			69	429
1911	100,000.00	8,000	10,550	496		14,460	246			68	309
Total	971,000.00	68,700	71,085	3,366	47,680	114,045	3,057	459	72		
Percentage of total area of Alaska		11.72	12.12	0.57	8.16	19.45	0.52				

[a] The areas presented in this table differ somewhat from those previously published. This is due in part to the reclassification of the work and in part to the fact that the areas have been more carefully scaled from the maps than formerly.

[b] In addition to the above, the International Boundary Survey and the Coast and Geodetic Survey have made surveys of parts of Alaska.

GEOGRAPHIC DISTRIBUTION OF INVESTIGATIONS.

GENERAL WORK.

The writer was employed in office work until August, when he proceeded to Seattle and joined the party of the Secretary of the Interior. Details in regard to the itinerary of the Secretary's party have been published elsewhere. It will therefore be sufficient to state that parts of the Bering River coal field and of the Katalla oil field were visited and that the itinerary included journeys over the Copper

River, Alaska Northern, and White Pass railways, down the Lewis River to Lake Labarge, and about 15 miles of the Valdez-Fairbanks military road. The writer left the party at Skagway on September 4 and proceeded to Juneau, where he spent two days in visiting some of the mines. Thence he returned to Valdez, arriving on September 11. The succeeding 10 days he devoted to a rapid reconnaissance of a part of the Port Valdez mining district (see pp. 108–130), reaching Seward on September 24. Ten days were then spent in studying the geology and mineral resources of a part of the Kenai Peninsula in company with Mr. Johnson and Mr. Martin, and conferences were also held in regard to topographic surveys with Mr. Sargent and Mr. Bagley. Returning, the writer reached Seattle on October 15, whence he proceeded to San Francisco to meet the Director of the Survey, and after attending the meeting of the American Mining Congress, at Chicago, returned to Washington, arriving on October 28.

Of the time spent in the office, the geologist in charge has devoted about 38 days to reading and revision of manuscripts, 35 days to preparing matter for progress report, 33 to writing scientific articles, 5 days preparing the annual press bulletin, 7 days to statistics of mineral production, 7 days to public land surveys and the remainder to routine and miscellaneous matters.

R. H. Sargent continued the general supervision of the topographic surveys and map compilation in addition to carrying on his own field work. J. W. Bagley spent considerable time in devising methods and instruments for photo-topographic surveys. These were successfully applied by him in his field work.

E. M. Aten continued as office assistant to the geologist in charge and supervised the office work during the writer's absence in the field. He also continued to assist in collecting statistics of production of precious metals in Alaska.

Arthur Hollick continued the study of the fossil flora of the coal measures of Alaska, a work which it is believed will have great economic value in the determination of the stratigraphy of the coal fields. W. W. Atwood also continued some office studies bearing on the coal resources of Alaska.

SOUTHEASTERN ALASKA.

Systematic surveys and investigations were begun in southeastern Alaska in 1901 and continued each season until 1910. The demands for surveys in other parts of the Territory prevented any further work in this province in 1911. This was unfortunate, for though the preliminary examination of much of this area has been made and detailed surveys of the most important mining districts have been completed, there is still great need for reconnaissance surveys which shall outline more definitely the geologic formations and thus furnish further evidence on the distribution of mineral resources.

Some office work was done on a report treating of Glacier and Lituya bays region, by F. E. Wright. C. W. Wright still has in hand the report on the copper deposits of the Kasaan Peninsula and Copper Mountain regions. His professional duties in Sardinia have prevented him from completing this report as he had hoped. The report on the Sitka mining district has been published and that on the Eagle River district is in press. Both these reports are by Adolph Knopf.

COPPER RIVER REGION.

During a few weeks in the fall of 1900 the lower Copper River was covered by an exploratory survey, which yielded results that have been of inestimable value to prospectors and railway engineers but were not up to the present standards of mapping. In view of the importance of the region it was decided to revise this work, and this task was assigned to D. C. Witherspoon, who was also charged with the work of extending the reconnaissance survey southward from Hanagita Valley to the Bremner River region. Mr. Witherspoon, with a party of four men, began field work on June 13 and continued it until October 3. During this time he revised the mapping of an area of 900 square miles and surveyed a new area of 1,000 square miles. This work was done for publication on a scale of 1:250,000. Mr. Witherspoon also occupied some 20 triangulation stations, which formed part of a scheme for a system of triangulation from Copper Center to Chitina and from Chitina to head of Bremner River.

F. H. Moffit, assisted by Theodore Chapin, made a geologic reconnaissance survey of about 1,500 square miles in the Hanagita Valley and Bremner River region and also examined the copper lodes and gold placer prospects of the region. (See pp. 93–104.) The party, which consisted of three men besides the geologist, began work on June 13 and continued until September 15.

PRINCE WILLIAM SOUND.

J. W. Bagley, with three men, made a detailed topographic survey of the most important part of the Port Valdez mining district. Work in this district was begun on April 25 and continued until July 21, when the party was transferred to Kenai Peninsula. He was assisted by C. E. Giffen up to May 30. An area of 160 square miles was covered in this survey for publication on a scale of 1:62,500, with 50-foot contours. The geologic reconnaissance of this area by the writer, which has already been noted, is reported on pages 108–130.

KENAI PENINSULA.

R. H. Sargent, with a party of four men, began field work at Kachemak Bay on June 9 and carried a topographic reconnaissance survey northward to Turnagain Arm. The work included the revision and original mapping of part of the Sunrise placer district, and later the drainage basin of Resurrection River near Seward was surveyed. Surveys were continued until October 5. All told, an area of 3,100 square miles was surveyed, besides which the mapping of some 660 square miles was revised. These surveys were made for publication on a scale of 1:250,000, with 200-foot contours.

J. W. Bagley, who began work on Kenai Peninsula on July 25 and continued it, so far as weather permitted, until October 13, made detailed topographic surveys of an area of 86 square miles (scale, 1:62,500) in the Moose Pass region and also covered some 360 square miles by reconnaissance surveys, besides revising the mapping of an area of 170 square miles. These surveys were made by photo-topographic methods.

G. C. Martin, assisted by Harmon Lewis, carried a geologic reconnaissance northward from Port Graham to Kenai River, then eastward to Alaska Northern Railway. In addition, Mr. Martin made some special geologic investigations in other parts of the peninsula. The Martin party began field work on June 23 and closed it on September 30, during which time an area of 800 square miles was mapped on a scale of 1:250,000.

In view of the discovery and developments of auriferous lodes in the northern half of Kenai Peninsula, a special investigation of these lodes was determined upon, and B. L. Johnson was assigned to this work. Mr. Johnson began field work near Seward on May 31 and closed it on October 26. He made a more or less detailed examination of most of the important lodes and of many of the gold placers (see pp. 131–173) and also mapped the geology of the area covered by Mr. Bagley's survey in the Moose Pass region.

To summarize the results accomplished in Kenai Peninsula: Detailed topographic and geologic surveys were made of 86 square miles, topographic reconnaissance surveys of 3,520 square miles, and the mapping of 830 square miles was revised. Some 800 square miles were covered by geologic reconnaissance surveys, and in addition most of the important lode and placer deposits were studied in some detail.

It has been decided to incorporate the results of the surveys of the southeastern part of the peninsula made in 1909 [1] by U. S. Grant and D. F. Higgins in a report which shall include all the data collected by the above parties.

[1] Preliminary report on the mineral resources of the southern part of Kenai Peninsula: Bull. U. S. Geol. Survey No. 442, 1910, pp. 166–178.

SUSITNA BASIN.

S. R. Capps, with one man, completed a geologic reconnaissance of the Yentna placer district between June 10 and September 15. The area covered was about 2,000 square miles, and the work included the examination of all the important gold placers of the district. (See pp. 174–200.)

YUKON BASIN.

L. M. Prindle, assisted by J. B. Mertie, with a party of three men, completed the areal reconnaissance mapping of the larger part of the Circle quadrangle, located in the Yukon-Tanana region. Field work was begun on June 23 and continued until September 9, when an area of about 4,000 square miles had been covered. Mr. Prindle also made a study of the placers of Fourth of July Creek. (See pp. 201–210.)

Henry M. Eakin completed the geologic reconnaissance mapping of that part of the Rampart quadrangle (Yukon-Tanana region) which had been previously covered by topographic surveys. He also carried the work west of the Yukon over a previously unmapped area, where some topographic sketch maps were made. The Eakin party, consisting of two men, mapped an area of about 2,000 square miles during the field season, which extended from June 24 to August 29, and also examined the gold placers of the Rampart, Hot Springs, and Gold Mountain districts. (See pp. 271–286.)

The investigation of the water resources of the Yukon-Tanana region, which was begun at Fairbanks in 1907, was continued in 1911. E. A. Porter, who began work April 27, carried on investigations in the Fortymile district, where 27 gaging stations were maintained for 17 weeks and 80 measurements were made; in the Eagle district, where 6 stations were maintained for 15 weeks and 28 measurements made; and in the Seventymile district, where 9 stations were maintained for 14 weeks and 46 measurements made. Mr. Porter continued his field work until September 15. (See pp. 219–239.)

C. E. Ellsworth began work in the Birch Creek district on April 20, where 15 stations were maintained for an average of 15 weeks and 78 measurements were made. Later he extended work to Fairbanks district, where 10 stations were maintained for an average of 15 weeks and 74 measurements made; and to the Salchaket district, where 1 station was maintained for 15 weeks and 3 measurements were made. Mr. Ellsworth continued his field work until August 21. (See pp. 240–270.)

NORTHEASTERN ALASKA.

By courtesy of the boundary commissioner, Mr. O. H. Tittmann, the Survey was enabled to attach a geologist to the party which was engaged in surveying the boundary north of Porcupine River. A. G. Maddren, assisted by J. M. Jessup, was detailed for this work.

Field work was begun on Porcupine River on June 7 and was closed on August 31. The topographic maps of the boundary surveyors (scale 1:45,000) were used as a base, and the areal mapping covered about 400 square miles, in addition to which about 200 square miles were mapped in a reconnaissance way. A brief statement of results is published in this bulletin on pages 297–314.

NORTHWESTERN ALASKA.

P. S. Smith, with C. E. Giffin, topographer, and a party of four men carried an exploration up Alatna River, across the divide to the Noatak, and down that river to the Arctic Ocean at Kotzebue Sound. Field work began on July 1 and closed on August 27. An area of about 10,000 square miles was mapped topographically, of which the principal geologic features of about 8,000 square miles were mapped. (See pp. 315–338.) The party traveled by canoes and had an eminently successful season.

COLLECTION OF STATISTICS.

As in previous years, the statistics of the gold, silver, and copper production of Alaska were collected by the writer, assisted by members of the field force and by Mr. Aten. Every year a larger percentage of the operators show their interest in this work by furnishing data of production. As in previous reports, the attention of the mining public is directed to the fact that a rather large number of placer-mine operators still neglect to make returns of production, though the schedules are mailed to them each year. Such action, by decreasing the accuracy of the published totals for each district, injures the mining industry. There is no reason for this failure to make returns, as replies are held absolutely confidential, the figures being used only to make up totals. This is practically the only phase of the Survey's Alaskan work which has not had the full support of nearly every mining man with whom the Survey men have come in contact. It is the earnest hope of the writer that all the placer miners of the Territory will soon come to realize that they are not only running no risk in furnishing the Survey with figures showing production but that in withholding them they are injuring the mining industry.

PUBLICATIONS ISSUED OR IN PREPARATION DURING THE YEAR.

During 1911 the Survey published one professional paper, five bulletins, and three separate maps relating to Alaska. One professional paper and six bulletins are in press. In addition to these, the author's work on two other bulletins and one water-supply paper has been completed, and these publications will be sent to press not later than July 1. Six other reports are in preparation, which it is expected will be ready for publication before the end of the calendar year.

REPORTS ISSUED.

PROFESSIONAL PAPER 70. The Mount McKinley region, Alaska, by Alfred H. Brooks, with descriptions of the igneous rocks and of the Bonnifield and Kantishna districts, by L. M. Prindle; including geologic and topographic reconnaissance maps.

BULLETIN 446. Geology of the Berners Bay region, Alaska, by Adolph Knopf; including detailed geologic and topographic maps.

BULLETIN 448. Geology and mineral resources of the Nizina district, Alaska, by F. H. Moffit and S. R. Capps; including detailed geologic and topographic maps.

BULLETIN 449. A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska, by P. S. Smith and H. M. Eakin; including geologic and topographic reconnaissance maps.

BULLETIN 467. Geology and mineral resources of parts of the Alaska Peninsula, by W. W. Atwood; including geologic and topographic reconnaissance maps.

BULLETIN 480. Mineral resources of Alaska (report on progress of investigations in 1910), by Alfred H. Brooks and others; including general map of Alaska showing distribution of metalliferous deposits.

REPORTS IN PRESS.

PROFESSIONAL PAPER 69. The Yakutat Bay earthquake of September, 1899, by R. S. Tarr and Lawrence Martin. [Issued June 24, 1912.]

BULLETIN 485. A geologic reconnaissance of the Iliamna region, Alaska, by G. C. Martin and F. J. Katz; including geologic and topographic reconnaissance maps. [Issued March 9, 1912.]

BULLETIN 498. Headwater regions of Gulkana and Susitna rivers, Alaska, with accounts of the Valdez Creek and Chistochina placer districts, by F. H. Moffit; including geologic and topographic reconnaissance maps.

BULLETIN 500. Geology and coal fields of the lower Matanuska Valley, Alaska, by G. C. Martin and F. J. Katz; including detailed geologic and topographic maps. [Issued March 15, 1912.]

BULLETIN 501. The Bonnifield region, Alaska, by S. R. Capps; including geologic and topographic reconnaissance maps.

BULLETIN 502. The Eagle River region, southeastern Alaska, by Adolph Knopf; including detailed geologic and topographic maps.

BULLETIN 504. The Sitka mining district, Alaska, by Adolph Knopf. [Issued February 2, 1912.]

REPORTS COMPLETED, FOR WHICH ILLUSTRATIONS ARE BEING PREPARED.

Coastal glaciers of Prince William Sound and Kenai Peninsula, by U. S. Grant and D. F. Higgins.

The surface water supply of Seward Peninsula, by F. F. Henshaw and G. L. Parker; with sketch of geography and geology, by P. S. Smith, and report on placer mining, by Alfred H. Brooks; including topographic reconnaissance map.

Geologic reconnaissance of Fairbanks quadrangle, Alaska, by L. M. Prindle; with detailed description of the Fairbanks district, by L. M. Prindle and F. J. Katz; including detailed and reconnaissance geologic and topographic maps.

REPORTS IN PREPARATION.

Geology and ore deposits of Kasaan Peninsula and the Copper Mountain region, Prince of Wales Island, by C. W. Wright; including detailed geologic and topographic maps.

Geology of Glacier Bay and Lituya region, by F. E. Wright and C. W. Wright; including geologic reconnaissance maps.

Kenai Peninsula, by G. C. Martin, B. L. Johnson, and U. S. Grant; including geologic and topographic reconnaissance maps.

The Koyukuk-Chandalar gold region, by A. G. Maddren; including geologic and topographic reconnaissance maps.

The Iditarod-Innoko region, by A. G. Maddren; including geologic and topographic reconnaissance maps.

Geology of the Nome and Grand Central quadrangles, by F. H. Moffit; including detailed geologic and topographic maps.

MAPS.

Five topographic maps were issued as illustrations to reports (see p. 15), of which two were on a scale of 1: 62,500 (1 mile to the inch), and three on a scale of 1: 250,000 (4 miles to the inch). In addition to these, a general map of Alaska was published as an illustration to Bulletin 480. Three reconnaissance and two detailed topographic maps are included in the reports which are in press. In addition to the above, three topographic maps were issued separately as sale publications, as follows:

Circle quadrangle, No. 641; scale, 1:250,000 (4 miles to the inch); contour interval, 200 feet. Topography by D. C. Witherspoon, T. G. Gerdine, R. B. Oliver, G. T. Ford, and J. W. Bagley. Price 25 cents.

Kasaan Peninsula, Prince of Wales Island, Alaska, No. 540A; scale, 1:62,500 (1 mile to the inch); contour interval, 50 feet. Topography by D. C. Witherspoon, R. H. Sargent, and J. W. Bagley. Price 5 cents.

Copper Mountain and vicinity, Prince of Wales Island, Alaska, No. 540B; scale, 1:62,500 (1 mile to the inch); contour interval, 100 feet. Topography by R. H. Sargent. Price 5 cents.

THE MINING INDUSTRY IN 1911.

By Alfred H. Brooks.

GENERAL STATEMENT.

The metalliferous mining industry of Alaska had a very successful year in 1911. Much progress was made in placer and lode gold mining. The copper production was very large, and the outlook for the development of the tin deposits in the Seward Peninsula is more promising than it ever has been. Some successful developments were made in the Katalla oil field, and the output of the marble and gypsum deposits was about the same as in previous years. On the other hand, no advances were made in the exploration of the coal fields, for this phase of the mining industry still awaits the establishment of definite policy in regard to the disposition of the public coal lands. In 1911, therefore, as in previous years, stagnation existed in all enterprises depending on the opening of the coal fields. These enterprises include not only coal mining ventures but railway construction and, to a certain extent, metalliferous mining and other industries whose successful prosecution depends on an abundant supply of cheap fuel.

The favorable showing made by the Alaska mining industry during the year is due, first, to the very large output of copper and, second, to the greater production, compared with 1910, of the gold placer mines in the Innoko-Iditarod region. Aside from the increased production of copper and gold, the most important event of the year was the opening of the Copper River region by the completion of a railway. The industries already stimulated by this road strikingly illustrate the importance of railway communication to Alaska.

Although most of the gold still comes from the placers, much progress was made during 1911 in paving the way for an increased output from auriferous lodes. This work was carried on in most of the gold-bearing areas of Alaska, but the advances were most notable in the Juneau, Valdez, Kenai Peninsula, Willow Creek, and Fairbanks districts. Aside from the increase in copper mining the progress made in developing gold-lode mines is the most encouraging feature of the year's operations. Great progress was also made in dredge mining, notably in the Nome region. It is estimated that in the entire Territory 27 dredges were operated for the whole or a part of the open season of 1911. In addition to those operated, at least half a dozen were in process of construction.

The value of the total mineral production in 1911 is estimated at $20,650,005; in 1910 it was $16,887,244. In the following table the sources of this wealth, as well as a comparison with the production of the previous year, are presented. The statistics for 1911 are not yet completed and may be subject to change. In the table the output of marble, tin, gypsum, lead, etc., are combined, because a separate listing might reveal the production of individual properties.

Mineral production of Alaska, 1910–11.

	1910.		1911.		Increase (+) or decrease (−).	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
Gold........ounces..	780,131	$16,126,749	[a] 815,276	$16,853,256	+ 35,145	+ 726,507
Silver........do....	157,850	85,239	[a] 460,231	243,923	+ 302,381	+ 158,684
Copper........pounds..	4,241,689	538,695	27,267,871	3,366,584	+23,026,182	+2,827,889
Coal........short tons..	1,000	15,000	900	9,300	− 100	− 5,700
Marble, gypsum, tin, lead, etc.	....	121,561	....	176,942	....	+ 55,381
	....	16,887,244	....	20,650,005	....	+3,762,761

[a] Preliminary estimates.

NOTE.—In the above table copper is valued at 12.7 cents a pound for 1910 and 12.35 cents for 1911; silver at 54 cents an ounce for 1910 and 53 cents for 1911.

Mining began in Alaska in 1880, but for many years no very accurate records of mineral output were kept. Since 1905, however, fairly reliable statistics of mineral production are available. These data are summarized in the following table, both by years and by substances:

Value of total mineral production of Alaska, 1880–1911.

By years.				By substances.	
1880–1890	$4,686,714	1901	$7,007,398	Gold	$195,619,776
1891	916,920	1902	8,400,693	Silver (commercial value)	1,524,364
1892	1,096,000	1903	8,941,614	Copper	8,705,293
1893	1,048,570	1904	9,567,135	Coal	347,489
1894	1,310,257	1905	16,478,142	Marble, gypsum, tin, etc	731,119
1895	2,386,722	1906	23,375,008		206,928,041
1896	2,980,087	1907	20,847,055		
1897	2,538,241	1908	20,142,272		
1898	2,585,575	1909	21,141,019		
1899	5,703,076	1910	16,887,244		
1900	8,238,294	1911	[a] 20,650,005		
			206,928,041		

[a] Preliminary estimate.

TRANSPORTATION.

As improvement in transportation is the most important element in the advancement of the mining industry, the progress of the year in this respect will be briefly summarized. The Copper River & Northwestern Railway was completed to Kennecott in April, 1911, giving a total length for this line from Cordova, on Prince William Sound, of 197 miles. Repairs were kept up on the Alaska Northern Railway, including the rebuilding of the crossing of Placer River, and traffic was maintained from Seward to the end of the track (71½ miles) for all except the winter months. The owners of this railway state that no extension of the line will be made until the coal fields are opened. No other railway construction was undertaken during the year, but traffic was maintained over the White Pass, Tanana Valley, Seward Peninsula, and other roads.

At the close of 1911 there were 465 miles of railway in the Territory, compared with 371 miles in 1910. This mileage is distributed among nine different railways, from 5 to 197 miles in length. The existing railways emphasize the need of additional transportation facilities. The most urgent need is for a railway to connect an open port on the Pacific with the Yukon basin. (See pp. 45–76.) Until such a line is built only the richest placers and only the most favorably located lodes can be profitably exploited.

There was little change in ocean steamer service during the year. The building of lighthouses and the installing of other aids to navigation increased the safety and promptness of navigation, which will tend to decrease the cost. Attempts to use steamers on the Copper River above Chitina have been practically abandoned, because of the difficulties of navigation. River steamer service has also been discontinued on the Susitna, because of insufficient business. The small amount of freight distributed in this region is now handled by launches. On the other hand, several steamers are now in use on Kuskokwim River, ascending the stream about 600 miles to the mouth of the Takotna. They also run up that stream some 15 miles to a point connected by winter trail with the placer mines on Gaines Creek. The Kuskokwim is navigable to the Forks, about 50 miles above the mouth of the Takotna.

The Alaska Road Commission continued its important work of making mining districts accessible by building wagon roads and trails. Probably the most important undertaking of this kind was the completion of the winter trail from Seward, on the Pacific seaboard, to the Iditarod placer district. This not only serves several placer-mining camps, but also shortens the winter route to Nome by some 300 miles. Work was also continued on the Valdez-Fairbanks trail, which can now be used not only as a winter route but also as a wagon road in summer. A cut-off was built which connects the wagon road with Chitina, on the railway. At the close of 1911 the total mileage of road and trail constructed by the commission was as follows: Wagon roads, 800 miles; winter sled roads, 534 miles; trails, 1,107 miles; winter trails temporarily staked, 450 miles. The inadequacy of this mileage to serve the many mining districts scattered over a territory of nearly 600,000 square miles is so obvious that no comment is necessary.

METAL MINING.

PRODUCTION.

In 1911 about one-quarter of the gold production came from lode mines and three-quarters from placer mines, the same ratio between lode and placer output that was maintained in 1910. It is to be expected that before long the percentage of lode production will increase, which will result in a greater stability in the annual gold output than is possible where the maintenance of the production depends on the exploitation of rich gravel deposits. The increased use of dredges will also bring about less fluctuation in the annual placer gold production. In the following table, which is based on preliminary estimates, the production of precious metals has been distributed as to sources.

Sources of gold, silver, and copper in Alaska, 1911, by kinds of ores.

	Tonnage.	Gold.		Silver.		Copper.	
		Ounces.	Value.	Ounces.	Value.	Pounds.	Value.
Siliceous ores	1,594,404	204,465.99	$4,226,687	29,829	$15,810		
Copper ores	68,975	4,187.78	86,569	320,114	169,660	27,267,871	$3,366,584
Placers		606,622.50	12,540,000	110,288	58,453		
	1,663,379	815,276.27	16,853,256	460,231	243,923	27,267,871	3,366,584

To arrive at the total metal production of Alaska the amount of tin produced should be added. This is discussed by Mr. Hess in Bulletin 520-B. A small amount of lead is also recovered each year, incidentally to the treatment of other ores. In the following table the production of gold, silver, and copper is given by years:

Production of gold, silver, and copper in Alaska, 1880–1911.

Year.	Gold.		Silver.		Copper.	
	Quantity (fine ounces).	Value.	Quantity (fine ounces).	Commercial value.	Quantity (pounds).	Value.
1880	967	$20,000			3,933	$326
1881	1,935	40,000				
1882	7,256	150,000				
1883	14,566	301,000	10,320	$11,146		
1884	9,728	201,000				
1885	14,513	300,000				
1886	21,575	446,000				
1887	32,653	675,000				
1888	41,119	850,000	2,320	2,181		
1889	43,538	900,000	8,000	7,490		
1890	36,862	762,000	7,500	6,071		
1891	43,538	900,000	8,000	7,920		
1892	52,245	1,080,000	8,000	7,000		
1893	50,213	1,038,000	8,400	6,570		
1894	61,927	1,282,000	22,261	14,257		
1895	112,642	2,328,500	67,200	44,222		
1896	138,401	2,861,000	145,300	99,087		
1897	118,011	2,439,500	116,400	70,741		
1898	121,760	2,517,000	92,400	54,575		
1899	270,997	5,602,000	140,100	84,276		
1900	395,030	8,166,000	73,300	45,494		
1901	335,369	6,932,700	47,900	28,598	250,000	40,000
1902	400,709	8,283,400	92,000	48,590	360,000	41,400
1903	420,069	8,683,600	143,600	77,843	1,200,000	156,000
1904	443,115	9,160,000	198,700	114,934	2,043,586	275,676
1905	756,101	15,630,000	132,174	80,165	4,805,236	749,617
1906	1,066,030	22,036,794	203,500	136,345	5,871,811	1,133,260
1907	936,043	19,349,743	149,784	98,857	6,308,786	1,261,757
1908	933,290	19,292,818	135,672	71,906	4,585,362	605,267
1909	987,417	20,411,716	147,950	76,934	4,124,705	536,211
1910	780,131	16,126,749	157,850	85,239	4,241,689	538,695
1911	815,276	16,853,256	460,231	243,923	27,267,871	3,366,584
Total	9,463,106	195,619,776	2,578,862	1,524,364	61,062,979	8,705,293

In the following table the total gold production is distributed according to districts, so far as the information at hand will permit. The error in distribution for the production previous to the year 1905, when the systematic collection of statistics of Alaska's mineral output was begun, is believed to be less than 15 per cent. Complete statistical returns from all producers are not even now available, so that there is probably still some error in the distribution of the totals to the various districts. This error is, however, believed to be less than 3 per cent, and it is hoped that in future it may be eliminated altogether.

The production from the Pacific coast belt is derived principally from the lode mines of southeastern Alaska, but includes also the output of a lode mine of Unga Island, as well as a small output from gold placers. Previous to 1885 the placers of the Juneau district yielded considerable gold, and since 1899 the Porcupine district of southeastern Alaska has been a small but steady producer. The beach placers along the Pacific seaboard have been worked spasmodically since about 1890.

Up to 1909 all the gold from the Copper River and Cook Inlet region was derived from gold placers; since then there has been a small output from the auriferous lodes of Willow Creek and the Kenai Peninsula. The gold output of the Seward Peninsula and the Yukon basin is practically all derived from placers. One gold lode mine and several prospects on Seward Peninsula have been worked spasmodically since 1903, and there has been a small lode production from the Fairbanks district during the last two years. (See p. 30.)

Value of gold production of Alaska, with approximate distribution, 1880–1911.

Year.	Pacific coast belt.	Copper River and Cook Inlet region.	Yukon Basin.	Seward Peninsula and northwestern Alaska.	Total.
1880	$20,000				$20,000
1881	40,000				40,000
1882	150,000				150,000
1883	300,000		$1,000		301,000
1884	200,000		1,000		201,000
1885	275,000		25,000		300,000
1886	416,000		30,000		446,000
1887	645,000		30,000		675,000
1888	815,000		35,000		850,000
1889	860,000		40,000		900,000
1890	712,000		50,000		762,000
1891	800,000		100,000		900,000
1892	970,000		110,000		1,080,000
1893	838,000		200,000		1,038,000
1894	882,000		400,000		1,282,000
1895	1,569,500	$50,000	709,000		2,328,500
1896	1,941,000	120,000	800,000		2,861,000
1897	1,799,500	175,000	450,000	$15,000	2,439,500
1898	1,892,000	150,000	400,000	75,000	2,517,000
1899	2,152,000	150,000	500,000	2,800,000	5,602,000
1900	2,606,000	160,000	650,000	4,750,000	8,166,000
1901	2,072,000	180,000	550,000	4,130,700	6,932,700
1902	2,546,600	375,000	800,000	4,561,800	8,283,400
1903	2,843,000	375,000	1,000,000	4,465,600	8,683,600
1904	3,195,400	500,000	1,300,000	4,164,600	9,160,000
1905	3,430,000	500,000	6,900,000	4,800,000	15,630,000
1906	3,454,794	332,000	10,750,000	7,500,000	22,036,794
1907	2,891,743	275,000	9,183,000	7,000,000	19,349,743
1908	3,448,318	401,500	10,323,000	5,120,000	19,292,818
1909	4,264,716	265,000	11,580,000	4,302,000	20,411,716
1910	4,182,730	351,330	8,062,389	3,530,000	16,126,749
1911	4,265,573	313,538	9,139,145	3,135,000	16,853,256
	56,477,874	4,673,668	74,118,534	60,349,700	195,619,776

The production from the Yukon basin in the above table includes, of course, only that part of the basin on the Alaska side of the boundary. Mining has been going on in the Canadian Yukon since 1885. The following table of the Canadian Yukon will make it possible to compare the output of each year with those of the Alaska districts:

Production of gold in Yukon district, Canada, 1885–1910.[a]

Year.	Quantity (fine ounces).	Value.
1885, 1886	4,387	$100,000
1887	3,386	70,000
1888	1,935	40,000
1889	8,466	175,000
1890	8,466	175,000
1891	1,935	40,000
1892	4,233	87,500
1893	8,514	176,000
1894	6,047	125,000
1895	12,094	250,000
1896	14,513	300,000
1897	120,937	2,500,000
1898	483,750	10,000,000
1899	774,000	16,000,000
1900	1,077,553	22,275,000
1901	870,750	18,000,000
1902	701,437	14,500,000
1903	592,594	12,250,000
1904	407,938	10,500,000
1905	381,001	7,876,000
1906	270,900	5,600,000
1907	152,381	3,150,000
1908	174,150	3,600,000
1909	191,565	3,960,000
1910	220,166	4,550,000
1911	....	[b] 4,580,000
	6,593,548	136,299,500

[a] From reports of Mines Branch, Dept. of Mines, Ottawa, Canada.
[b] Preliminary estimate.

METALLIFEROUS LODES.

STATISTICS.

The total gold production from the auriferous lode mines of Alaska which have been productive since 1882 is estimated to be 2,550,107 fine ounces, valued at $52,808,921. These mines have also produced 1,029,743 fine ounces of silver, with a commercial value of $626,901. The total copper production up to the close of 1911 was 61,062,979 pounds, valued at $3,905,279. Tin mining began in the York region in 1902, since which time it has been carried on spasmodically. The value of the total tin product, which has come almost entirely from the placers, up to the close of 1910 is $192,042. There has also been some recovery of lead from ores valuable chiefly for other metals.

Alaska's auriferous lodes are estimated to have produced during the year 204,465.99 fine ounces of gold, valued at $4,226,687, as compared with an output of 198,601 fine ounces, valued at $4,105,459 in 1910. The increased production is to be credited to southeastern Alaska, for there was little change in the lode output from other districts. As in 1910, there was much prospecting of auriferous lodes near Port Valdez, in Kenai Peninsula, at Willow Creek, and in the Fairbanks district.

Eighteen gold-lode mines (including several properties in the new lode districts which made only small outputs) were operated the whole or a part of the year in Alaska in 1911—six more than in 1910. Work was also done on many gold prospects, a few of which produced some gold as an incident to the development work. Of the producing mines, eight were in southeastern Alaska.

It is estimated that these mines had an output of 1,594,404 tons of ore, as compared with 1,375,612 tons, the total output for 1910. In 1910 the average value of gold-silver contents for all the ores mined was $2.77; the average in 1911 is estimated to have been $2.79.

There were eight productive copper mines in 1911, as compared with seven in 1910. Of these, three were in the Ketchikan district, four on Prince William Sound, and one in the Kotsina-Chitina district. The total copper production in 1911 was 27,267,871 pounds, valued at $3,366,584, compared with 4,241,689 pounds, valued at $538,695 in 1910. About $86,570 worth of gold and $169,660 worth of silver was recovered from the copper ores. It is estimated that in 1911 about 68,975 short tons of copper ore were hoisted, as compared with 39,365 tons in 1910. The average copper content of the ore was about 17.87 per cent, and the gold-silver values about $3.84 to the ton. The large average copper percentage is due to the very high-grade ores shipped from the Bonanza-Kennicott mine.

SOUTHEASTERN ALASKA.

GENERAL CONDITIONS.

The auriferous lode mines of southeastern Alaska are estimated to have produced gold to a value of $3,990,786 in 1911, as compared with an output of $3,839,626 in 1910. In this region eight gold mines and four copper mines were operated in 1911 and nine gold mines and three copper mines in 1910. Although there was a decrease in the number of productive mines, much dead work was done on several large mining enterprises in the Juneau gold belt, and a number of small properties in the Ketchikan district were systematically prospected. The Chichagoff and Golden Gate mines, in the Sitka district, each supplied ore to 10 stamp mills. It is reported that these two properties are to be consolidated. The success of these two properties has stimulated the development of a number of prospects in the adjacent regions. A customs mill was built at Skagway in 1911 for the purpose of testing ores from the prospects of the vicinity.

There can be no question that the gold output of southeastern Alaska will be much increased within a very few years. In copper mining the advances were less marked, but several properties promise to become productive in 1912, and should copper continue to advance, a considerable increase of the copper output from this field is to be expected.

JUNEAU PRECINCT.

The Treadwell group of mines, on Douglas Island, continued in 1911 to be the source of most of the gold output of southeastern Alaska and, in fact, of the lode production of the entire Territory. Among the important developments on this property was the installation of a new central hoisting plant and crusher, which was completed in 1911. At the Treadwell mine ore was taken from the 1,450 and 1,600 foot levels, and considerable dead work was done on the 1,750-foot level. The 1,210 and 1,320 foot levels furnished most of the ore at the Alaska-Mexican mine, and the mine workings were extended on the 1,460 and, to a less extent, on the 1,570 foot levels. The ore from the Ready Bullion came chiefly from the 1,650-foot and 1,800-foot levels, and the dead work was chiefly on the 1,100 and 1,350 foot levels. In the 700-foot claim productive mining was done chiefly on the 1,210-foot and 1,320-foot levels, and dead work on the 1,600-foot level and in the shaft. Twenty stamps were added to the mill of the 700-foot claim.

Besides the Treadwell group, only two other properties on Douglas Island received any attention in 1911. A new company is reported to have taken hold of the Bear's Nest property and to have done some prospecting. Operations at the Alaska Treasure, on Nevada Creek, which had been temporarily suspended about the close of 1910, were resumed in 1911. The main crosscut was extended from 3,100 to 3,400 feet, giving a depth of 750 feet below the upper (the Hudson) crosscut. Some ore bodies are said to have been found. The work in hand consists in driving from the face of the main crosscut in a northerly direction in the expectation of intersecting the ore body exposed in the Hudson (the upper) level.

In 1911, as in previous years, the Perseverance mine, in the Silverbow Basin of the mainland portion of the Juneau gold belt, was operated during the open season, which amounted to 153 days. The mill at the Alaska-Juneau mine was also operated for a part of the year, but chiefly for sampling. Plans to develop this property on a large scale, which have been under consideration for some years took definite form in 1911. About 100 feet of an adit tunnel was completed, which will undercut the ore body of the Alaska-Juneau at a depth of about 600 feet. The portal of this tunnel is on Snowslide Gulch, a tributary of Gold Creek. A tram road for carrying ore has been graded from the portal of the tunnel to a mill at tidewater near Juneau. The tunnel, which follows a fault line, will be about 6,000 feet long. A ditch to bring water from Gold Creek has also been constructed. The California Nevada Copper Co. continued work on its tunnel on the Ebner property. Little information has been obtained regarding the mines north of Juneau. Systematic development has been continued on the Kensington property at Berners Bay, which will soon become productive. Some plans were also made to reopen the Jualin mine, located in the same district. In the aggregate considerable work was done also on numerous other properties between Juneau and Berners Bay. The mill at the Eagle River mine was operated only a short time during the year, and most of the work at this place was directed to further underground exploration.

KETCHIKAN DISTRICT.

The copper deposits of the Ketchikan district are still by far the most important of its mineral resources, but in 1911 more attention was given to the auriferous lodes than in the previous year. The Mount Andrew and Jumbo mines were producing ore, as in previous years, but details in regard to development are lacking at this writing. At the Jumbo, where about 40 men were employed, a crosscut is being driven to the main haulage adit to bring cars direct to bunkers. Ore shipments were also continued from the It mine, where operations, which had been temporarily suspended, were resumed in April. A 1,400-foot tunnel, destined to undercut the ore body at a depth of 500 feet, was driven at the It mine, and is said to have intersected an ore body. At the Joker mine only assessment work was done in 1911. Some small shipments of ore were made from the Rush & Brown mine, where, it is reported, an ore body of high grade was discovered. Developments have also been pushed at the Redwing mine, which has been equipped with a compressor and is to be put on a productive basis in 1912. It is reported that a 12-foot vein of copper ore has been found on this property. The main tunnel on the Victory property at Seal Bay, Gravina Island, has been driven a distance of 1,900 feet, and other underground developments have been made. New discoveries of copper ore are also reported on the Copper Center and Gopher (Hyda) properties. The Northland Development Co., whose property is near Klawak, continued sinking a shaft and is reported to have blocked out some ore.

The Lon de Van Mining & Milling Co. continued to drive a crosscut tunnel on Georges Inlet, an indentation of Revillagigedo Island, which is intended to cut an ore body outcropping 900 feet above sea level. At the close of the year the tunnel is said to have been driven about 2,000 feet and to have penetrated an ore body carrying chiefly silver-bearing galena and containing some gold. A gold-bearing vein is said to have been discovered on the Goo Goo claim on Thorne Arm. Some further developments were also made on the auriferous lode on the Gervis property near Hollis. Only assessment work was done at the Moonshine and Old Glory mines. Some developments were made by a company which had a bond on the Goldstream group of claims, located on Gravina Island.

The advances made in the Portland Canal region of British Columbia stimulated prospecting on the Alaska side of the boundary and within the Ketchikan district. Some encouraging results are reported in this field.

PRINCE WILLIAM SOUND.

The mining industry in Prince William Sound had its most prosperous season in 1911, in both development and production. The estimated total value of the minerals produced, including copper, gold, and silver, exceeded $1,000,000. One gold mine, the Cliff, near Valdez, and three copper mines, the Beatson-Bonanza, the Ellamar, and the Threeman, were productive, and several other copper properties were developed sufficiently to give assurance of an output of metal at an early date. Much development work was also done on a score or more of auriferous quartz veins, some of which will probably produce gold in 1912. A customs mill was established at Valdez, to which ore was brought from several quartz claims of the district. The Port Valdez gold-bearing region is described elsewhere (pp. 108–130). Some advances were made in prospecting auriferous quartz veins in the McKinley Lake district, tributary to Cordova, but this field has not developed into a producing district so rapidly as was expected last year. The following notes are by no means complete, but are believed to cover most of the more important operations during the year.

The ore shipped from the Ellamar copper mine was taken from above the upper level, which had been made available by a cofferdam completed in 1910. Work was continued on the property of the Hemple Mining Co., on Landlocked Bay. It is reported that a total of 2,000 feet of tunnel has been driven on this property.

The Threeman Mining Co. completed its wharf and bunkers and made its first shipment of ore in November. The mine is developed on five levels, with an aggregate of 4,000 feet of underground work. Some work was also done by this company on the Mason and Gleason claims, near Irish Cove. Developments were continued on the property of the Standard Copper Mines Co., near Landlocked Bay. In all 50 feet of shaft have been sunk and 1,100 feet of tunnel have been driven on this property. The Fidalgo-Alaska Copper Co. completed its aerial tram, its wharf, and its 1,000-ton bunkers, besides continuing underground developments. Some ore was delivered at the bunkers before the close of the year, although no shipments were made.

In 1911, as in previous years, the Beatson-Bonanza mine, on Latouche Island, was the largest shipper of copper ore on the sound, and made substantial progress in both surface equipment and underground workings, details regarding which are lacking at this writing. Considerable prospecting was also done on the adjacent Barrack-Girdwood property, and a crew of men were also employed on the claims of the Reynolds Alaska Development Co., near Horseshoe Bay. The Seattle-Alaska Mining Co. completed the installation of a concentrating plant on its property, located near Montgomery Bay. It is reported that at this place a mineralized shear zone carrying copper and high gold values has been crosscut at a depth of 400 feet. The property has been equipped and made ready for production, but no ore has been shipped.

Development work has been continued on the property of the Knight Island Copper Co., located about 3,500 feet from tidewater at Drye Bay. The mine is equipped with an air compressor and drills run by water pressure. There are two tunnels on the property, aggregating 450 feet in length, and a shaft 60 feet deep. Plans have been formulated to put in a wharf connected with the mine by aerial trams. The only ore produced thus far is that won incidentally to development work. Work on the Pandora claim in 1911 consisted of a winze sunk some 20 feet, near the face of the adit, which is 140 feet long. Development work has been done also on other copper prospects on the sound, notably near Cordova, but detailed information regarding these is not now available.

KENAI PENINSULA AND SOUTHWESTERN ALASKA.

Auriferous lode development was active in Kenai Peninsula during 1911. Details regarding mining in this district are presented by Mr. Johnson on pages 131–173. It is reported that an auriferous quartz vein has been found near Malina Bay, on Afognak Island. No new discoveries are reported in the Iliamna region, and but little prospecting was done in this field. The Apollo mine, on Unga Island, was, as in previous years, the only productive property in southwestern Alaska. Ten stamps were operated at this mine during the summer months.

SUSITNA BASIN.

Lode mining in the Willow Creek district made considerable advances during 1911, and some prospecting was done on lodes in other parts of the Susitna basin. A little work was done on a copper-bearing lode on Iron Creek,[1] but no notable discoveries in this part of the field are reported. Some discoveries of gold-bearing quartz are reported from the Valdez Creek district. The occurrence of gold in the Yentna district is described by Mr. Capps on pages 174–200.

[1] Brooks, Alfred H., The mining industry in 1910: Bull. U. S. Geol. Survey No. 480, p. 33.

It is estimated that about 50 men were employed in developing lode prospects in the Willow Creek district during the summer of 1911 and a smaller number during the previous winter. Gold to the value of between $50,000 and $60,000 was produced. The Willow Creek district was not visited in 1911[1] by any member of the Survey, but the following notes on development have been obtained from what are believed to be reliable sources.

The Alaska Gold Quartz Mining Co. operated its three-stamp mill (500-pound stamps) with water power from June 30 to September 17. Over 230 tons of ore were treated. The tailings were yarded, no concentrator having yet been installed. About 300 feet of adit has been driven at this mine and 1,500 feet of open-cut work has been done, the operations in 1911 covering about 150 feet of adit and considerable stripping. Material for two trams, each a little less than 2,000 feet long, is on the ground. In 1911 the ore was trammed about 1,000 feet and then hauled nearly 2,000 feet on a go-devil.

Some developments were continued on the adjacent group of claims belonging to the Alaska Free Gold Co. Here a 20-foot shaft was sunk on a vein in one claim and assessment work was done on the other claims. Some ore from this property was put through the mill of the Alaska Gold Quartz Mining Co. A considerable force of men was employed at the Gold Bullion property from about the 1st of April to the middle of September. A 3,400-foot tram was installed and five new stamps were added to the mill, making seven in all. The mill was started on July 15 and was operated, with some interruptions on account of shortage of water and repairs, until the middle of September. Most of the ore milled was taken from an open cut, but one adit is reported to have been driven about 75 feet. Only assessment work was done on the adjacent Gold Top Mining Co. property.

A force of men was employed for most of the year on the claims of the Matanuska Gold Mines Co. The development work consisted chiefly of open cuts made for the purpose of tracing the veins. An adit some 40 feet in length was also driven. It is reported that water power is available and that a mill will be installed on this property in 1912. The Brooklyn Development Co. resumed operations on its property in 1911 about June 1. A total of 245 feet of underground work, besides considerable open cutting, represents the excavating accomplished to date. A stamp mill was purchased by this company in 1910, but has not yet been installed. So far as known only assessment work was done on other quartz claims located in the Willow Creek district.

[1] The occurrence of gold and the progress of mining in 1910 were described by Frank J. Katz in an article entitled "A reconnaissance of the Willow Creek gold region": Bull. U. S. Geol. Survey No. 480, 1911, pp. 139-152.

FAIRBANKS DISTRICT.

GENERAL CONDITIONS.

Although some lode prospecting was done in other parts of the Yukon-Tanana region, the only notable advances in hard-rock mining were made in the Fairbanks district. The writer was unfortunately prevented from visiting this district, as planned, and for the facts contained in the following summary has been forced to rely on information gleaned from various sources. Had all the mine operators promptly transmitted the statistical data requested on schedules mailed to them, it would have been possible to present more details in regard to the lode-mining developments and thereby to do fuller justice to the district.

It is reported that during 1911 development work in excess of that required annually for assessment work was done on or about 25 to 30 properties. About 8 or 10 of these produced gold to the value of $1,000 or more. Most of the ore produced was crushed at the two customs mills at Chena and Fairbanks, and in addition some ore was treated at three mills erected on different properties in the later part of the year. The equipment of these five mills aggregated 26 stamps. It is estimated that about 875 tons of ore were treated during the year in the district, yielding about $64,100. Probably about 8 or 10 per cent of this represents the value of the concentrates, the rest being free gold. The high value per ton is accounted for by the fact that much of the ore sent to the mills is picked and does not represent an average of the ore mined. It is estimated in the district that transportation and milling charges have averaged $20 to $30 a ton, prices that prohibit the shipment to the mills of any but high-grade ores, so that mills have been erected on several properties. Most of the ores also carry silver. The ores mined in 1911 are estimated to have yielded 582 ounces of silver, valued at $308.

The total amount of hard-rock underground work done at the close of 1911 is estimated to have been about 6,000 feet whereas the amount done at the close of 1910 was about 3,000 feet. About two-thirds of the hard-rock work represents adits, crosscuts, and drifts, and the remainder represents shafts, raises, and winzes. The total gold production of the quartz lodes to the close of 1911 has a value of about $120,000, which will probably nearly pay for the underground work done. The lode mining so far has been almost entirely in the hands of local men, backed by local capital.

NOTES ON MINING PROPERTIES.

Although claims were staked and more or less prospecting was done during the year in much of the Fairbanks district, the most important developments were confined to certain areas, which will be mentioned in geographic order from east to west.

The most easterly prospect in the Fairbanks Creek belt is the Charles claim, located near Coffee Dome, where a ledge is reported to be 18 inches wide. A 50-foot shaft, showing 3 feet of ore, is said to have been sunk on the Eureka claim, and work was continued on the McCarty Creek ledge. Both these properties produced some ore, which was milled at Chena. A 30-foot shaft, in which a ledge 1 foot wide is reported to have been exposed, was sunk on the Governor claim, in the upper Fairbanks Creek basin.

The divide between Wolf and Fairbanks creeks was the scene of considerable development work. Here some ore was taken from the Pennsylvania claim, and some 350 feet of adits has been driven on the Russian Kid. More extensive developments took place in 1911 on the Rexall, located close at hand. Here the total developments are reported to include a 127-foot crosscut and a 50-foot drift, revealing a vein from 8 inches to 2 feet 8 inches wide. Considerable ore was shipped from this property to one of the customs mills. A new ledge some 18 inches wide is said to have been discovered in this vicinity. Work was continued on several properties in the upper Cleary Creek basin. At the Free Gold (Roads & Hall) a total of about 1,200 feet of underground work had been completed at the close of 1911. In midsummer a five-stamp mill (1,000-pound stamps) was erected on the Free Gold mine. It was operated about one month and then closed on account of shortage of water. Not only was ore treated at the mine but shipments were made to the Chena customs mill.

Work was continued in 1911 on the adjacent property of the Tanana Quartz Hydraulic Co., which is said to have two veins, one 10 inches to 7 feet, and the other 4 feet wide. The development work done is said to aggregate about 400 feet. It is not yet known whether any ore was shipped from this property.

After being closed down for several months the Tanana Quartz Mining Co. again started operations in March, 1911. A 50-foot winze was sunk from main tunnel and drifting began on the vein at this depth, which is said to be 14 to 30 inches wide. Another vein, reported to be 4 feet wide, is exposed in a 70-foot adit. Some shipments of ore were made to one of the customs mills, and in October a five-stamp mill was erected on the property. Water for the mill is procured from a well sunk in the creek bottom, close at hand. Some ore was shipped from the Pioneer property, on Chatham Creek, where the total development is said to consist of 128 feet of adit. Some work is also known to have been done on the Jupiter-Mars, Rex, and on other properties of the vicinity, but details are lacking.

Much work was done on the Newsboy property, located near the divide between Cleary Creek and Little Eldorado. Here a shaft was sunk to a depth of some 200 feet and the mine was opened on two levels. At the close of the year the sinking of a shaft to the 315-foot level was being pushed, as was the drifting on the 215-foot level, where the vein is said to be 4 feet wide, with no marked change in gold content. Ore was shipped to a customs mill from the 65-foot and 115-foot levels, where stoping was done. In October a five-stamp mill was installed. Some drilling was done for water, but it appears that the mill was supplied from the shaft. Considerable work was also done on what is known as the Cleary Extension of the Newsboy. Developments were continued in 1911 on the Rainbow property, on Skoogy Gulch, and some shipments were made to mill at Chena. A 2½ to 3 foot vein is said to be developed. The workings include two shafts and drifts and crosscuts, the total aggregating about 500 feet. Some ore was also shipped by Hirchberger & Zimmerman from a vein said to be 1 to 5 feet wide, which is located near the Rainbow.

Anderson & Birch have opened up a vein at the head of Granite Gulch, near Pedro Dome. They shipped some ore from this property to the Citizens' Test Mill, at Fairbanks. Freeman & Sharf also did some work on a vein located at the head of Fox Gulch. Some silver-bearing galena, also carrying gold, was found on this property. The Wild Rose claim, which is somewhere in Dome Creek basin, also received attention during 1911. Ore was shipped from this property to the Citizens' Test Mill at Fairbanks.

The Reliance Mining Co. did relatively a large amount of work on its property in the upper Dome Creek basin, shipping some ore to the Chena Mill. It is said that a vein on this property has been traced for a long distance by open cuts. A 100-foot shaft has been sunk on a vein which is reported to be 7 feet wide at the bottom of the shaft. One adit has been started to tap this vein at the bottom of the shaft and a second adit for the purpose of developing the vein at a depth of 200 feet. At last reports the upper adit had been driven 60 feet, the lower 160 feet. A second shaft has been sunk 50 feet near the entrance of lower level. Practically all workings are said to be on the vein and to be well timbered.

Developments were continued in 1911 on the Freiderich property, near Ridgetop, and some ore was shipped. On this property a 100-foot shaft has been sunk and 120 feet of adit has been run. The latest available reports are that a 2-foot vein has been developed in which there is a very rich ore chute 8 inches wide. At a depth of 70 feet in the shaft a very rich pocket of ore was struck.

It is said that about 280 feet of shaft and 60 feet of drifting was done on a property near the divide between Wildcat and Vault creeks, owned by Hoel Bros., Johnson, and Witmer. Current reports are to the effect that a 30-foot ledge carrying low-gold values and a richer vein, 8 inches to 2 feet in width, have been found on this property. The Little Eva claim was staked on the west slope of the valley of

Eva Creek in 1910. Among the first developments was a 70-foot adit, which was later abandoned. Later a shaft was sunk to a depth of 40 feet and a 12-inch vein was found, which was followed for 40 feet by a drift, then lost by faulting. Later the vein was picked up again by a 30-foot crosscut.

Much work was done in 1911 on the Ryan ledge, located near the divide between Eva and St. Patrick creeks. It is reported that a 3 to 8 foot ledge was traced for some 1,200 feet by drilling and test pits. Two other undeveloped ledges are said to have been found on this property. Some ore was shipped to the customs mill from this property. No information is available at this writing regarding the developments of other lode claims in the Fairbanks district. It is quite possible that there may be some, not here listed, on which an amount of work has been done equal to that done on those here described.

SUMMARY AND CONCLUSIONS.

The mining developments in the Fairbanks district have borne out Mr. Prindle's[1] hypothesis that igneous intrusions determined the loci of mineralization. Nearly every lode reported occurs in the schists near their contact with granitic or other intrusives. An obvious deduction from this fact is that the search for auriferous lodes should be directed to the contact zones of the granitic or other intrusive rocks which have not yet been prospected.

The notes at hand do not furnish any additional data on which to base conclusions regarding the probable continuity of the veins. There seems to be little question that a number of the lodes that have been developed follow well-defined fissures. Probably no greater irregularity in the veins will be revealed by more extensive mining than has already been found. The evidence at hand indicates that the veins are in part, at least, faulted, a condition which must be reckoned with in estimating the cost of mining.

Most of the veins thus far developed are small, being 3 feet or less in width. Some veins, reported to carry high values, are 5 to 7 feet wide and several much wider lodes carry low values in gold, but have received relatively little attention. The data at hand are too fragmentary to indicate whether there is more than one system of fissuring. Mr. Prindle's studies have, however, shown that there were at least two periods of quartz veining—an older, during which it appears that some large quartz veins were formed which are relatively little mineralized, and a later period of deformation, during which some of the veins of the first generation were fractured and then recemented. So far as known, the rich gold-bearing veins were introduced during this second period of intrusion.

[1] Prindle, L. M., Auriferous quartz veins in the Fairbanks district: Bull. U. S. Geol. Survey No. 442, 1910, pp. 210-229.

The average gold content of the lodes developed in the district has not been determined, for the results of the little systematic sampling that has been done are not available to the writer. Much of the ore milled has been taken from small rich stringers which would not afford sufficient material to warrant systematic development. Again, a good part of the ore treated at the mills and taken from the larger veins was hand sorted and therefore the returns do not express the average contents of the lodes. It has already been pointed out that operators who desired to meet in part the expenses of development have been forced to do this because of the high cost of transporting and milling the ores.

There are no new data on the probable character of ores at depth. Practically all the developments have been on the slopes of ridges and above ground-water level. Therefore, although a depth of about 300 feet has been attained, this does not appear to be below the zone that is affected more or less by surface waters. No change in character of ore has been reported at the greatest depths attained.

The miner in the Fairbanks, as in other inland districts, is always confronted with the high cost of transportation, which is reflected in the expense of supplies, equipment, and labor. This cost will not be materially reduced until a railway to tidewater has been constructed. The high cost of fuel is another drawback, but could be reduced by making available the extensive coal deposits of the Nenana field, some 60 miles away. More difficult to overcome is the scarcity of water near many of the properties that have been opened up. In some of the valleys water for milling could probably be obtained by drilling, though efforts thus far made to obtain a water supply by drilling have not been successful. An alternative plan is to locate the mills near the watercourses that maintain a supply during the winter and in dry summers. For the information of those who are not familiar with the winter conditions at Fairbanks it may be added that, aside from the scarcity of water, they are not unfavorable to lode mining.

NOTES ON AURIFEROUS LODES IN OTHER DISTRICTS.

Relatively little prospecting was done on the lodes of the Bonnifield district in 1911, but assessment work has been kept up. Late in the fall about a ton of ore was taken from a ledge in the Wood River basin, which will be sledded to Fairbanks for a mill test. It appears that the only lode developments in the Chandalar region were those of the Alaska Chandalar Mining Co., which continued driving an adit on its property in the Squaw Creek basin. This company has secured the use of a small prospecting mill, erected in 1910, on the Gold King claims, and will utilize it for testing ore.

It is reported that some quartz veins bearing gold, silver, and antimony have been found in the basin of the Riglugalic River, an easterly tributary of the lower Kuskokwim. The country rock is reported to be slate, with granitic and other intrusive rocks, and the mineralization to occur along shear zones. A group of claims called the Royal Quartz mines has been staked in this region, and a little development work has been done.

A customs mill was erected at Nome late in the summer of 1911, and considerable ore was tested there during the last month of the year. This has stimulated development work on a number of lode prospects in the Seward Peninsula.

GOLD PLACERS.

GENERAL CONDITIONS.

The value of the placer-gold production in 1911 is estimated at $12,540,000; that of 1910 was $11,984,806. This increase was due to the fact that the output from the Innoko-Iditarod region was more than three times as large and that of the Hot Springs district more than twice as large as in the previous year. Moreover, the production of the Fortymile and Birch Creek districts made substantial increases in 1911 over those of 1910. On the other hand, the output of the Fairbanks and Seward Peninsula districts was about $2,000,000 less in 1911 than in 1910.

It is estimated that a total of 740 placer mines were operated in Alaska during 1911, compared with 650 in 1910. About 170 mines were operated during the winter, employing about 670 men, and 775 during the summer, employing about 4,900 men. In addition to these probably 1,000 to 1,500 men were engaged in prospecting and other nonproductive work relating to placer mining.

In accordance with past practice, a table is given here to show approximately the total bulk of gravel mined annually in Alaska for several years and the value of the gold recovered per cubic yard. This table is based on certain assumptions which do not now admit of proof, but which are supported by a large number of facts. Therefore, although the table is only approximately correct, it indicates the magnitude of the true figures.

Estimated total amount of gravel sluiced in Alaska placer mines and value per cubic yard of gold recovered, 1908–1911.

	Total quantity of gravel (cubic yards).	Value of gold recovered per cubic yard.
1908	4,275,000	$3.74
1909	4,418,000	3.66
1910	3,800,000	3.20
1911	5,790,000	2.17

The figures presented in the above table, showing the gradual decline of the average gold recovery per cubic yard, are a reflection of the improvements in mining conditions. They show that year by year deposits carrying less gold are being successfully exploited and are furnishing a larger percentage of the placer-gold output of the Territory. This is the most encouraging feature of Alaska placer mining, for it assures a degree of permanency which can not be hoped for so long as the gold output is won chiefly from the quickly exhausted rich bonanzas which have heretofore played so large a part in furnishing the gold. That there is still room for improvement is indicated by the fact that the average gold recovery from placer mines in the States is less than 13 cents a cubic yard.

Twenty-seven dredges were in profitable operation in Alaska during 1911, in addition to which half a dozen were in course of construction. It is estimated that these dredges handled between 2,100,000 and 3,000,000 cubic yards of material and that the aggregate value of their gold output was about $1,500,000. Hydraulic mining is playing from year to year a more important part in the placer-mining industry of Alaska. In 1911 hydraulic plants were operated in the Porcupine, Nizina, Kenai Peninsula, Birch Creek, and Seward Peninsula placer districts. Underground placer mining is now being done more cheaply than formerly but is still and will remain the most expensive method of gold recovery. The improvements in methods of recovering gold and the wide distribution of placer gold in Alaska give assurance of a continuation of profitable mining, in spite of the rapid exhaustion of the bonanza deposits. It is not to be expected, however, that the annual gold output from the placers will increase, or even hold its own, unless improved means of transportation are established.

SUMMARY OF PLACER MINING BY LOCALITIES

PACIFIC COAST REGION.

For the purposes of this discussion the Pacific coast region will be defined as covering not only the seaboard, but all the drainage basins tributary to it, including the Copper and Susitna. The placers of this province are estimated to have had in 1911 an output valued at $325,000, as compared with $425,000 in 1910.

Southeastern Alaska.—The only placer mining in southeastern Alaska was done in the Juneau and Porcupine districts. One mine was operated in Silverbow Basin by hydraulic methods, supplemented by pick and shovel. Two hydraulic mines were worked in the Porcupine district, one on Porcupine and one on Cahoon Creek. Considerable work was also done on Nugget Creek, where preparations are being made to install a hydraulic plant.

Beach mining.—As in previous years, from 25 to 40 men were engaged in mining beach placers at several places between Lituya Bay and Unga Island. Yakataga is the most important center of this industry. According to C. C. Naughton, of Katalla, from 15 to 20 men were engaged in beach mining near Yakataga in 1910 and 1911. Most of these worked about two months in the year, but some worked five or six months. The gold-bearing beach gravels stretch from a point 1½ miles west of the settlement of Yakataga to a point about 15 or 16 miles east of it. The gold appears to be concentrated in the beach by wave action, and as this process continues there seems to be no diminution in the amount of gold. Mining is done by shoveling into sluice boxes that are washed by water taken from a lagoon or lake which is separated from the sea by an elevated beach. This elevated beach carries gold, but not in sufficient quantity to justify exploitation, at least not by the manual methods now in use.

The hydraulic plant installed on White River some years ago was again operated in 1911. White River is about 8 miles east of Yakataga and the placer mine is about 5 miles from the beach. The best values have been found on a bench whose floor is about 10 feet above the water level. The gravel is said to be about 8 feet thick. The coastal region near Yakataga is heavily timbered and contains some coal and petroleum seepages. Some beach mining was done in 1911 near Anchor Point on Cook Inlet (p. 161) and on Popof and Unga islands. It is reported that some new beach placers were discovered late in the summer of 1911 near Uyak, on Kodiak Island.

Copper River region.—Mining operations in the Nizina district are described on pages 93–107 of this report. About 100 men were engaged in mining in the Chistochina (Chisna) district in 1911, and the gold output is reported to have had a value of about $80,000. The most extensive operations were on Slate Creek, Miller Gulch, and Chisna River. Milo Dempsey continued the installation of a hydraulic plant on the Chisna, but did not finish a new ditch. Some mining was done with this plant. A drill was used to prospect ground on the Chistochina.

Cook Inlet and Susitna River region.—Descriptions of mining operations on the Kenai Peninsula and in the Yentna district are presented in this bulletin on pages 131–200. A little placer mining was done on Willow Creek, on the upper Chickaloon, and in the Talkeetna and Cashwitna basins.

Five placer mines were reported to have been worked in the Valdez Creek basin during 1911. During the summer an examination was made of some of these properties, with a view of consolidation and operations on a large scale. It is reported that this plan will be carried into execution.

YUKON BASIN.

Production.—The value of the placer production of the Yukon basin, including the Innoko-Iditarod region, is estimated at $9,050,000 in 1911, as compared with $8,020,000 in 1910. This gain is due largely to the increased production from the Innoko-Iditarod region, but the output from the Hot Springs, Birch Creek, and Fortymile region was greater than in 1910. Nearly $5,000,000 worth of gold passed through Fairbanks in 1911, but of this amount about $500,000 came from the Tanana Valley districts other than Fairbanks. The gold placer [1] mining developments of the Yukon-Tanana and Ruby Creek districts are described on pages 211–314.

Bonnifield and Kantishna districts.—There appear to have been no important developments in the Bonnifield and Kantishna districts in 1911. The total value of the gold output from this region, lying south of Tanana River, was less than $50,000. Details are lacking in regard to mining in the Bonnifield region, but the productive creeks were probably the same that produced last year, including Moose Creek and tributaries of the Tatlanika, Totatlanika, and Wood River. About 20 men were engaged in mining in the Kantishna district, chiefly on Glenn, Bearpaw, Eureka, and Moose creeks and McKinley Fork.

Chandalar and Koyukuk districts.—A little productive mining was done on Big Creek, in the Chandalar district. It is reported that a shaft was sunk on Crooked Creek to a depth of 286 feet and one on Mammoth Creek to a depth of 172 feet, but that no workable placers were found. Both these are in the Chandalar district.

It is estimated that gold to the value of $140,000 was produced from the Koyukuk district in 1911, whereas the output was $160,000 in 1910. Among the important events of the year was the finding of valuable placers in the benches of Sheep Gulch and of the extension of the pay streak on Nolan Creek. Some new discoveries of gold-bearing gravel are also reported in the basin of Hammond River. In 1910 auriferous gravels were found in the basin of Indian Creek, which is a tributary of Koyukuk River from the east about 4 miles above Waite Island, 374 miles from the mouth of the Koyukuk. These discoveries were made on Snyder and Felix creeks, which are tributaries to the headwaters of Indian Creek. The scene of the discovery can be reached by an overland journey of about 20 miles from Hughes City, a new settlement on the east bank of the Koyukuk, about 380 miles by river from the Yukon. Placer-gold prospects are also said to have been found on Dome Creek, which flows northward, being a part of the Kanuti drainage basin. This district is often known as the Red Mountain region of the Koyukuk.

[1] Lode mining is described on pp. 32–36.

The bedrock of these creeks is reported to be slate and granite and the gravels to be shallow. Several claims were worked in this district in 1911, the value of the output being estimated at $14,000. The discovery is said to have attracted about 50 to 100 men, about 20 of whom remained to do further prospecting. This district lies in a belt running between Koyukuk and Yukon rivers, in which auriferous gravels are known to be widely distributed, but within which but little productive mining has yet been done.

Innoko-Iditarod region.—Placer mining was very successful in the Innoko-Iditarod region during 1911, the value of the gold output being estimated to have been about $3,000,000, compared with a value of $825,000 for the output of 1910. The open season was unusually long, mining continuing until November. As a consequence only a part of the gold mined during the year was brought out by the usual steamer route. More than half a million dollars' worth of gold is said to have been transported by dog team to Seward, and most of this did not reach the States until after the close of the year. As a consequence many conflicting statements were current in regard to the amount of gold produced.

The district is now connected with Seward by a good winter trail, along which road houses have been established. Moreover, the wireless station at Iditarod furnishes communication at all times with the outside world. Some roads and trails have been constructed in the district, details concerning which are lacking. It is reported that the horse tram connecting Iditarod with Flat Creek is to be replaced by a narrow-gage railway.

Most of the placers are shallow and are mined by open-cut methods. Consequently there is little work in the district in winter, when probably not over 15 or 20 mines are operated. Most of these are in the Innoko part of the field. The fact that there is little winter work for miners and that transportation to the region is expensive makes the operating costs high. These conditions are not favorable to those who expect to work for wages.

The valuable gold discoveries made thus far are limited to a few creeks, and the mines are few in number compared with the amount of gold produced. The conditions have therefore not been favorable to the prospector and small operator. Furthermore, the real miner and prospector has been discouraged by an almost universal practice of staking large areas in association claims by those who have little thought of systematic development of the lands they thus preempt. As a consequence many men left the region, and reports were circulated which did not do justice to the promising possibilities of this field. The best information at hand indicates that considerable areas in this region give promise of yielding returns to careful prospecting.

The developed gold placers of the Innoko-Iditarod region can be grouped into three districts. The first district in amount of production is the Iditarod district, which includes the streams of the Iditarod River basin. The second Innoko district embraces the headwater region of the river of the same name. The third district embraces the creeks tributary to Takotna and other streams which flow into the Kuskokwim.

Flat Creek, a tributary of Otter Creek, was the largest producer of gold in the entire region in 1911. Mining was also done on Otter Creek and on several of its tributaries besides Flat, including Glen Gulch and Black Creek. In 1911, as in 1910, the mines of the Willow Creek basin made a considerable output. Mining was also done on the divide between the head of Flat Creek and Happy Gulch, which flows into Willow Creek, as well as on Gold Creek, also tributary to Willow. Chicken Creek is also reported to have been the scene of productive mining in 1911. Late in the year good prospects are reported to have been found on Bonanza Creek, to which Chicken Creek is tributary. Good prospects are also said to have been found on Little Creek, tributary to the upper Iditarod. No information is at hand regarding developments on other creeks of the Iditarod district.

Much prospecting and considerable mining has been done on the Kuskokwim side of the divide. Of the tributaries of the Takotna, Moore and Fourth of July creeks were the scene of considerable mining. These creeks head in the same divide with streams that flow into Georgetown[1] River. In this part of the field there was some mining on Donlin, Julien, Beaver, Marietta, and Crooked creeks, and on Snow Gulch, and prospects are said to have been found on Michigan, Ruby, Kieland, Spruce, and other creeks.

It is estimated that in the Innoko district about 13 claims were worked by 25 men during the winter, and about 25 claims were worked by some 200 men during the summer. The largest output of gold came from the mines of Yankee, Ophir, and Gaines creeks, but mining was also done on Little, Spruce, and other streams. A ditch was completed which will furnish water for mining the benches on Spruce Creek.

Kuskokwim and Goodnews Bay region.—The reports of prospectors indicate that placer gold has been found at numerous places in a belt that stretches southwestward from the Iditarod district to Goodnews Bay on Bering Sea. It is rumored that placer gold has been found on "Holokuk, Hoholitna, or Holiknuk" River. This is probably Chulitna River, which flows into the Kuskokwim from the south about 100 miles above Georgetown. Auriferous gravels were found

[1] Variously called the Ukinilok and Yuniluk River.

in the Chulitna basin about 10 years ago, but so far as known they have never been developed. Another discovery is reported on "Anniok River" and on its tributaries, Cripple and Salmon creeks. "Anniok River" is unknown to the writer, but it is probably the stream joining the Kuskokwim from the north about 100 miles below Georgetown—the stream called Yukwonilnuk River on the maps. A little placer mining was done on Tuluksak River, which flows into the lower Kuskokwim from the east about 100 miles above Bethel. It is reported that about $15,000 was taken from these placers in 1911. Rigugalik River joins the Kuskokwim about 30 miles below the mouth of the Tuluksak. Fine gold has been found on this stream, and in 1911 some tests were made with a small hydraulic plant, which is reported to have yielded encouraging results. The bedrock is said to be arkose, sandstones, and slate, with interstratified volcanic rocks and intrusive granites.[1] Gold prospects are said to have been found on the Kwisluk and Eek and other rivers that flow into the Kuskokwim from the east below the mouth of the Rigugalik.

In 1910 placer gold was found in streams tributary to Goodnews Bay, a small indentation of the east shore of Kuskokwim Bay. In August, 1911, workable placers were found in this district, on Butte Creek, about 25 miles from tidewater. Here mining was done on four claims, which made a total output of about $12,000. There are said to be about 20 men in the district. The bedrock is reported to be slates, with some limestones and schists cut by igneous dikes.[2]

These fragmentary data indicate that geologic conditions similar to those known in the Iditarod region occur in a zone stretching through to Bering Sea. Although no very rich placers have yet been found, the presence of alluvial gold and other evidences of mineralization in this field are encouraging to the prospector.

NORTHWESTERN ALASKA.

The placer districts of Seward Peninsula are the only productive ones in northwestern Alaska except those of the Kobuk Valley, from which the output is very small. An account of mining in Seward Peninsula, specially of the developments in dredging, is presented on pages 339–344. During 1911 a little mining was done in both the Shungnak and Squirrel River districts of the Kobuk Valley. The total value of gold output from this region, as reported by operators, is only about $15,000. There is reason to suppose that several operators did not reply to the request for statement of production,

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[1] The writer is indebted to H. W. Reeth for information about this region.

[2] The writer is indebted to John D. Leedy for information about the Goodnews Bay district.

and that gold to the value of about $35,000 was produced in 1911. Though several claims were worked in the Squirrel River district, most of the production came from two or three. During the winter some shafts were sunk to considerable depth (75 feet is reported), but the results do not seem to have been encouraging, except on one claim, where coarse gold was found at a depth of 28 feet.

Klery Creek appears to be the only stream in the Squirrel River region on which productive mining has been done, though alluvial gold has been found on other streams. At least two placer mines were worked in the Shungnak region, but high water seriously hampered operations. A nugget valued at about $600 was found on Dahl Creek in 1911. This nugget is a large, subangular, thin slab of gold, to which no schist or quartz is attached. The occurrence of alluvial gold in the Noatak is described on pages 315–338.

COAL.

Only one coal mine in all Alaska was operated commercially in 1911, but a little coal was mined at several places in the Territory, chiefly by those who themselves utilized the product. The total estimated output of coal in 1911 was about 900 tons; the total output in 1910 was about 1,000 tons.

The Chignik Coal Mining Co.[1] operated its mine, located on Thompson Creek about 2 miles from tidewater at Chignik Bay. During 1910 and 1911 an entry about 1,000 feet long was driven at this mine. In this a roll was encountered which cut out the coal for 210 feet, but beyond this roll the bed was again picked up. The bed is said to be 10 feet thick and to include 8 feet of coal, occurring in two benches separated by shale. A wagon road about 2 miles long has been built to connect the mine with the wharf. Bunkers have been erected at the mine and at the wharf. Plans are under consideration to build either an aerial or surface tram. The coal mined has been sold to local steamers and canneries. Some coal was mined along the beach at Cook Inlet, much of it being picked below high tide without actual excavation. A little coal was probably also mined in the Chicago Creek region of Seward Peninsula to supply some near-by placer camps, and doubtless some other small coal mining of this kind was done in other parts of the Territory, but no information concerning these small enterprises is at hand.

[1] The writer is indebted to Henry S. Tibbey, manager of the property, for information about developments.

Coal consumption of Alaska, by sources, 1899 to 1911, in short tons.

Year.	Imported from States, chiefly from Washington.		Produced in Alaska, chiefly subbituminous and lignite.[a]	Total domestic.[b]	Total foreign coal, chiefly bituminous, from British Columbia.[b]	Total coal consumed.
	Bituminous.	Anthracite.				
1899	[c] 10,000	....	1,200	11,200	50,120	61,320
1900	15,048	....	1,200	16,248	56,623	72,871
1901	[c] 24,000	....	1,300	25,300	77,674	102,974
1902	[c] 40,000	....	2,212	42,212	68,363	110,575
1903	64,625	1	1,447	66,073	60,605	126,678
1904	36,689	....	1,694	38,383	76,815	115,198
1905	67,707	6	3,774	71,487	72,567	144,054
1906	68,960	533	5,541	75,034	47,590	122,624
1907	45,130	1,116	10,139	56,385	88,596	144,981
1908	23,402	491	3,107	27,000	72,831	99,831
1909	33,112	....	2,800	35,912	74,316	110,228
1910	32,138	....	1,000	33,138	73,904	107,042
1911	32,255	....	900	33,155	88,573	121,728
	492,066	2,147	36,314	531,527	908,577	1,440,104

[a] By calendar years. [b] By fiscal year ending June 30. [c] Estimated.

The annual coal consumption in Alaska is shown in the above table, which indicates that there was an increase in the use of coal in 1911 as compared with 1910. This increase is probably due to the amount used by the Copper River Railway, which began operating a regular train service during 1911. The consumption of coal in 1912 will probably be considerably less, for oil is rapidly supplanting coal as fuel. Of the larger consumers of fuel in the Territory the Copper River Railway, most of the ocean steamers, the Treadwell group of mines, most of the Yukon river boats, and 18 of the 24 dredges operated on Seward Peninsula are using oil-consuming engines. The passenger service on the Tanana Valley and Alaska Northern railways is maintained by gasoline motor cars. The increased use of fuel oil and gasoline in Alaska is shown by the table on page 46. These facts clearly indicate that the local market for Alaska coal is certainly not increasing.

PETROLEUM.

There was considerable activity in the Katalla oil field during 1911. In the previous year two wells, located near Katalla Slough, between 1902 and 1904, which had been purchased by the Amalgamated Development Co., were cleaned out, a tank was erected on Kanak Island, Controller Bay, and connected by pipe line with the wells, and a small refinery was erected on Katalla Slough. No use appears to have been made of the tank; but in 1911 oil was pumped from the wells and refined, the product being disposed of at Cordova, Valdez, and other local settlements. In August, 1911, this company had erected a new derrick near the producing well and prepared to do some more drilling.

Meanwhile the British Columbia Katalla Oil Co. erected a derrick on Mirror Slough, about 7 miles northwest of Katalla, and in August had reached a depth of about 500 feet. Later in the year the Mirror Slough Oil Co. put in a rig near the one mentioned above. It is also reported that further drilling is to be done on Katalla Slough and on Katalla and Martins rivers. The season of 1912, therefore, promises to be one of considerable activity in this field. In describing the oil from this region Martin[1] says: "The petroleum is clearly a refining oil of the same general nature as the Pennsylvania petroleum. It resembles the latter in having a high proportion of the more volatile compounds and a paraffin base and in containing almost no sulphur." Oils of this character should find a special market on the Pacific seaboard, in which the fuel oils of California could not compete.

The following table gives the shipments of petroleum products to Alaska from 1905 to 1911, inclusive:

Shipments of petroleum products to Alaska from other parts of the United States, 1905–1911, in gallons.

Year.	Crude.		Naphtha.		Illuminating.		Lubricating.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
1905	2,715,386	$91,068	713,496	$109,921	627,391	$113,921	83,319	$31,660
1906	2,688,100	38,409	580,978	100,694	568,033	109,964	83,992	32,854
1907	9,104,300	143.506	636,881	119,345	510,145	99,342	100,145	37,929
1908	11,891,375	176,483	939,424	147,104	566,598	102,567	94,542	36,423
1909	14,034,900	334,258	746,930	118,810	531,727	98,786	85,687	35,882
1910	18,835,670	477.673	788,154	136,569	626,972	95,483	104.512	38,625
1911	18,142,364	406,400	1,238,865	167,915	423,750	57,896	100,141	34,048

MISCELLANEOUS MINERAL PRODUCTS.

The value of the total marble and gypsum production in 1911 is estimated at $140,000, compared with $117,162 in 1910. One marble quarry and one gypsum mine were operated in 1911, the same number as in 1910. These properties are in southeastern Alaska. During 1911 work was continued on a deposit of garnet in the Wrangel district in southeastern Alaska, from which some shipments have been made at various times. In 1911 surveys of this property were made for patent.

[1] Martin, G. C., Geology and mineral resources of the Controller Bay region, Alaska: Bull. U. S. Geol. Survey No. 335, 1908, p. 124.

RAILWAY ROUTES FROM THE PACIFIC SEABOARD TO FAIRBANKS.

By Alfred H. Brooks.

INTRODUCTION.

The full industrial development of inland Alaska can be brought about only by constructing railways to some of the open ports on the Pacific. Many railways have been planned and parts of some have been constructed, but the work done supplies only in small degree an urgent need. Though Alaskans have long been clamoring for adequate transportation facilities, the general public outside of the Territory has only recently begun to understand that the opening up of the mineral wealth and arable lands of this great empire is a matter of national importance. Since public interest has been aroused there has been much discussion about the relative merits of the several possible railway routes from the Gulf of Alaska to navigable waters of the Yukon. Much of the discussion has consisted either of ex parte statements by those who were advocating some particular route or of generalizations by those who were inadequately informed as to the true conditions. As a matter of fact, topographic maps have been made by the Geological Survey as well as private railway surveys, which afford a very large amount of information about most of the railway routes under consideration, the harbors and shore lines have been charted by the Coast and Geodetic Survey, and investigations of the mineral wealth have been made by the Geological Survey, and of the arable lands and forests by the Department of Agriculture. All these data, together with the statistics on population, commerce, and industries, as well as the climatic records of the Weather Bureau, constitute a wealth of information bearing on railway routes.

It is here proposed to summarize the data obtained from these various sources, which will help to elucidate the problems of railway location. Two articles [1] on this subject, published five and six years ago, will be freely drawn upon, but much information which has been made available since these articles were published will also be utilized.

[1] Brooks, Alfred H., Railway routes [Alaska]: Bull. U. S. Geol. Survey No. 284, pp. 10–17, 1906; Railway routes in Alaska: Nat. Geog. Mag., May, 1907, pp. 165–190.

As this summary must of necessity be brief, it can include but few details regarding the several routes, which aggregate over 2,000 miles. Details can be obtained from Government reports on Alaska, a list of which is given on pages 76–88. For convenience of reference this list is arranged by routes and includes also references to certain unpublished data in the Government archives, consisting chiefly of notes and plats of private railway surveys on file in the General Land Office.

COST OF RAILWAY CONSTRUCTION.

In any discussion of railway routes the cost of construction is obviously important, and, although this matter lies entirely outside of the writer's experience and should be left to the engineer, a few facts bearing on it will be presented. First, it should be noted that the cost of construction in Alaska is usually estimated by engineers at from 50 to 100 per cent more than similar work in the Western States. It is obvious also that the cost per mile will be a variant determined by the limitations put on curvature and grade and also by the character of the work. Moreover, the cost of building a railway over any particular route must be estimated by experienced engineers from detailed location surveys. But few such estimates have thus been made, and these have not been made public. Some 270 miles of railway have been built over the routes here to be discussed, including the Alaska Northern and Copper River railways. It appears that the average cost per mile of these railways has been about $60,000 and $90,000, respectively. The White Pass & Yukon Railway (110 miles long, running from Skagway to White Horse) is reported by the management[1] to have cost an average of $62,000 a mile.

These figures are not to be regarded as average costs of a railway from tidewater to the Yukon. They represent not only the pioneer work, which is always expensive, but appear to include the cost of terminals and expensive bridges, and all the routes built include the most difficult construction which would be required in Alaska. These railways traverse the rugged coastal mountain barrier, where difficult engineering problems must be solved. This coastal province presents a strong contrast to the region of broad, open valleys and gently rolling upland that lies beyond the coastal ranges—a region where railway construction would be simple, and, except for bridges, comparatively inexpensive. Experienced engineers[2] familiar with northern conditions estimate that a serviceable standard-gage rail-

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[1] Statement of O. L. Dickinson: Hearings before Committee on Territories of the House of Representatives on Transportation in Alaska, Apr. 6, 1912, p. 79.

[2] Hawkins, E. C., Railroads in Alaska: Hearings before Committee on Territories of the House of Representatives, 59th Cong., 1st sess., Feb. 1, 1906, p. 60. Joslin, Falcon, Railroads of Alaska: Hearings before Committee on Territories of the Senate, 62d Cong., 2d sess., Apr. 12, 1912, p. 9. Swanitz, A. W., Transportation in Alaska: Hearings before Committee on Territories of the House of Representatives, Apr. 6, 1912, p. 86.

way could be built from tidewater to Fairbanks at an average cost of about $40,000 a mile.

CONDITIONS AFFECTING RAILWAY LOCATION.

CLASSIFICATION AND ANALYSIS.

For the purpose of clarifying the discussion to follow, an attempt will first be made to analyze and classify the principal factors that enter into the problem of railway location. As classified by the writer the most important of these fall into two general groups which can be termed (1) commercial and (2) geographic. The first of these includes all matters relating to present and future traffic, including developed and undeveloped resources and population as well as to competitive and supplementary lines of transportation. Obviously this class embraces the most important elements in the problem, for without adequate tonnage no railway can be a financial success, no matter how favorable may be the topographic conditions. In the second group fall the geographic conditions which embrace the physical features of the proposed route. Obviously these are of secondary importance, for if the assured tonnage warrants it almost any physical obstacle will yield to modern engineering. Certain subdivisions of the commercial and geographic conditions are indicated in the following table which is intended to present a terse analysis of the problem of railway routes.

I. Commercial conditions:
- (1) Developed resources. (Statistics of production and commerce.)
- (2) Undeveloped resources:
  - Mineral. (Economic geology.)
  - Agricultural. (Climate, soil, botany, and distribution of arable lands.)
  - Timber. (Distribution, quality, and quantity of forests.)
- (3) Population.
- (4) Competitive or supplementary lines of transportation. (Navigable waters and existing railways.)

II. Geographic conditions:
- (1) Position. (Terminals and connecting lines of transportation.)
- (2) Distances. (Comparison of distances of different routes.)
- (3) Relief. (Mountain ranges, passes, and valleys in relation to distances and gradients.)
- (4) Watercourses. (Depths and widths of rivers as affecting construction of bridges or ferries.)
- (5) Climate. (Snow, rain, etc.; their effect on cost of construction and maintenance.)

Among other conditions which may affect railway location are political boundaries, but with the present methods of handling customs matters boundaries are usually not important. If, however, a railway is to be put to military use they become all-important.

It will be evident, too, that the financial backing of any particular railway enterprise may exert very great influence on the choice of routes. Thus a lack of capital may force the choice of a route where the first cost of construction is lowest and without regard to considerations of ultimate economy in construction, operation, and maintenance.

COMMERCIAL CONDITIONS.

DEVELOPED AND UNDEVELOPED RESOURCES.

The area which would be developed by railways from the Pacific to upper Yukon waters is roughly blocked out by the Yukon on the north, the Pacific Ocean on the south, the international boundary on the east, and the Alaska Range on the west. (See Pl. I, in pocket.) This province, here termed central Alaska, includes about 200,000 square miles, or more than a third of the entire area of the Territory. It includes the extensive gold-placer districts of the Yukon-Tanana region, in which lies the Fairbanks district. This region has produced gold to the value of about $67,000,000, and its gold output for 1911 had a value of about $6,000,000. In the same province, to be opened up by railway, are a number of smaller placer districts, including those of the Copper and Susitna valleys, which have produced some $4,500,000 worth of gold, of which $300,000 represents the value of the production of 1911. Though not immediately in the province tributary to the railway routes discussed, the Iditarod-Innoko district could be reached by a branch line from the Susitna Valley. In 1911 this district produced gold to the value of $3,000,000.

The entire region tributary to the railway routes here considered has produced gold to the value of about $75,000,000, of which about $9,300,000 represents the value of the output in 1911. The mining has been done in spite of very high operating costs due to the lack of means of transportation. Auriferous gravels are very widely distributed in this province, and many that can not be exploited under present conditions could be profitably worked if transportation were provided.

Relatively little search has been made for auriferous lodes in the province, for under the existing primitive and expensive methods of transportation there has been little hope of profitable exploitation of lodes, even if they were found. The prospect of finding auriferous lodes in part of this field is encouraging, and a little gold-lode mining has been done on Kenai Peninsula, in the Willow Creek region of the Susitna basin, and in the Fairbanks district.

There is only one productive copper district in this field, except that of Prince William Sound, which does not need railway transportation. The Kotsina-Chitina copper-bearing district lies in the lower Copper River basin and includes the famous Kennicott-Bonanza mine. Ore shipments from this property were begun in April, 1911, as soon as the Copper River Railway was completed. The activity in this district since then illustrates strikingly the benefit of railways. Another copper belt lies in the headwater region of Tanana and White rivers, and some copper ore has also been found in the Susitna basin, but these two districts, being far from railways, are entirely undeveloped. Some silver-lead, iron, and tin deposits have also been found in this central Alaska region, but they are undeveloped and their value has not been determined.

The coal fields of the central Alaska region are extensive and include the best coal of the Territory (Pl. I, in pocket). Of these, the Bering River field includes 45 square miles and the Matanuska field over 80 square miles of coal land. They contain high-grade steaming and coking bituminous coal and some anthracite. Their development awaits the settlement of the coal-land question and the construction of railways. Lignitic coals are widely distributed in central Alaska. The Nenana, the largest inland field of lignitic coal, contains about 165 square miles of coal land.

In this province there are extensive tracts of arable lands, which are almost unutilized. The largest areas of agricultural lands are in the Susitna and Tanana valleys and there are smaller areas in the basins of Copper and other rivers. Considerable profitable farming has been carried on near Fairbanks, where a local market is reached by wagon roads. A large number of homesteads have been taken up near Knik, in the Susitna region, and more would be entered if there were any means of getting products to market. Agricultural land in Alaska is not likely to yield any crops for export for a long time, but with the increase of local markets that will follow mining development, brought about by the building of railways, a farming population would be attracted. In addition to the farming lands there are much larger areas of good grass land, and cattle raising is likely to become an important industry. With the decrease of the western ranges in the States Alaska may before long be drawn upon for beef and mutton.

Except at a few places near the seaboard, there is little or no merchantable timber in central Alaska. In favored localities spruce trees reach diameters of 2 feet, but in most places the diameter of few of the largest trees exceeds 12 to 18 inches. This timber has great value for local use, but its consumption as fuel should be discouraged as far as possible by developing the coal fields. At Fairbanks and other places there are sawmills, which supply in part the local demands for lumber.

POPULATION.

The present population of central Alaska is about 22,000, or one-third of the total population of the Territory. These are mostly whites and include probably[1] over half of the total white population of the Territory. The largest coastal towns of central Alaska are Cordova (population 1,152), Valdez (population 810), and Seward (population 534). Fairbanks, which is in the Tanana Valley and is the inland objective point of most of the railways, has a population of 3,541. There are some 150 people in the town of Chena, located on the Tanana River 10 miles below Fairbanks. In 1910 the population of these two towns and of the tributary mining camps aggregated 7,875. The census on which these figures are based was taken in winter, so only the permanent residents were enumerated, the number being augmented each summer by several thousand men who spend only the open season in the mining camps.

The population of central Alaska not included in the towns above mentioned is scattered in small settlements and mining camps. There has been a considerable influx of population to the lower Copper River basin since the railway was completed to this province in 1911.

The town of Chitina, on the west bank of the Copper, where the railway turns eastward, is the nearest point to Fairbanks on the Copper River Railway, and much of the inland travel that formerly started from Valdez now goes from Chitina. Practically no settlements have been established along the military road between Valdez and Chitina and Tanana except road houses, but several hundred miners and prospectors live in camps that are tributary to it. There are also several hundred people in the mining camps of Kenai Peninsula and adjacent region. In this part of the field the largest settlements are Hope, Sunrise, Girdwood, and Knik, which have a population probably aggregating about 200. The Yentna placer district has a population of probably 200. No settlements have been established in the upper Susitna basin or north of it as far as Tanana River except a few mining camps in the Valdez Creek and Bonnifield districts. Most of the settlements in the Iditarod-Innoko region have sprung up since the census was taken, so that the population of this region is not known but probably includes 1,500 or 2,000 people. Though it will be evident from the above statements that the population of central Alaska is scant, it must be remembered that up to the present time the industrial conditions have been such as attract only the placer miner. Even placer mining has been limited almost entirely to the exploitation of bonanzas. No titles have been granted for coal lands, and even if titles had been given the coal

[1] The census of Alaska was taken in 1910 and the details of it have not yet been published. The total population is reported to be 63,700, of which about 36,000 are whites.

could not be mined without railways. Copper and gold lode deposits and much of the low-grade placer ground can not be developed without improved transportation facilities. In the absence of means of communication only the arable lands that lie close to the settlements have been taken up, so that the farming population is very small.

COMPETITIVE AND SUPPLEMENTARY MEANS OF TRANSPORTATION.

A number of good harbors along the Pacific seaboard of Alaska are available for coastal terminals of railways leading inland. These harbors are open throughout the year and are from 1,000 to 1,400 statute miles from Puget Sound. At present a steamboat service of six trips a month is maintained with most of these ports, and in addition some freighters carry coal and other supplies north and bring back salmon and copper ore.

Three routes are now in use for reaching Fairbanks and other settlements in the interior. A military road connects Valdez on the coast and Chitina on the Copper River Railway with Fairbanks. The distance by this route from Chitina to Fairbanks is about 324 miles; from Valdez to Fairbanks, winter trail, about 376 miles. Most of the travel over this route is in winter, when it is also used for the mail service. Freight for the local mining camps is also hauled over this road during the winter at a cost of 10 to 20 cents a pound.

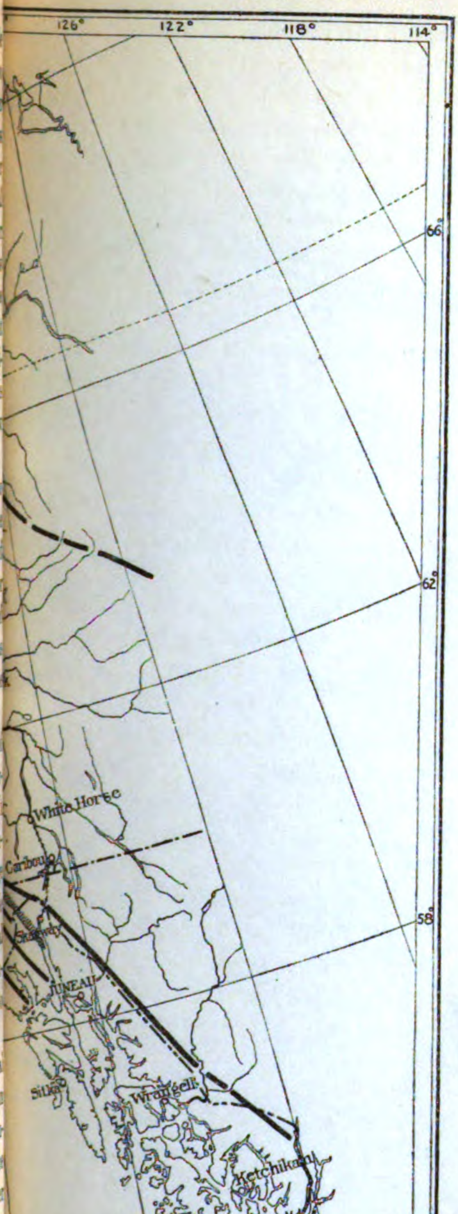
Most of the freight for Fairbanks is shipped to St. Michael by ocean vessels and thence by steamers up Yukon and Tanana rivers. From Seattle by this route the ocean voyage is about 2,700 miles and the river journey about 1,100, and usually about a month is used in transit. Moreover, this route is open only from about the end of June to the middle of September. Some freight and many passengers are carried to Fairbanks by the so-called White Pass route. This route necessitates an ocean voyage of about 1,000 miles to Skagway, in southeastern Alaska, and thence a railway journey of 110 miles by the White Pass & Yukon Railroad to White Horse, in Yukon Territory, where transfer is made to a Canadian river steamer, which is used as far as Dawson, a distance of about 460 miles. The distance from White Horse to Dawson by winter road is 330 miles. From Dawson an American bottom is utilized going down the Yukon and up the Tanana to Fairbanks, a distance of about 1,000 miles. The actual journey from Seattle to Fairbanks by this route occupies about two weeks, but is usually much longer when delays occur at transfer points. River navigation on this route is usually possible from about the 1st of June to the end of September. It is used chiefly for urgent freight and passengers.

Both the upper and lower routes are subject to interruptions because of low stages of water, which at times has interrupted all navigation for 10 days at a time. At best these routes are available only during four months in the year. The high freight charges are at least in part accounted for by the fact that the profits on the larger investment of river steamers and equipment must all be made in less than a third of the year. Wood, too, is expensive, and a large number of the steamers are using California petroleum for fuel. An additional item of expense is the cost of transshipping at least once by the lower Yukon River route, or three times by the upper river and White Pass route. Freight charges to Fairbanks are from $50 to $150 a ton, the average being probably $75. This cost is incurred to reach a point less than 500 miles distant from the Pacific coast. By feasible railway route to the coast, and thence by ocean steamer, Fairbanks is only about 2,000 miles distant from Seattle, though supplies are now transported nearly 4,000 miles by the indirect route now in use.

No exact figures are available on the amount of freight carried to the Yukon, but it was estimated at about 30,000 tons in 1910. The cost of transportation on this freight from Puget Sound to the end of river navigation was probably about $2,500,000, or about $250 for every man, woman, and child in the district and about 25 per cent of the value of the entire gold output of the region. An equal sum was probably expended for hauling the freight from the river bank to the mines.

The Yukon and Kuskokwim basins embrace some 5,000 miles of waters navigable by river steamers (Pl. II). This mode of transportation, as has been shown, is both expensive and time consuming. It has served the purpose of the pioneer and has made possible the opening of the richer placer districts without expenditure of the large amount of capital needed for railways. But gold and copper lode mining and many large placer-mining operations, not to mention coal mining, are impossible without railways, supplemented by an adequate system of wagon roads. Steamboats should be relied upon to supplement railways and not to supplant them.

Little need be said of the other means of communication in central Alaska. The Alaska Northern Railway supplemented by wagon roads and trails makes accessible the mining camps of the Kenai Peninsula. A winter sled road has been built from end of track to the Iditarod-Innoko region. This trail passes near the Yentna placer district, which can also be reached by steamboats and launches up Susitna River and its tributaries. There is also a trail from Knik to the Willow Creek lode district and another up the Matanuska Valley to the coal field. In summer small launches ply on Cook Inlet and between the end of the railway on Turnagain Arm to Knik and up Susitna River. Ocean steamers during the open season can go up Knik Arm as far as Ship Creek.



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The Tanana Valley Railway at Fairbanks, 45 miles in length, together with a number of good wagon roads, renders the tributary mining camps accessible. There are also some good winter roads and trails in other districts of the Yukon-Tanana region.

To sum up: Central Alaska, whose area is about three-quarters that of Texas, has less than 300 miles of railway, not over 600 miles of wagon road, and probably less than 1,000 miles of trail; Texas has nearly 13,000 miles of railways and about 130,000 miles of wagon road.

GEOGRAPHIC CONDITIONS.

Details in regard to geographic position of terminals, distances, and topography of proposed railway routes are given on pages 57–76, and it is therefore necessary here to consider only the larger features of relief and drainage and the general climatic conditions.

RELIEF AND DRAINAGE.

A rugged mountain mass called the Pacific mountain system (see Pl. II), which fringes the coast line of British Columbia and stretches northward into Alaska, presents along thousands of miles of the Pacific seaboard a formidable barrier to inland travel. This mountain system, however, is broken by a number of transverse valleys and low passes which form natural highways into the interior. Beyond the coastal mountains lies a province of less relief, which presents but few obstacles to railway or road construction.

The Pacific mountain system, which is represented by a single range 50 to 80 miles in width along the boundary of British Columbia and Alaska, broadens out as it enters the Territory, reaching an extreme width of 200 miles and being made up of a number of parallel ranges. Through this series of ranges the railway engineer who desires to tap the mineral resources of inland Alaska must seek a route.

In southeastern Alaska three rivers—the Unuk, Stikine, and Taku—have their sources beyond the coastal barrier, and hence their valleys are possible railway routes to the inland region. Such routes would, however, serve to open up Canada and not Alaska and will not here be considered. Farther north Skagway River reaches far back into the mountains, though it does not traverse the entire coast range. The White Pass, 2,880 feet high, separates its waters from those flowing into the Yukon and is used by the White Pass & Yukon Railway. A few miles to the north is Chilkoot Pass, 3,100 feet high, not feasible for a railway route, but long an Indian route into the interior and extensively used during the Klondike days. About 40 miles south of Chilkoot Pass Chilkat River debouches into Pyramid Harbor, an arm of Lynn Canal. This river also lies entirely within the mountains, and its headwaters are separated from streams flowing into the Alsek by passes about 3,200 feet high. West of Icy Strait the St. Elias Range forms the coastal barrier and is traversed by Alsek River, whose sources lie in the plateau region of the interior. The valley of Alsek River, though perhaps topographically feasible as a railway route, will probably never be used. for reasons which will be considered later (p. 60).

The Copper River valley is the first gap in the mountains west of the Alsek (Pl. III). This stream drains a large basin which lies entirely within the Pacific mountain system. In its lower 130 miles the valley of this stream is narrow, but it broadens out above, embracing the gravel-floored upland called the Copper River Plateau. The southwest margin of this plateau is drained westward by Matanuska River, which flows into Cook Inlet. The watershed between the two basins lies at an altitude of about 2,800 feet. The lowest part of the divide between the Copper and Susitna waters is between the Middle Fork of the Gulkana, flowing east, and McClaren River, flowing west, and is about 3,000 feet high. Several broad passes lead from the Copper River basin into the Tanana Valley, one of which, between Chistochina and Delta rivers, is about 3,300 feet, and another, the Mentasta Pass, about 2,900 feet above the sea. The headwaters of the Copper are separated from the Nabesna, a tributary of the upper Tanana, by a broad gap having an altitude of 3,400 feet. Skolai Pass, probably about 5,000 feet high, separates the head of White River from streans flowing into the Chitina, an eastern tributary of the lower Copper River. Between the head of Lowe River, which enters Prince William Sound at Valdez, and the Tasnuna, a westerly tributary of the Copper, is Marshall Pass, about 1,900 feet in altitude. Thompson Pass, about 2,500 feet high, is also on the divide that separates Lowe River drainage from that flowing into the Copper. Nearly all of the above-described passes have at one time or another been proposed for railway routes. The Copper River Railway has been built up Copper River for some 131 miles and thence eastward for 67 miles to the Bonanza mine.

The Chugach Mountains, which at the mouth of the Copper form the coastal barrier, swing to the west around Prince William Sound, and, bending to the south, merge with the range that forms the backbone of Kenai Peninsula. West of this range lies Cook Inlet, which occupies a part of a broad depression between the Kenai Mountains on the east and the southwestern extension of the Alaska Range. This trough is extended northward by the Susitna basin, which is bounded on the east by the Talkeetna Mountains and on the west by the Alaska Range. The Talkeetna Mountains are separated from the Chugach Mountains, to the south, by the Matanuska Valley, a broad trough whose upper end opens to the Copper River Plateau. (Pl. III.)

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The upper Susitna waters are separated from the Nenana basin by Broad Pass, about 2,700 feet high. An account has already been given of the divide between the Susitna and Matanuska waters on the west and the Copper River drainage on the east. On the west the rugged Alaska Range separates the waters of the Susitna from those flowing into the Kuskokwim. Several passes lead from the Yentna basin, tributary to the Susitna from the west, to the Kuskokwim Valley. Of these, Rainy Pass, about 2,950 feet high, is probably the lowest.

As upper Cook Inlet can not be navigated in winter on account of ice, it is important to consider the passes leading through the Kenai Mountains to open waters on the east side of the peninsula. There are several of these passes, one of which, between Placer River and Kenai Lake drainage (1,060 feet high and probably the lowest) is used by the Alaska Northern Railway. This railway also crosses another divide, about 700 feet high, between Kenai Lake and the streams tributary to Resurrection Bay. A route long used by natives journeying from Cook Inlet waters to Prince William Sound crosses a glacier-covered pass said to be about 1,000 feet high, lying between the head of Turnagain Arm on the west and Portage Bay on the east.

High, rugged, snow-covered mountains lie west of the upper half of Cook Inlet and form what seems to be an impassable barrier. Farther south, however, these mountains split up into a number of subordinate ranges of no great altitude and in the Iliamna Lake region are broken by several low passes, which lead to waters flowing into Bristol Bay. To the west are streams which flow into Kuskokwim River and which have not been surveyed. This region is said to be a rolling upland, with no high ranges and many broad valleys. Still farther west lies the main Kuskokwim Valley, which is separated from the Yukon by only a low watershed.

CLIMATE.

Central Alaska includes two provinces which are climatically very distinct. The Pacific seaboard is characterized by heavy precipitation, cool summers, and comparatively mild winters. This climate contrasts strongly with that of the region beyond the mountains, which is semiarid, has short, hot summers, and long, cold winters. Variations between these extremes are found in the many subordinate climatic provinces of the region.

In the coastal region stretching from Lynn Canal to Cook Inlet the total precipitation varies from 54 to 190 inches and the winter snowfall from 4 to 14 feet. The average temperature for the three summer months is from 50° to 54° F.; for the three winter months from 20° to 30° F. In different parts of the region there are 127 to 208 days in the year on which there is more or less precipitation. The incomplete records indicate an average annual precipitation of about 28 inches at Skagway, 126 inches at Katalla, 133 inches at Cordova, 74 inches at Valdez, 54 inches at Seward, and 35 inches at Sunrise on Turnagain Arm.

The lower Copper River valley has very much the same climate as that of the coast, but above the Tasnuna it is more of the inland type. At Copper Center the precipitation is about 9 inches annually, and the snowfall about 3 feet. Few records have been made in the Matanuska and Susitna valleys, but these districts are drier than the coast. At Chickaloon, on the Matanuska, one year's records showed precipitation of only 10 inches. At Fairbanks the average annual precipitation during a record covering five and a half years was 12 inches. At the mouth of the Tanana the records show about the same precipitation. At Eagle, near the boundary, the mean annual precipitation is less than 12 inches. In the Yukon-Tanana region the average temperature for the three summer months is about 54° F., and for three winter months about −12° F. The average snowfall in that region is 2½ to 5 feet. There is some precipitation for about 80 days in the year, but the total precipitation indicates that few of the rains are heavy.

The heavy snowfall along the seaward slope of the mountains is the only serious climatic obstacle to the operation of railways. Another drawback is the very marked fluctuation in the run-off. With the opening of spring the winter snows melt rapidly, and there is a correspondingly rapid rise in the streams. The danger to bridges and trestles is increased by the presence of ice, which may be not only thrown directly against structures but also may form temporary dams, which break and precipitate a sudden flood that carries cakes of ice.

The presence of glaciers in the Pacific mountain system may also affect railway construction. Glacial streams are heavily charged with sediment and are subject to great fluctuation. Their channels are constantly shifting. These conditions may considerably increase the cost of railways that must cross glacial streams, especially if the crossing be made near the ice front.

Some of the passes that will be described are filled with glacial ice, and hence are impassable for railways. For example, Prince William Sound is separated from the head of Turnagain Arm by a neck of land only 15 or 20 miles wide, and the divide is said to stand only 1,000 feet above the sea, but this pass is ice covered and unavailable for a railway.

Most of the Alaska glaciers are retreating, but some have advanced within the last decade.[1] Therefore in projecting railway routes that

[1] Tarr, R. S., The Yakutat Bay region: Prof. Paper U. S. Geol. Survey No. 64, 1909.

pass close to the front of glaciers the possibility of an ice advance should be carefully considered. Moreover, some of the moraines of existing glaciers, which appear to be made up entirely of gravel, sand, and loose material, may prove on excavation to be composed very largely of ice. Excavation of the glacial detritus will reveal the ice, which on exposure will thaw and cause endless difficulties in maintaining the grade. Glaciers are, however, limited to the Pacific mountain system and chiefly to the coastal slopes.

The fact that the ground is frozen in many places in the interior must also be considered in railway construction. In most of the Yukon basin the ground is frozen to bedrock. At one locality near Fairbanks ground frost was encountered to a depth of over 300 feet. In summer the ground thaws to a depth of only 18 inches to 2 feet. The ground is not everywhere frozen, for the beds of the larger watercourses are as a rule not frozen, and some other ground, such as the high gravel benches along valley walls, where drained, proves to be unfrozen. The talus-covered slopes of valleys are generally frozen, and a cut made into them leads to thawing, which is in places followed by slides that may be disastrous to railroad construction work. In building across frozen ground engineers have found it advisable to expose as little of the ground as possible to the air, in order to prevent thawing.

PRINCIPAL ROUTES.

LINES AND GRADES.

The foregoing account of the topography indicates that there are a number of possible routes of approach for railways from the Pacific to central Alaska. Those which are most important to this discussion fall into three general zones: (1) From Lynn Canal by way of the Chilkat, Alsek, White, and Tanana River basins; (2) by way of the Copper and Tanana basins; (3) by way of Kenai Peninsula and Susitna and Tanana River basins. Within these general zones there are several alternate routes. All the above routes are shown on the accompanying map (Pl. II), on which the mountain barriers as well as the transverse valleys and passes are indicated. The foregoing descriptions of the topography and the features represented on the map (Pls. II and III) indicate that there are other possible railway routes to the interior of Alaska. These also will be briefly described, though they do not pertain to the main subject of this article. All these routes will be described in geographic order from south to north.

Generalized profiles (Pl. IV) have been made of the principal routes. These profiles are based on the best information obtainable and indicate approximately distances and grades. This matter is presented in somewhat greater detail in the table of distances and altitudes, which are included in the description of the principal routes to Fairbanks. It can not be too strongly emphasized that the surveys of these routes are far from complete and that the data here presented can be of service to the locating engineer only in suggesting the general choice of routes. Accurate distances and grades can be determined only by detailed location surveys.

WHITE PASS ROUTE.

The White Pass & Yukon Railway, a narrow-gage road, has its coastal terminal at Skagway (Pls. I and II), which is at the head of Lynn Canal, about a 1,000-mile journey by inland water from Seattle, and is well provided with wharves. The railway ascends Skagway River for about 12 miles, then, leaving it, crosses White Pass at the international boundary, 20 miles from tidewater, at an altitude of about 2,880 feet. In this distance there is a grade of a little less than 4 per cent for a distance of some 15 miles.[1] From the pass the railway has a down grade for 90 miles to its terminal at White Horse (elevation 2,090 feet), on Lewis River. The steamboat trip down Lewis and Yukon rivers to Dawson (460 miles) takes about two days; the return journey about four. The steamboat route from Dawson to Fairbanks is about 1,000 miles long.

All but about 20 miles of this railway lies in Canadian territory. The chief reason for mentioning this railway here is because some plans have been suggested for extending it to the copper district of the White River valley and to other parts of the Yukon basin, which would bring it into competition with other railway routes here described. Moreover, it would in a certain degree compete with any railway built to Fairbanks, to which point, in connection with river steamers, it now handles freight and passengers.

The White Pass Railway could be extended to Lake Kluane by building about 120 miles. This route would lead over easy grades. At Lake Kluane it would intersect the route to be described from Lynn Canal to the Tanana. The distance from Lake Kluane to the White River copper deposits is about 120 miles.

ROUTE FROM PYRAMID HARBOR, SOUTHEASTERN ALASKA, TO FAIRBANKS, BY WAY OF WHITE AND TANANA VALLEYS.

The Pyramid Harbor-Tanana Valley route (Pls. II and IV) leaves tidewater at Pyramid Harbor, which is about 1,000 miles by inland water route from Seattle. Pyramid Harbor affords good water and shelter and presents no difficulties in wharf construction. The route extends up Chilkat River and crosses the international boundary about 6 miles from tidewater. Several passes, about 3,200 feet in

[1] Dickinson, O. L., Transportation in Alaska: Hearings before the Committee on Territories, House of Representatives, Apr. 6, 1912, p. 74.

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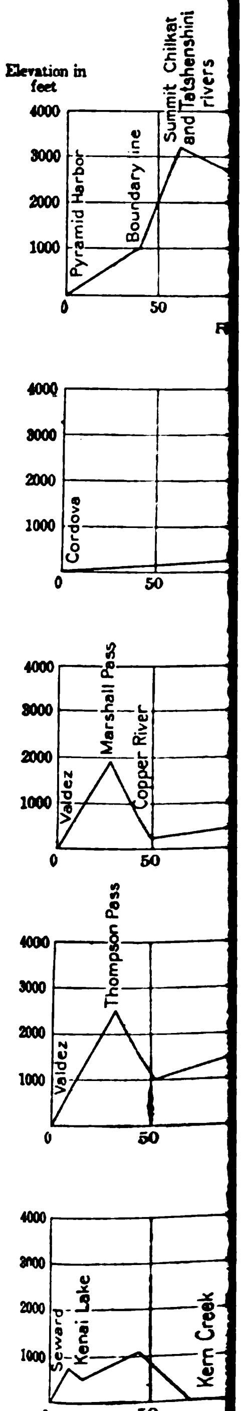

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height, lead from the Chilkat basin to the Alsek basin. Once over this divide the railroad route follows a series of natural depressions and valleys all the way to Fairbanks. These depressions, which parallel the inland front of the St. Elias Range (Pl. II), afford an admirable route for a railway. One route would be by Dalton Port and thence due west to Kaskawulsh River and up that stream to a low divide that separates it from Slims River, which flows into Lake Kluane. An alternate route would go farther northeast, by Lake Dezadeash and on to Lake Kluane. Detailed surveys would have to be made to decide which of these two routes is the better, but either would be entirely feasible. The route would continue to the west along the south side of Lake Kluane and beyond, crossing Donjek River in an almost straight course to the canyon of White River, where a suitable place for a bridge could be found. From this place the route would cross the broad flat that separates the White and Tanana basins. The rest of the route would be down the Tanana Valley, probably on the north side.

As will be seen from the accompanying table of distances and altitudes, the only bad grade is the one to the first divide from the coast. As a part of the route lies transverse to the main drainage lines, many bridges would have to be built. Of the larger streams crossed the Alsek, the Donjek, and the White would be the most expensive to bridge.

Approximate elevations and distances along railway route from Pyramid Harbor to the Tanana Valley and Fairbanks.

	Elevation.	Local distances.	Distance from Pyramid Harbor.
	Feet.	*Miles.*	*Miles.*
Pyramid Harbor	0	0	0
Klaheela River crossing		24	24
Alaska-Yukon Territory boundary line		19	43
Divide between Chilkat and Tutshenshina rivers	3,200	20	63
Dalton Post	2,520	26	89
Alsek River	2,500	44	133
Oconnor Glacier		32	165
South end Kluane Lake	2,600	14	179
Donjek River crossing	3,100	67	246
East branch White River divide	3,600	16	262
White River crossing	2,800	25	287
Alaska-Yukon Territory boundary line (141st meridian)		41	328
Tanana crossing	1,500	119	447
McCarty, mouth of Delta River	900	120	567
Washburn	600	29	596
Fairbanks	510	52	648

The Chilkat basin is well timbered (chiefly with spruce and hemlock) and contains some auriferous gravels, though the producing district lies somewhat off the proposed railway route. The copper deposits of Rainy Hollow, on the Canadian side of the boundary and 20 miles off the main route, are but little developed. In the inland region the route lies near no developed mineral resources until it reaches Lake Kluane, where there is a small placer district. It should be borne in mind, however, that what little is known of this region indicates that it may contain a continuation of the mineralized belt of southeastern Alaska and may possibly contain workable ore deposits. The copper belt of the upper White and Tanana basins, which lies near this route (Pl. I), is almost entirely undeveloped, but the prospect of finding workable ore bodies is encouraging. The placer districts of the Yukon-Tanana region are in part tributary to this route. The Tanana and Alsek basins are timbered with spruce and contain also considerable grazing and agricultural land.

There can be no doubt that this is a natural route into the interior and that a railway along it would open up a large inland region that contains valuable resources. Long before the white man came to the region this route was used by the natives in their intertribal intercourse. It has the disadvantage that for about 300 miles it traverses Canadian territory, and it would therefore not afford an all-Alaskan route. Moreover, it would not help to develop the resources of the Copper River and Susitna River basins.

YAKUTAT BAY-ALSEK ROUTE.

The lower Alsek River valley lies transverse to the St. Elias Range and has been proposed as a route into the interior (Pl. II). The line would run southeastward from Yakutat Bay for about 50 miles to the mouth of the Alsek. A narrow-gage railway, called the Yakutat Southern, has already been built for about 9 miles of this distance for the purpose of bringing fish to the salmon cannery at Yakutat. The Alsek Valley is only in part surveyed, but no doubt a railway could be built through it. It would intersect the Pyramid Harbor-Tanana route about 200 miles from the coast and would there attain an altitude of about 2,500 feet.

Yakutat Bay, which is about 1,150 statute miles (1,000 nautical miles) by sea from Puget Sound, is but an indifferent harbor and, so far as known, the proposed railway would not tap any mineral deposits, though such may exist in the unexplored St. Elias Mountains. It is open to the same objection as the Pyramid Harbor route, for it passes through Canadian territory. Much of the route being unexplored, a table showing distances and altitudes along it is not here given.

ROUTES TO BERING RIVER COAL FIELD.

The surveyed portions of the Bering River coal field include about 45 square miles known to be underlain by high-grade steaming and coking bituminous and anthracite coal. The field lies on the coastal flank of the Chugach Mountains and extends into the unsurveyed portion of the mountains. The coal field lies about 12 miles in an air line north of Controller Bay, 12 miles northeast of Katalla Bay, and 50 miles east of Orca Bay, an arm of Prince William Sound (Pls. II and III).

The southwestern end of the field touches Bering Lake, which is a very shallow tidewater inlet of Controller Bay. A small amount of coal has been brought to the coast on barges from Bering Lake, but the field can be developed on a large scale only by building a railway from the coast. Three general routes of approach to the coal field have been surveyed, and each has been advocated as the best by engineers who were familiar with local conditions. These are (1) from Controller Bay, (2) from Katalla Bay and Fox Islands, and (3) from Cordova on Orca Bay. Controller Bay, as a whole, is a shallow body of water with, however, a deep channel sheltered from the Pacific by Ocalee Spit, Kayak, Wingham, and Kanak islands. Ocalee Spit and Kanak Island are low, with no relief except sand dunes. Kayak and Wingham islands have considerable relief. Controller Bay is bounded on the north by the mainland, here a treeless coastal swamp traversed by many winding streams and broken near the sea by tidal inlets. A deep waterway called Ocalee Channel enters Controller Bay between Wingham and Kanak islands. It trends northeastward for about 4¼ miles and is continued beyond, to the east and northeast, for about 3 miles. At the entrance the channel is a little over half a mile wide and has a depth of about 66 feet at mean low water. It continues for this width about 3 miles, and then narrows to about five-eighths of a mile, and at the big bend shoals to about 42 feet. It maintains this depth of water and width of channel for about 2 miles to the southeast, beyond which it narrows, but except for one shoal 36 feet deep, practically maintains this depth of water to the extreme end of the channel, where it is a little less than a quarter of a mile wide. From half a mile to a mile of water about 3 feet deep separates the Ocalee Channel from the tidal flats which skirt the mainland and are about 2 miles wide. Ocalee Channel is separated by about a mile of shoal water and tidal flats from the southern end of Kanak Island.

About 3 miles from the entrance a narrow channel, a little over a mile in length, extends northward between Kanak Island and the tidal flats. This has a depth of nearly 20 feet and lies about three-quarters of a mile east of the southern end of Kanak Island. Bering River empties into the ocean at the north end of Controller Bay. Its silt-laden waters in part reach the sea through the shallow strait separating Kanak Island from the mainland to the north.

Controller Bay was first investigated as a tidewater outlet for the coal some 10 years ago, when the main features of the hydrography were determined by J. L. McPherson, a Seattle engineer. Since then the Coast and Geodetic Survey has charted the bay, disclosing the channel described above. As there are no landing facilities on Controller Bay, nor any buoys or beacons to mark the channel, it has never been much used by vessels. Surveys have been made for at least half a dozen different tidewater terminals on Controller Bay and there seems to be little choice between these terminals. The railways surveyed with terminals on the mainland would require about 3¼ miles of approaches across the tidal flats and shoal water that intervene between the shore and the channel. From the shore the railways would traverse about 20 to 25 miles of gravel flat at water grade to reach the margin of the coal field. This route would all be on water grade, the rise to the margin of the coal field being only some 50 feet. To reach different parts of the coal field many spurs and branches would have to be constructed. Bering River is the only large stream to be bridged and offers no difficulties.

Those who advocate the Controller Bay route contend that it is the shortest way to the coal field from tidewater and offers the best grade, with very cheap construction of the land line. They also point out that Controller Bay is only 1,300 statute miles (1,100 nautical miles) from Puget Sound, as compared with 1,400 for Cordova. They contend that while the channel is ample for present shipping the soft silt bottom could readily be dredged to meet any requirements of the future. Three chief points have been made against Controller Bay as an outlet of the coal field. First, it is asserted that cost of a terminal will be so expensive that interest charges will offset the cost of the extra haul to Cordova. Second, that while the bay is sheltered from the sea the adjacent lands do not afford adequate protection against the winds, which at certain seasons of the year are severe. Third, that the ice which forms on the mud flats and in the mouths of the rivers is carried into the bay in large cakes, which on being moved back and forth by the tide in the narrow channel, will be a serious menace to shipping as well as to the railway approaches. In reply to these criticisms it should be said that Controller Bay has now been under observation for a number of years by those who are advocating it as a railway terminal and that the engineers employed in this work are confident that the advantages of its use are greater than its disadvantages.

In 1907 two plans were in execution for providing a coastal terminal near Katalla, on the mainland about 10 miles west of Controller Bay. One of these provided for a breakwater from Palm Point, which was to make Katalla Bay, now exposed to storms from the south-southwest, available for shipping. Inside of this proposed breakwater depths of 20 to 30 feet are found within a quarter of a mile of the land. It was proposed to build a railway from this point up to the coal field and also one up Copper River. A wharf was built, later destroyed by the storms, and some 7 or 8 miles of track were laid. No work has been done on the project since 1907. From this terminal the surveyed railway route extends up Katalla River and across the flat, about 50 feet above sea level, to Bering Lake, which is shallow and could be crossed on trestles. The nearest coal could be reached with about 12 miles of track and the heart of the field with about 20 miles. This project would have the same easy grades as the route from Controller Bay. The Copper River line was planned to swing around Martin Point and follow up the alluvial flat that marks the eastern margin of the Copper River delta. It would join the present Copper River Railway about 30 miles from Katalla.

The second plan for a railway from the coast near Katalla contemplated making a harbor at the Martin Islands by building breakwaters. It was proposed to connect Whale Island with the mainland by a causeway, and to connect this island with Fox Island by breakwater, and also to extend a breakwater westward from Fox Island. The harbor thus formed would have a depth of 24 to 40 feet. The plan was to build a railway from this terminal into the coal fields and up Copper River along the routes already described. In 1907 work was started on this project and several miles of track were laid, since which time it appears that nothing further has been accomplished.

The third route of approach to the Bering River coal field is from the town of Cordova, on Orca Bay, which will be described below. This route is in part in use by the Copper River Railway, now in operation. The railway takes an easterly course from Cordova across the flats, which here intervene between the highlands and the sea. Many small glacial streams but no large rivers are crossed before Copper River is reached. Copper River is crossed 5 to 10 miles below the head of its delta by several bridges connecting islands that lie between the channels. The nearest point to the coal field is on the east side of the Copper and about 38 miles from Cordova. From this point there are two alternate routes to the coal field. One of these runs southeastward and reaches the field by way of Katalla. This is on water grade and has already been described. By this route the distance from Cordova to the coal is about 90 miles. The other route runs eastward from Copper River, crosses Martin River, and, passing near the southern margin of Martin Glacier, climbs to a pass about 350 feet high, beyond which it descends to the coal field by way of Lake Charlotte. The distance from Cordova to the coal field is about 60 miles by this route.

The quality and extent of the Bering River coal has already been described (pp. 60–61). There are no other resources known in the region except the petroleum of the Katalla field. The extent of this field is not known, but oil has been found by drilling at several localities, besides which there are numerous seepages. This petroleum is a refining oil and hence should find a ready market on the west coast (pp. 43–44).

The lower slopes of the hills to the edge of the flats in the Controller Bay region are densely forested with spruce and hemlock, which will yield lumber of fair quality. The best timber extends up to an altitude of about 1,200 feet. This timber will have value for local use, though none for export. Good grass is found in the flats, where there is also some arable land. There is little prospect for agriculture in the district, though truck farming will probably be carried on in places when the development of the coal creates a local market. There are quite a number of good water powers in the district.

These railway routes to the Bering River coal field have been described in greater detail than the general purpose of this article would seem to justify because of the great public interest taken in them. Although the opening of the Bering River coal field is important to industries in Alaska as a possible source of fuel, yet it will in no way settle the transportation problem of the Territory, for these coal fields are near the coast, and a railway to them will not give access to the great inland region.

COPPER RIVER ROUTES.

As already pointed out, Copper River affords a good route of access into the interior. (See Pls. III, IV.) Three different general routes up the valley of this river have been proposed—(1) from Cordova or Katalla up Copper River, (2) from Valdez across Marshall Pass down the Tasnuna to the Copper and up that stream, and (3) from Valdez over Thompson Pass down to Tonsina and to the Copper. The first is the longest and is by water grade. The second is over a 1,900-foot pass near the coast, and the third over a 2,500-foot pass, also near the coast. These routes will first be described and next an account of the branch lines will be given, to be followed by a brief review of the resources of the region to be opened up.

CORDOVA-FAIRBANKS ROUTE.

The town of Cordova is on the east side of Orca Bay, which is tributary to Prince William Sound. It is about 1,400 statute miles (1,210 nautical miles) from Seattle and about 60 miles from the entrance to Prince William Sound. The harbor at Cordova is well sheltered. Though the channel at the present wharf is only about a quarter of a mile wide ample provision can be made on Orca Bay for terminals for all future needs. Among other projects is an ocean terminal and town site, which has been located in a broad flat that opens out at the head of Orca Bay 8 miles northeast of Cordova. The Cordova-Fairbanks route extends up Copper River to the mouth of the Gulkana, ascends that river and one of its tributaries, crosses the divide to Delta River, and descends that stream and the Tanana to Fairbanks. The Copper River Railway has been built along this route as far as the mouth of the Chitina, where it turns east to traverse the southern margin of the Kotsina-Chitina copper belt.

This railway has already been described as far as the Copper River crossing, where it would join a proposed line to the coal field. Here it turns northward and at mile 49 crosses the Copper just above Childs Glacier. From this glacier to the town of Chitina (mile 131) it follows the west side of Copper River. Above Tasnuna River the building of the line involved much heavy rock work. At Chitina there is a bridge across the Copper, and from there the line is extended up Chitina River for about 66 miles, to the Kennicott-Bonanza mine, its present terminal. From Chitina the route to Fairbanks follows the left bank of the Copper as far as the mouth of Gulkana River, crossing in turn the Tonsina, the Klutina at Copper Center, and the Tazlina. Somewhere near the mouth of Gulkana River it would leave the Copper and follow the valley of the former stream as far as its Middle Fork. Here it would cross the Gulkana and follow the Middle Fork to its head in a broad gap, some 3,100 feet high. The information at hand indicates that from the Chitina to the pass there would be little or no rock work. For the most of this distance the river valley proper is marked by an escarpment of gravel and silt, which forms the eastern margin of the Copper River Plateau. From the pass the route would descend to the Tangle Lakes and thence follow the outlet stream draining these to Delta River. An alternative route would follow the Gulkana to the lake at its head and then cross to the Delta over a divide about 3,300 feet high. There is also another pass, about 3,000 feet high, between Gulkana Lake and the Tangle Lakes, which might be preferable.

The route down Delta River would run along the east side of the valley to avoid a glacier that discharges from the west, so that it would be necessary to bridge the Delta below the canyon. In the Delta Valley considerable rock work would be required. After crossing the Delta the route would lead probably nearly straight to Fairbanks, a bridge being built across the Tanana. One bridge could be avoided by following the Delta to its mouth and then bridging the Tanana, but this would increase the length of track about 14 miles.

Approximate elevations and distances along railway route from Cordova to Fairbanks, by way of Copper River.

	Elevation.	Local distances.	Distance from Cordova.
	Feet.	*Miles.*	*Miles.*
Cordova	0	0	0
Tasnuna crossing	240	82	82
Chitina	580	49	131
Crossing of Copper at Kotsina River	540	51	132
Copper Center	1,000	43	175
Tazlina River crossing	1,150	7	182
Gulkana River crossing	1,500	16	198
Crossing of creek outlet of Gulkana Lake	2,600	42	240
Paxsons	2,700	15	255
Summit near Gulkana Glacier	3,300	12	267
Delta River at mouth of Phelan Creek	2,700	13	280
Black Rapids	2,300	15	295
Donnely, on Delta River	2,000	12	307
Washburn, on Tanana River	600	51	358
Fairbanks	510	52	410

ROUTE FROM VALDEZ TO FAIRBANKS BY WAY OF MARSHALL PASS.

Surveys have been made for a railway from Valdez to Copper River by way of Marshall Pass. The town of Valdez is at the head of Port Valdez, a northeastern arm of Prince William Sound. The bay is deep and well sheltered and affords excellent conditions for wharves and terminal facilities. Several town sites have been located on the bay, but Valdez, built on the delta of the streams draining Valdez Glacier, is the only important settlement. It is about 1,420 statute miles (1,230 nautical miles) from Seattle.

From Valdez to Marshall Pass (elevation 1,900 feet) the distance is about 30 miles, and the route would lie up Lowe River. Engineers report that a good deal of rock work will be necessary for about half this distance. Beyond the pass the route would descend the broad valley of Tasnuna River to the Copper, which would be reached in about 31 miles. From this point the route would be identical with the one up the Copper, already described. The distance from Valdez to Fairbanks by this route is about 380 miles.

Approximate elevations and distances along railway route from Valdez to Fairbanks by way of Marshall Pass.

	Elevation.	Local distances.	Distance from Valdez.
	Feet.	*Miles.*	*Miles.*
Valdez	0	0	0
Loop in Heiden Canyon	....	26	2[illegible]
Marshall Pass	1,900	2	2[illegible]
Tasnuna River at Copper River	240	21	4[illegible]
Chitina	580	49	9[illegible]
Copper Center	1,000	44	142
Tazlina River crossing	1,150	7	14[illegible]
Gulkana River crossing	1,500	16	16[illegible]
Crossing of creek, outlet of Gulkana Lake	2,600	42	20[illegible]
Paxsons	2,700	15	2[illegible]
Summit at Gulkana Glacier	3,300	12	23[illegible]
Delta River at mouth of Phelan Creek	2,700	13	24[illegible]
Black Rapids	2,300	15	2[illegible]
Donnely, on Delta River	2,000	12	27[illegible]
Washburn, on Tanana River	600	51	32[illegible]
Fairbanks	510	52	37[illegible]

ROUTE FROM VALDEZ TO FAIRBANKS BY WAY OF THOMPSON PASS.

Thompson Pass is about 8 miles west of Marshall Pass, and the route to it from Valdez is up the Lowe River valley, which it leaves about 18 miles from tidewater. Here it turns northward, and in a distance of about 15 miles more crosses Thompson Pass (elevation about 2,500 feet). A better grade can be obtained by swinging around toward the head of Lowe River, thus increasing the mileage of approach to the pass. Beyond the pass the route follows down Tsina River to the point where that stream joins the Kanata to form the Tiekel. It thence follows up the Kanata Valley to Ernestine Pass and crosses a divide, about 1,800 feet high, to Mosquito Creek, which it follows to its junction with the Tonsina. Beyond Tonsina there are two alternative routes; one would follow the Tonsina Valley to the Copper and would be the natural route to the Chitina Valley; the other would keep to the north, and after climbing about 400 feet would join the Copper River route about 10 miles below Copper Center. From there on the route to Fairbanks would be identical with the one already described from Cordova. The distance from Valdez to Fairbanks by this route is about 342 miles.

Approximate elevations and distances along railway route from Valdez to Fairbanks by way of Thompson Pass.

	Elevation.	Local distances.	Distance from Valdez.
	Feet.	*Miles.*	*Miles.*
Valdez	0	0	0
Loop in Heiden Canyon		26	26
Thompson Pass	2,500	7	33
Tiekel River	1,000	19	52
Tonsina River crossing	1,500	31	83
Copper Center	1,000	24	107
Tazlina River crossing	1,150	7	114
Gulkana River crossing	1,500	16	130
Crossing of creek, outlet of Gulkana Lake	2,600	42	172
Paxsons	2,700	15	187
Summit at Gulkana Glacier	3,300	12	199
Delta River at mouth of Phelan Creek	2,700	13	212
Black Rapids	2,300	15	227
Donnely, on Delta River	2,000	12	239
Washburn, on Tanana River	600	51	290
Fairbanks	510	52	342

Some grading has been done on several railways leading out of Valdez designed to cross either Marshall or Thompson Pass. A little rock work was also done at the Keystone Canyon, in the Lowe River valley. These projects seem to have been quiescent for a number of years, except for some new surveys over the Thompson Pass route.

CHITINA VALLEY AND WHITE RIVER ROUTES.

A trunk line up the Copper Valley will necessitate a number of feeders to reach the mining camps tributary to it. The present railway up the Chitina Valley can be regarded as the most important of these feeders, but this itself will have to be supplemented by a number of spurs to reach many of the copper deposits. It has been suggested that this line be extended up Nizina and Chitistone rivers to Skolai Pass and across the divide to the White River copper deposits. Only a part of this route has been mapped by the United States Geological Survey. It appears, however, that the distance to the pass from the nearest point on the railway is about 25 miles, and from the pass to the flats at the head of White River is about 15 miles. Skolai Pass, which is occupied by a glacier, stands probably less than 5,000 feet above the sea. The railway at the proposed junction point has an elevation of about 1,400 feet, whereas the White River Flats, on the other side, are approximately 4,000 feet above the sea. This route traverses a rugged mountain region and would be expensive to construct. A railway reaching White River by this route would tap only the eastern end of the copper-bearing zone. The western end is in the Tanana drainage. To reach this by direct route from White River would necessitate crossing a divide about 6,400 feet high, to Chisana River, the east fork of the Tanana, a distance of about 25 miles, where a descent to about 4,000 feet would be made. The route would then be continued northwestward over the Cooper Pass (5,600 feet), and in a distance of about 25 miles would reach Nabesna River, the west fork of the upper Tanana. At the Nabesna the elevation would be about 3,000 feet. The same districts could be reached from White River on water grade, but by a very circuitous route, by extending the railway down the White Valley and crossing the flat which separates it from the Tanana basin. This route has already been described (pp. 59–60). Then, by building down the Tanana Valley, the upper Chisana and Nabesna regions could be reached by branch lines. This would require a total length from White River of about 160 miles, but the road would be easy of construction. It seems probable that this Nabesna-White River copper region can be best opened up by a railway from Pyramid Harbor (already described, pp. 60–62), or from Copper River by way of Batzanitas, or Mentasta Pass. (See pp. 69–71.)

ROUTE FROM COPPER RIVER TO MATANUSKA COAL FIELD.

A project for building a railway from Copper River to the Matanuska coal field has received some consideration. This route is only in part covered by the maps of the Geological Survey, and hence some of the distances and altitudes here stated are only approximate. A private survey has been run over the route, but the results are not yet available. The route leaves Copper River at the mouth of the Tazlina (elevation, 1,100± feet,) about 7 miles above Copper Center, 114 miles from Valdez by way of Thompson Pass and 182 miles from Cordova, and follows up the Tazlina for about 50 miles to a point within 10 miles of its glacial source. Here the route would reach an altitude of about 2,200 feet. From this point the route ascends to Tanneta Pass, 2,800± feet above the sea, in a distance of about 10 miles. From Tanneta Pass it would continue down one of the streams tributary to the Matanuska and reach the easternmost known coal in a distance of about 30 miles, here having an altitude of about 1,400 feet. About 18 miles more would carry the railway to the mouth of the Chickaloon (elevation 800 feet), in the heart of the Matanuska field.

To summarize briefly: The proposed railway would start at an elevation of 800 feet in the coal field, and in a distance of about 50 miles would reach the watershed at an altitude of 2,800 feet. It is possible by striking the Chickaloon higher up that 200 or 300 feet of elevation could be saved. From the watershed it would run on a down grade to Copper River for a distance of about 60 miles. The distance from the Matanuska coal field to Valdez by Thompson Pass would be about 222 miles and to Cordova by lower Copper River route about 290 miles.

BRANCH LINES TO UPPER COPPER, TANANA, AND WHITE RIVER REGION.

A railway through the Copper River valley and down Delta River, without branch lines, would fail to provide for the upper Copper basin and adjacent portions of the Tanana and White basins—a region of much mineral promise. The Chistochina or Chisna gold-placer district could be reached from the main line by branches on several routes. One route would start from the main line, about 20 miles from the Copper and near the Sourdough road house, would extend across a low divide to Gakona and up that stream to Chisna, centrally located in the gold field. This route would be on water grade and would be about 50 miles long. Another route would trend eastward from a point near the Delta River divide, leaving the main line at an altitude of about 3,200 feet, lead eastward, passing near Summit Lake, and reach Chisna by crossing two low divides in a distance of about 30 to 40 miles.

From Chisna a good route, about 50 miles long, extends eastward by way of the Mankomen Valley to Mentasta Pass, which has an elevation of about 2,900 feet above the sea. There is a good route from Mentasta Pass down Tok River to the Tanana, a distance of about 40 or 50 miles. A line could be extended up the Tanana on water grade to the copper deposits of the Nabesna, Chisna, and White rivers, as already described. About 240 miles of track would be required to reach all parts of this copper district. There is a more direct route to the copper-bearing district from Mentasta Pass by way of the pass (elevation 3,200 feet) at the head of Little Tok River, which leads into Tuck Creek, a tributary of the Tanana. By this route the different parts of the Nabesna-White River copper district could be reached from Mentasta Pass by about 240 miles of track.

A more direct route into this copper belt leads up the main Copper River valley from the Gulkana. This route would pass the native settlement of Batzulnetas and ascend Tanana Creek to a pass about 3,400 feet high to Jack Creek, a tributary of Nabesna River. From the Nabesna there are the two alternate routes to White River, a long one by water grades, and another, a direct route, over two high divides, which have already been described (pp. 67–68). The distance from the main line at the Gulkana by this route is about 90 miles. It may be added that construction work will be easy in this entire upper Copper River and White River region.

It will be evident that the White River region can be reached from the Copper River valley either by long, circuitous routes having easy grades or by shorter routes having steep grades. The distance from the head of White River over Skolai Pass to Cordova is about 240 miles; to Valdez, by way of Marshall Pass, about 160 miles. By direct route to the Copper River valley at Batzulnetas, the distance from White River to Cordova is about 340 miles; to Valdez, by way of Thompson Pass, about 270 miles. The route from White River, by way of the upper Tanana, to Cordova is about 440 miles; to Valdez, by way of Thompson Pass, about 370 miles. Going eastward, the distance from White River to tidewater at Pyramid Harbor (see pp. 67–68) is about 300 miles.

SUMMARY OF COPPER RIVER ROUTES.

The Copper River valley affords an excellent route to the interior of central Alaska. The Copper River Railway, now in operation, has aided much in developing the copper and gold deposits of the Chitina Valley. This road could be extended into the Tanana Valley by way of Delta River or by way of Mentasta Pass. An alternate plan is to build from Valdez over Thompson Pass or Marshall Pass to Copper River. Branch lines might be built to the Nabesna-White River region. The two copper belts, one north and the other south of the Wrangell Mountains, could thus be made accessible. Some productive placer districts would also be served by these lines, as would some auriferous lodes that have been found but that are undeveloped. The Matanuska coal field lies about 100 miles west of the central Copper River, and the Bering River coal field about 30 miles southeast of the Copper River delta. Either field could furnish the coking coal needed to smelt the copper. In this province there are also some water powers that could be utilized for mining development.

The timber resources of this region are not specially good. Around Cordova and Valdez there is some fairly good spruce and hemlock which, in the sheltered valleys, reaches up the hill slopes to an altitude of about 1,000 feet. There is no timber in the lower Copper Valley except an occasional cottonwood grove. Above Tasnuna River scattered spruces are found. In the Chitina Valley spruces grow up to an altitude of 2,000 to 3,000 feet. In favored localities along the valley cottonwood trees up to 18 inches in diameter are found. There is a similar growth of timber along the main Copper above the Chitina, but the trees growing at higher elevations, notably those on the Copper River Plateau, are stunted and have no value except for fuel. Similar forest conditions prevail in the upper Copper Basin and adjacent regions.

On the hill slopes above timber line, where they are not too steep, good grass usually grows in summer. There is little good grass on the Copper River Plateau, but some is found in the valley bottoms below the plateau level. The upper Copper, Tanana, and White River basins are noted for their good grass lands. Here the snowfall is so light that winter pasturage can be had, and the region gives promise of becoming a good cattle country.

There is much arable land in the valley bottoms of the Copper River and adjacent region. The plateau does not seem favorable for agriculture. The mineral and agricultural resources of the Tanana Valley have already been discussed (pp. 48, 60).

ROUTE FROM SEWARD TO FAIRBANKS BY WAY OF TURNAGAIN ARM AND SUSITNA VALLEY.

The Susitna Valley and Broad Pass, at its head leading to the Tanana Valley, affords a favorable railway route to inland Alaska. As the upper part of Cook Inlet is closed to navigation from about November 1 to April 1, a railway up the Susitna must find an open port on the east side of Kenai Peninsula. Such a route has been found to Resurrection Bay, and is now being utilized by the Alaska Northern Railway. This railway has been completed from Seward, on Resurrection Bay, to Kern Creek, on Turnagain Arm, a distance of 71½ miles. The Matanuska coal field is the objective point of this railway, but construction work has been stopped pending a settlement of the coal-land question. Seward, which is excellently located at the head of Resurrection Bay, is about 1,420 statute miles (1,235 nautical miles) from Seattle. The harbor is good, and the conditions are favorable for terminal facilities. The railway route to Fairbanks has been described briefly as follows:[1]

> It leaves the Pacific seaboard at Seward, about 1,235 nautical miles from Seattle, on Resurrection Bay, and, traversing a broad, heavily timbered valley, climbs by easy grade to 700 feet at mile 12. It then descends to Kenai Lake, about 500 feet in altitude. Another easy grade brings it at mile 45 to a second pass, 1,060 feet in altitude. Both

[1] Brooks, Alfred H., The Mount McKinley region: Prof. Paper U. S. Geol. Survey No. 70, 1911, pp. 220–221. Some of the elevations and distances have been corrected in this quotation to agree with the latest information.

these summits are reached with a maximum grade of 2 per cent. From this second summit it descends by a series of loops, trestles, and tunnels with a maximum grade of 2.2 per cent to the valley of Placer River. It is stated by the company that by changing the location of the line to the west wall of the Placer River valley this descent can be made with a maximum grade of only 1.5 per cent. Placer River, which has a glacial source, is crossed on pilings, and the line then follows the east side of the valley. Swinging around the head of Turnagain Arm on a broad grass-covered and timbered flat, the railway crosses two more small glacial rivers. It then follows the north side of Turnagain Arm with a series of rock cuts and fills. The line, which is standard gage, is completed and in operation to Kern Creek, 71½ miles from Seward (1910). Beyond this point location surveys have been made and in all about 2 miles of grading completed.

From Kern Creek the surveyed line follows the north side of Turnagain Arm to Point Campbell, at the entrance to Knik Arm. Here there are no serious difficulties except in the last 10 miles, where there will be a good deal of heavy rock work. The line follows the east shore of Knik Arm from Point Campbell to the mouth of the Matanuska, which is about 140 miles from Seward. It appears that in this part of the line very little rock work will be required. After crossing the Matanuska it is planned to extend the main line westward to the Susitna and a branch line about 40 miles long up the Matanuska Valley to the coal field. Much of the branch line will require no heavy construction.

The coal field appears to be the immediate objective point of this railway, but the manager reports that plans and preliminary surveys have been made for extending the line up the Susitna to the junction of the Chulitna and up that stream to Broad Pass, about 2,700 feet in altitude and about 320 miles from Seward. So far as known, an easy grade can be maintained to this point, and there are no serious engineering difficulties. From Broad Pass the route follows down Nenana River to the Tanana Flats, and here again, it is believed, an easy grade can be established. From this point any locality on Tanana River can be easily reached. If the route is extended north of the Tanana, that river could best be bridged at the big bend near Tortella. Details in regard to this route are presented in the following table, in which the distances and altitudes given are, however, only approximate:

Approximate elevations and distances along railway routes from Seward to Fairbanks by way of Susitna Valley.

	Elevation.	Local distance.	Distance from Seward.
	Feet.	*Miles.*	*Miles.*
Seward, Resurrection Bay	0	0	0
First summit	700	12	12
Kenai Lake	500	6	18
Second summit	1,060	27	45
Head of Turnagain Arm		18	63
Kern Creek (end of track, 1911)		8	71
Ship Creek	180	44	115
Mouth of Matanuska River		32	147
Matanuska Branch (Junction)		2	149
Willow Creek	300	38	187
Talkeetna River	300	43	230
Broad Pass	2,700	88	318
Nenana River (mouth of canyon)	800	79	397
Tanana River at mouth of Nenana River	400	23	420
Chena	490	41	461
Fairbanks	510	7	468

The company reports that plans for a branch line to the Kuskokwim, Innoko, and lower Yukon have also been made, but it is not known that this route has yet been surveyed. Such a line would cross Susitna River and ascend the Skwentna Valley to Rainy Pass, about 2,950 feet above tide level and about 150 miles from the Matanuska junction described above. From Rainy Pass to the Kuskokwim at the mouth of Tatina River, where the elevation is about 1,000 feet above the sea, the distance is about 15 miles. The route would then be down the Kuskokwim and across a divide not over 1,000 feet high to the Innoko, the distance being about 160 miles. The distance from Seward to the Innoko or Haiditarod is about 520 miles. [The distance from Seward to navigable waters on the Kuskokwim is about 320 miles; to the mouth of the Takotna, 430 miles.]

Various deviations from the accepted route of the Alaska Northern Railway have been proposed, but appear not to have been very seriously considered. It has been suggested that an easier grade to tidewater on the north side of Kenai Peninsula might be obtained by a route that extended down Sixmile Creek to Sunrise. This, however, would necessitate climbing to an altitude of about 1,300 feet at Moose Pass or 1,500 feet at the divide at Johnson Creek. This route would leave the present track in the vicinity of Trail Lakes. An alternate plan would be to swing around the north shore of Kenai Lake and cross the 1,300-foot divide at the head of Quartz Creek. The latter route would require some heavy rock work along the north shore of Kenai Lake. These routes would be 10 to 20 miles longer to tidewater than the existing line. About 18 miles of track, including much rock work, would be required to carry the line from Sunrise to the head of Turnagain Arm, there to be connected with the present railway. Therefore, though the grade on the Turnagain Arm side might be better over some of these routes, the expense of the additional mileage would hardly seem warranted.

In this connection it will be well to refer to a proposed scheme for bridging Turnagain Arm from Snipes Point, near Sunrise, on the south side, to Bird Point on the north side. The distance between these points is a little over 2 miles and the water is shoal. The enormous tides in the arm and the presence of ice in winter would seem to make this an exceedingly difficult, if not impossible, feat of engineering. So far as known to the writer, this project has not been indorsed by any competent engineer.

Before the Alaska Northern Railway was built several other plans were devised for a railway into the Susitna Valley. One of these was a route from Kachemak Bay northward along the west front of the Kenai Mountains to Turnagain Arm and around the head of the arm. This route is much longer than the one from Seward and misses most of the important developed gold resources of Kenai Peninsula, and its ocean terminal is inferior to that on Resurrection Bay. Another plan was to build from Snug Harbor or some other bay on the west side of Cook Inlet and follow the shores of the inlet northward to the Susitna Valley. This route would run on water grade, but would be longer to the Matanuska coal field than the one from Seward. Its ocean terminal would also be very inferior to that at Resurrection Bay and is sometimes blocked with ice. Another plan is to build from Portage Bay, on the west side of Prince William Sound, to Turnagain Arm. Though the distance is only some 15 or 20 miles the fact that the pass (1,000 feet) is occupied by a glacier seems to prohibit its use for a railway.

The establishment of a summer port of shipment near Ship Creek, on Knik Arm, is a part of the project of the Alaska Northern Railway. The charts of the Coast and Geodetic Survey show that a channel having a depth of about 36 feet enters Knik Arm and extends to the vicinity of Ship Creek, which is on the line of the proposed route of the Alaska Northern Railway. This is about 60 miles from the Matanuska coal field, which is reached from this point by water grade. The mouth of Ship Creek is about 1,650 statute miles (1,430 nautical miles) by ocean route from Seattle. This port would be available only from about May to October, being usually impassable during the remainder of the year on account of ice.

The Susitna route to Fairbanks traverses an area that includes important gold and coal resources, as well as some of the best agricultural lands in the Territory. Whatever may be the relative merits of the routes through the Copper and Susitna valleys to Fairbanks, it is certain that a railway up the Copper can not develop the resources of the Susitna Valley.

The Alaska Northern Railway route traverses auriferous districts in Kenai Peninsula and along the northern shore of Turnagain Arm. About 150 miles inland the main line will approach within 30 or 40 miles of the Matanuska coal field and close to the Willow Creek lode district. In the Susitna Valley it passes within 30 or 40 miles of the Yentna placer district. Copper and gold deposits have also been reported in other parts of the Susitna basin, but little is known about them. Beyond Broad Pass the route traverses the Nenana coal field, which contains very extensive deposits of lignite that should be of value for developing the Yukon-Tanana gold field. This gold field, which will be tapped by this route, has already been referred to (p. 48). The region, as a whole, contains little merchantable timber. There is a good stand of spruce and hemlock in the flat adjacent to Resurrection Bay, on lower Glacier Creek, and on a few other streams on Turnagain Arm, some trees measuring as much as 4 feet in diameter. Few of the largest trees in the heart of the peninsula measure more than 12 to 16 inches in diameter. Spruce, cottonwood, and birch are the principal forest types. Timber runs up to altitudes of 2,000 feet above the sea, but the best is confined to the valley floors and lower slopes. The same kind of forest is found in the Susitna and Matanuska region, where timber line is about 2,000 feet, but above 1,500 or 1,800 feet the trees are very scattering. Spruce, birch, cottonwood, and tamarack grow in the Tanana basin.

In the lowland areas some timber is found measuring 18 inches to 2 feet, but in most places the largest timber does not generally exceed 12 to 16 inches. In the Tanana basin timber line is about 3,000 to 3,200 feet above sea level, but the best timber is below 2,000 feet.

The Susitna basin and the adjacent region contains a large amount of good agricultural land and extensive tracts that are valuable for their grass. The Tanana Valley also contains much agricultural and grass land.

ROUTES FROM COOK INLET TO THE KUSKOKWIM AND LOWER YUKON.

This paper is concerned chiefly with routes from the Gulf of Alaska to the Tanana, but as plans have been made for a railway from Cook Inlet to the Kuskokwim, this project will also be briefly considered. It is proposed to build a railway from some port on the west side of Cook Inlet, through the Iliamna Lake region, thence across to the Kuskokwim Valley, and from there to the Yukon. Only a part of this region is covered by Geological Survey maps, and little is known of the topography and resources of the remainder.

In 1902 to 1908 a railway route was surveyed by the Alaska Short Line Railway Co. from Iliamna Bay westward to the Yukon. Iliamna Bay is a deep indentation of the mainland, but the larger part of it is too shallow for ocean-going vessels. Vessels therefore must lie near the entrance, and terminal facilities would be expensive to construct. By ocean route Iliamna Bay is about 1,530 statute miles (1,330 nautical miles) from Seattle. The proposed railway route leads from a point near the head of the north arm of the bay over a divide about 900 feet high to Iliamna Lake. It then swings around the eastern end of Iliamna Lake, crosses the outlet of Clark Lake, and extends up Chulitna River, crossing a low divide to Mulchatna River. It appears that the divide west of the Mulchatna probably drains into the Kuskokwim and that the proposed railway route would reach the latter stream somewhere near the big bend and not far from the Iditarod placer district. The plan of the Alaska Short Line Railway Co. contemplated reaching Yukon River at Anvik. Plans have also been proposed to extend this line to Nome, on Seward Peninsula. No data are at hand regarding distances or altitudes for most of this route. It appears, however, that 450 miles of track should reach the Yukon and that there are no high divides to overcome. It also appears that construction of most of the route would not be expensive. This railway is projected to reach the lower Kuskokwim and Yukon basins, but it would be in a measure a competitive route with the one from the Susitna over Rainy Pass to the Kuskokwim.

Not much is known of the resources of the region. In the Iliamna region there are some undeveloped gold and copper deposits. Some placer gold has been found on the Mulchatna. The Iditarod-Innoko region produced placer gold to the value of $3,000,000 in 1911, and some placer gold has been found at several localities to the southwest, between the Iditarod district and Bering Sea. From the meager information at hand the region seems to be of less agricultural promise than that along the other routes already described.

SUMMARY.

In the foregoing pages an attempt has been made to present a concise and unprejudiced statement of the known facts bearing on railway routes into Alaska from the Pacific. The subject is large and can not be adequately discussed in the few pages devoted to it. Moreover, the data are very incomplete, but it is hoped that this outline may be of service to those who are interested in Alaska transportation problems. No conclusions are here presented as to which is the best route into the interior. To arrive at a conclusion it would be necessary to take into account the cost of construction, which must be determined by the engineer. Of the feasibility of constructing any of the three trunk routes—Pyramid Harbor-Tanana, Copper Valley, and Susitna Valley—there can be no question (Pl. IV). The first would bisect central Alaska, but would not help the Copper or Susitna regions. The resources of the Copper basin and the Susitna basin must be developed by different railways. The only question is which one should now be extended through to the Tanana. In the opinion of the writer the resources of central Alaska justify the belief that eventually all three railways will be built to the Tanana and extended into other parts of the Yukon basin.

GOVERNMENT PUBLICATIONS AND RECORDS RELATING TO RAILWAY ROUTES.

INTRODUCTION.

The foregoing account of railway routes is based on a study of the many Government publications, including maps and records, all of which are summarized or mentioned here in order that they may be consulted by those who desire more detailed information than can be presented in this brief article. The publications mentioned are by no means all that have been issued relating to this subject, but it is believed that the list is sufficiently comprehensive to serve as a general guide.

Publications containing general data will be considered first, and reports dealing more specifically with the different railway routes already described will next be noted. The routes will be considered in geographic order from south to north. If a later and more comprehensive publication has supplanted an earlier one, only the later will be listed. References will be made not only to publications relating directly to railway location, but to those which contain data on climate, mineral resources, agriculture, forests, navigation, statistics of commerce, and population—subjects which must be considered in making choice of railway routes.

GENERAL REPORTS.

The general routes of approach to the Pacific seaboard of Alaska are indicated by the charts and publications of the United States Coast and Geodetic Survey, which has for many years been surveying the coast line of the Territory. Specific reference should here be made to Chart T, a general map of Alaska published by the Coast and Geodetic Survey. Directions for navigating the shore line, together with description of harbors, are contained in the publication entitled "United States Coast Pilot: Pacific Coast, Alaska," issued by the Coast and Geodetic Survey.

The United States Geological Survey began systematic surveys and investigations of Alaska in 1898. This Survey has made some investigation of every railway route now under consideration and has published reconnaissance and detailed maps showing topography and distribution of mineral resources. In 1905 the Director of the Geological Seuvey made specific recommendations for an appropriation to be expended for the survey and investigation of railway routes in Alaska.[1] Although no specific appropriation was made for this purpose, the Survey has directed its investigations to the end of obtaining information in regard to the topography and the resources along the different routes as rapidly as means permitted. As a consequence the publications of the Survey contain a large amount of information bearing on railway routes. General information on the character of the country and the distribution of mineral resources and statistics of mineral production are also contained in the Survey publications.

The larger topographic features of Alaska are discussed in a report entitled "The geography and geology of Alaska," by Alfred H. Brooks (Prof. Paper U. S. Geol. Survey No. 45, 1906). This report also contains a topographic map of Alaska on a scale of 1:2,500,000, which was not issued separately and is now out of date. The problems of railway location are more specifically discussed in articles entitled "Railway routes" (Bull. U. S. Geol. Survey No. 284, 1906, pp. 10–17) and "Transportation" (Bull. U. S. Geol. Survey No. 379, 1909, pp. 23–26), both by Alfred H. Brooks. A more popular account of the

[1] Twenty-sixth Ann. Rept. U. S. Geol. Survey, 1905, pp. 76–80.

same subject by Mr. Brooks has been published under the title "Railway routes in Alaska," in the National Geographic Magazine, March, 1907. Mr. Brooks has also discussed the present cost of transportation in Alaska under the heading "Transportation," in Survey Bulletin 442 (1910, pp. 23–31), and the relation of railway transportation to the coal fields in an article on "Alaska coal and its utilization" (Bull. U. S. Geol. Survey No. 442, pp. 47–100). This article considers the distribution, quality, and availability of Alaska coal.

The general coal situation has been discussed by the Hon. Walter L. Fisher in a report entitled "Alaskan coal problems" (Bull. Bureau of Mines No. 36, 1911). This subject has also been treated from another point of view by the Hon. James Wickersham, Delegate from Alaska, in a speech entitled "A national coal monopoly in Alaska" (speech delivered Feb. 23, 1911, in the House of Representatives; published Washington, 1911). There are many other public documents relating to the question of public policy toward the coal lands of Alaska, but these will not here be considered.

The general distribution of the mineral resources of Alaska is shown on a map published as Plate I in Survey Bulletin 345. A revised edition of this map is published herewith (Pl. I, in pocket). Statistics for mineral production of Alaska up to and including the year 1910 are contained in the Survey's Bulletin 480 (1911), and preliminary estimates of mineral production for 1911 are given in this report (p. 20).

The General Land Office has issued a map of Alaska on which the boundaries of the judicial divisions as well as of the national forests and other Government reservations are indicated. Information about the laws relating to the acquisition of public lands in Alaska is contained in the publications of the General Land Office.

A large number of plats and profiles of proposed railways based on surveys made under private auspices are on file in the General Land Office. These are more pertinent to the individual routes to be described below than to the general problem of railway location. A statement of the data filed in the General Land Office previous to November 28, 1908, is contained in a letter of the Secretary of the Interior of that date, printed as House Document 1201, Sixtieth Congress, second session. This document is accompanied by a map showing the location of the principal routes surveyed.

The Alaska Road Commission (War Department) has made many surveys for roads and trails, the results of which are on file in the office of the commission at Valdez, Alaska. It has also published a general map of Alaska, showing position of roads, trails, telegraph and cable lines, and wireless stations and annual reports giving information about roads and trails.

Many records relating to the climate of Alaska are on file in the United States Weather Bureau, Department of Agriculture. These have in part been published in the annual reports on agriculture in Alaska and in part have been summarized in a report entitled "The geography and geology of Alaska" (Prof. Paper U. S. Geol. Survey, No. 45), already referred to.

The reports on agriculture in Alaska, by C. C. Georgeson, published annually since 1898 by the Office of Experiment Stations, Department of Agriculture, contain much data bearing on the general subject of railway location in relation to agricultural development. This phase of the subject is also treated of in a report entitled "Grass lands of the south Alaska coast," by C. V. Piper (Bull. Bureau of Plant Industry, No. 82, Dept. of Agriculture, 1905). The distribution of timber in Alaska is the subject of a report entitled "The forests of Alaska," by R. S. Kellogg (Bull. Forest Service No. 81, U. S. Dept. Agr., 1905).

The reports of the governor of Alaska, published annually since 1885, contain much general information relating to railway routes and transportation. Many of these reports are accompanied by general maps of Alaska. Statistics of the commerce of Alaska are contained in the publications of the Bureau of Statistics ("Monthly summary of commerce and finance in the United States" and "Report on the commerce and navigation of the United States" [annual]). The reports of the Tenth, Eleventh, Twelfth, and Thirteenth Censuses include information regarding the population and industries of Alaska.

Many congressional documents contain information about the general transportation situation in Alaska, only a few of which have been examined and abstracted for this report. Among these are the following:

"Railway and telegraph and telephone lines in Alaska" (H. Rept. No. 3874, 59th Cong., 1st sess.).

"Conditions in Alaska: Report of subcommittee of Committee on Territories" (S. Rept. No. 282, pt. 1, 58th Cong., 2d sess.), accompanied by general map of Alaska, scale 1:3,600,000; 1904.

"Conditions in Alaska: Hearings before subcommittee of Committee on Territories" (S. Rept. No. 282, pt. 2, 58th Cong., 2d sess., 1904).

"Railroads in Alaska: Hearings before the Committee on Territories of the House of Representatives" (59th Cong., 1st sess., 1906), accompanied by sketch map showing railroads under construction and projected.

"Bills and reports of Committee on Territories of the House of Representatives," by J. C. Hance (58th Cong., 1st and 2d sess.), 3 volumes, 1904.

"Investigations of the Department of the Interior and the Bureau of Forestry" (by joint committee of Congress); 7 volumes, 1910.

"Conditions in Alaska: Hearings before the Committee on the Territories of the House of Representatives" (62d Cong., 2d sess., Jan. 16–Feb. 6, 8, 10, 13, 15, and 27, 1912).

"Transportation in Alaska: Hearings before the Committee on the Territories of the House of Representatives" (62d Cong., 2d sess , Feb. 27, Mar. 5, Apr. 5, 6, 16, and 19, 1912).

"Railroads for Alaska: Hearings before the Committee on Territories, United States Senate," April 12, 1912.

"Government railroad in Alaska: Hearings before the Committee on Public Lands, United States Senate" (62d Cong., 2d sess., May 22, 1912).

"Coal lands in Alaska: Hearings before the Committee on Public Lands, United States Senate" (62d Cong., 2d sess., June 1 and 5, 1912).

ROUTE FROM PYRAMID HARBOR TO FAIRBANKS.

The coastal terminal of the proposed roadway from Haines to Fairbanks is on Lynn Canal. (See charts Nos. 8300 and 8303 and "United States Coast Pilot, Pacific Coast, Alaska, Pt. I," 1908, published by the Coast and Geodetic Survey.) This route will follow Chilkat River, which has been surveyed by the International Boundary Commission, but the results of the survey have not yet been published. The mineral resources of the Porcupine district, tributary to this route, are described in a report entitled "The Porcupine placer district" by C. W. Wright (Bull. U. S. Geol. Survey No. 236, 1904). An account of the general character of the route is contained in publications entitled "A reconnaissance from Pyramid Harbor to Eagle City, Alaska" (Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, pp. 425–424) and "A reconnaissance in the Tanana and White River basins, Alaska" (Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 425–494), both by Alfred H. Brooks. Topographic exploratory maps (scale 1:625,000, or 10 miles to the inch) accompany these reports. Part of this route lies in Canadian territory; and this part is indicated on a map entitled "Map of the Kluane, White, and Alsek rivers, Yukon Territory, Canada," from surveys by International Boundary Commission, 1893–95, J. J. McArthur, 1900, A. C. Talbot, 1899, and J. B. Tyrrell, 1898; scale 1:400,000, James White, geographer (published by the Canadian Department of the Interior, 1905).

The mineral resources of a part of this district are described in "Summary report of R. G. McConnell" (Ann. Rept. Geol. Survey Canada, vol. 16, 1904, pp. 1–18, 1906), illustrated by a sketch map of the Kluane mining district, Yukon Territory.

This route also traverses the upper White River basin, whose topography and mineral resources have been described in a publication entitled "Mineral resources of the Nabesna-White River district," by F. H. Moffit and Adolph Knopf (Bull. U. S. Geol. Survey No. 417, 1910). A topographic map (scale 1:250,000, or 4 miles to the inch, with 200-foot contours) accompanies this report as an illustration. Detailed surveys have been made by the Boundary Commission of the international boundary in the headwater region of White River. The maps resulting from this survey have not yet been published.

The topography and mineral resources of the Fairbanks and Yukon-Tanana region are described in the following publications of the United States Geological Survey:

"The gold placers of the Fortymile, Birch Creek, and Fairbanks regions," by L. M. Prindle (Bull. 251, 1905, 89 pp.).

"The Yukon-Tanana region: Description of Circle quadrangle," by L. M. Prindle (Bull. 295, 1906, 27 pp.).

"The Fairbanks and Rampart quadrangles, Yukon-Tanana region," by L. M. Prindle, with a section on the Rampart placers, by F. L. Hess, and a paper on the water supply of the Fairbanks region, by C. C. Covert (Bull. 337, 1908, 102 pp.).

"Occurrence of gold in the Yukon-Tanana region," by L. M. Prindle (in Bull. 345, 1908, pp. 179–186).

"Water-supply investigations in the Yukon-Tanana region, 1907 and 1908," by C. C. Covert and C. E. Ellsworth (Water-Supply Paper 228, 1909, 108 pp.).

"The Fortymile quadrangle, Yukon-Tanana region," by L. M. Prindle (Bull. 375, 1909, 52 pp.).

"The Fairbanks gold-placer region," by L. M. Prindle and F. J. Katz (in Bull. 379, 1909, pp. 181–200).

"Auriferous quartz veins in the Fairbanks district," by L. M. Prindle (in Bull. 442, 1910, pp. 210–229).

"Geologic reconnaissance of the Fairbanks quadrangle," by L. M. Prindle (in preparation).

"Mining and water supply of Fortymile, Seventymile, Circle, and Fairbanks districts in 1911," by E. A. Porter and C. E. Ellsworth (Bull. U. S. Geol. Survey No. 520–H, 1912, 63 pp.).

"Gold placers between Woodchopper and Fourth of July creeks, upper Yukon River," by L. M. Prindle and J. B. Mertie, jr. (Bull. U. S. Geol. Survey No. 520–G, 1912, 12 pp.).

"The Rampart and Hot Springs regions," by H. M. Eakin (Bull. U. S. Geol. Survey No. 520–I, 1912, 18 pp.).

Many of these publications are illustrated by topographic maps (scale, 1:250,000, or 4 miles to the inch, with 200-foot contours), in addition to which the Survey has issued the following separate maps, covering areas adjacent to or near the Pyramid Harbor-Fairbanks railway route: Fortymile (No. 640); Circle (No. 641); Fairbanks (No. 642); and Rampart (No. 643), all on scale of 1:250,000, or 4 miles to the inch, with 200-foot contours. A map of the region adjacent to the town of Fairbanks on a scale of 1:62,500, or 1 mile to the inch, with 25-foot contours, has been published as the Fairbanks special (No. 642A). The region adjacent to and north of upper Tanana River has been surveyed (scale, 1:250,000, or 4 miles to the inch, with 200-foot contours), but the map has not been published.

The agricultural resources of the Tanana Valley are discussed in the annual reports of the Alaska Experiment Station, by C. C. Georgeson (published by the Office of the Experiment Stations, Department of Agriculture), and the timber in a publication entitled the "Forests of Alaska," by R. S. Kellogg (Bull. Forest Service No. 81, U. S. Dept. of Agr., 1910).

Some private railway surveys have been run over a part of the Haines-Fairbanks route. These are probably on file in the General Land Office and in the archives of the Canadian Government, but they have not been examined by the writer.

YAKUTAT BAY-ALSEK ROUTE.

A map of Yakutat Bay has been published by the Coast and Geodetic Survey as Chart No. 8455, and the approaches are described in United States Coast Pilot, Pacific Coast, Alaska, Part I (U. S. Coast and Geodetic Survey, 1908). The geography, geology, and mineral resources of the region are discussed in reports entitled "The Yakutat Bay region," by R. S. Tarr and B. S. Butler (Prof. Paper U. S. Geol. Survey No. 64, 1909), and "Reconnaissance on the Pacific coast from Yakutat to Alsek River," by Eliot Blackwelder (in Bull. U. S. Geol. Survey No. 314, 1907, pp. 82–88).

Topographic reconnaissance surveys of the coastal slope of the mountains stretching eastward from Yakutat Bay to the Alsek were made by boundary commission surveyors in 1888–1891. These have been published on a scale of 1:160,000, with 250-foot contours (Alaska Boundary Tribunal Atlas, vol. 3, Washington, 1904). A more detailed survey of this region has recently been made by the boundary commission, but the results have not yet been published. This survey was carried up Alsek River to the Canadian boundary. There remain about 50 miles of the Alsek Valley which have not been surveyed.

ROUTES TO BERING RIVER COAL FIELDS.

Katalla Harbor and Controller Bay are shown on Coast and Geodetic Survey Chart No. 8513. The approaches and hydrography are described in "Alaska Coast Pilot Notes from Yakutat Bay to Cook

Inlet and Shelikoff Strait" (Coast and Geodetic Survey, 1910). The hydrography and approaches to Cordova are shown on Charts Nos. 8550 and 8520 (Coast and Geodetic Survey) and are described in "Alaska Hydrographic Notes, sailing directions, etc." (Bull. Coast and Geodetic Survey No. 38, 1899). There is also a voluminous literature consisting chiefly of congressional documents bearing on this subject. The titles of two of these are given below:

"Chugach National forest lands, Alaska. Letter from Secretary of the Interior, including map of Controller Bay region with proposed railways" (S. Doc. No. 12, 62d Cong., 1st sess., 1911).

"Controller Bay lands. Hearings before the Committee on Expenditures in the Interior Department of the House of Representatives, on House Resolution No. 103," 1911.

The topography, geology, and coal resources of Bering River field are described in detail in a report entitled "Geology and mineral resources of the Controller Bay region," by G. C. Martin (Bull. U. S. Geol. Survey No. 335, 1908, 141 pp.). This report is accompanied by maps showing topography, geology, and coal resources (scale 1:62,500, 1 mile to the inch, with 50-foot contours). The topographic map has also been issued as a separate sheet under the title "Controller Bay region" (No. 601A). In 1911 the Bureau of Mines investigated the conditions of coal mining in the Bering River coal field, but the report has not yet been printed. Much information regarding the Bering River coal field is also contained in the "Hearings held before the Joint Committee of Congress relative to the investigation of the Department of the Interior and the Bureau of Forestry," volumes 1–7, 1910, and in the Message from the President of the United States transmitted in response to Senate Resolution No. 112, of December 21, 1909, 1910, pages 805. The maps of the Controller Bay region by the Geological Survey, already listed (Bull. 335), are reprinted in this document.

Many private railway surveys have been made from Controller Bay, Katalla, and Cordova, the results of which are on file in the General Land Office. Among these are the surveys of the Alaska Pacific Railway & Terminal Co., the Copper River & Northwestern Railroad, the Controller Bay Railway & Navigation Co., the Controller Bay & Bering Coal Railway, the Catalla & Carbon Mountain Railway, the Bering River Railroad, and the Kusktaka & Southern Railway.

ROUTE FROM CORDOVA TO FAIRBANKS.

The publications relating to Cordova, the coastal terminal of this route, have been referred to above. The mineral resources of the region around Cordova are discussed in a report entitled "Reconnaissance of the geology and mineral resources of Prince William

Sound," by U. S. Grant and D. F. Higgins (Bull. U. S. Geol. Survey No. 443, 1910, 89 pp.). The geology and mineral resources of the lower Copper River and Chitina regions are described in a report entitled "Mineral resources of the Kotsina-Chitina region," by F. H. Moffit and A. G. Maddren (Bull. U. S. Geol. Survey No. 374, 1909, 103 pp.). This report is accompanied by a topographic map of the lower Copper River region (scale, 1:250,000, or 4 miles to the inch, with 200-foot contours). The United States Geological Survey has also investigated and surveyed the Bremner River-Hanagita Valley region, which is tributary to this route. The maps based on these surveys are being drawn on a scale of 1:250,000 (4 miles to the inch) and a report is being prepared. A preliminary statement of the results of this survey has been published under the title "The Taral and Bremner River regions," by F. H. Moffit (in Bull. U. S. Geol. Survey No. 520–B). A detailed account of the Nizina district has been published under the title "Geology and mineral resources of the Nizina district," by F. H. Moffit and S. R. Capps (Bull U. S. Geol. Survey No. 448). This is accompanied by a detailed topographic map (scale, 1:62,500, or 1 mile to the inch, with 50-foot contours).

A statement of the topography and mineral resources of the central Copper River region, including that part of the route lying between Copper Center and Delta River, has been published as "Geology of the central Copper River region," by W. C. Mendenhall (Prof. Paper U. S. Geol. Survey No. 41, 1906, 133 pp.). This paper is accompanied by a topographic map (scale, 1:250,000, or 4 miles to the inch, with 200-foot contours). The region tributary to the upper Delta was surveyed and investigated in 1910, and a report published entitled, "Headwater regions of Gulkana and Susitna rivers," by F. H. Moffit (Bull. U. S. Geol. Survey No. 498). This report is accompanied by a topographic map (scale, 1:250,000, or 4 miles to the inch, with 200-foot contours). In 1910 surveys and investigations were also made in the region lying west of Delta River and forming part of the Tanana River basin. The results are printed in a report entitled, "The Bonnifield region," by S. R. Capps (Bull. U. S. Geol. Survey No. 501), which is accompanied by a topographic map (scale, 1:250,000, or 4 miles to the inch, with 200-foot contours). The publications relating to the Tanana Valley and to the Fairbanks district have already been listed (pp. 81–82).

A number of private surveys for railways over the Cordova-Fairbanks route have been filed in the General Land Office, a complete list of which is not at hand. These include those of the Copper River & Northwestern Railway Co., the Copper River Railway Co., and the Alaska Pacific Railway & Terminal Co.

ROUTES FROM VALDEZ TO FAIRBANKS.

Coast Survey charts Nos. 8519, 8520, 8521, and 8550 cover Port Valdez and its approaches. Sailing directions and descriptions of hydrography for this region are contained in "Alaska Coast Pilot Notes from Yakutat Bay to Cook Inlet" (Coast and Geodetic Survey, 1910).

The mineral resources of the vicinity of Valdez are discussed in "Reconnaissance of the geology and mineral resources of Prince William Sound," by U. S. Grant and D. F. Higgins (Bull. U. S. Geol. Survey No. 443, 1910, 89 pp.), and in "Gold deposits near Valdez," by Alfred H. Brooks (Bull. U. S. Geol. Survey No. 520–D, 1912). A detailed topographic survey of the Valdez mining district has been made, and the map is now being prepared (scale, 1:62,500, or 1 mile to the inch, with 100-foot contours). The Marshall Pass route from Valdez has not been mapped by the Geological Survey, though several private surveys of it have been made. The Thompson Pass route is shown on the topographic map of the lower Copper River region, published as an illustration (Pl. I) in Bulletin 374 (U. S. Geol. Survey) and not issued separately. Both these routes are described by Edward Gillette in a report to Capt. W. R. Abercrombie, United States Army, contained in "Copper River Exploring Expedition, 1899, Capt. W. R. Abercrombie, Second United States Infantry, commanding," Washington, 1900 (pp. 139–149). There are also references to this route in "Hearings of Committee on Territories of the House of Representatives on Transportation in Alaska" (62d Cong., 2d sess., Feb. 27 and Apr. 6, 1912). Beyond the coastal barrier the Valdez-Fairbanks route is identical with the Cordova-Fairbanks route. (See pp. 83–84).

No complete list is at hand of the numerous private railway surveys extending inland from Valdez on file in the General Land Office. Among these are those of the Alaska Central Railway Co., the Akron, Sterling & Northern Railroad Co., the Alaska Home Railway Co., the Copper River & Northwestern Railway Co., the Valdez-Yukon Railroad Co., the Valdez, Copper River & Tanana Railroad Co., the Valdez & Northern Railroad Co., and the Valdez, Marshall Pass & Northern Railroad Co.

ROUTE FROM SEWARD TO FAIRBANKS.

Seward is located on Resurrection Bay, which is shown on Chart No. 3538 of the Coast and Geodetic Survey. Sailing directions for this part of coast are included in "Alaska Coast Pilot Notes from Yakutat Bay to Cook Inlet" (Coast and Geodetic Survey, 1910).

The approaches to Seward on Resurrection Bay are shown on Chart No. 8538 of the Coast and Geodetic Survey. A discussion of the mineral resources in the vicinity of Seward has been published under the title "Preliminary report on the mineral resources of the southern part of the Kenai Peninsula," by U. S. Grant and D. F. Higgins (in Bull. U. S. Geol. Survey No. 442, pp. 166–176, 1910). A general account of the topography and resources of the Kenai Peninsula has been published as "Mineral resources of Kenai Peninsula," by F. H. Moffit and R. W. Stone (Bull. U. S. Geol. Survey No. 277, 1906, 88 pp.). This is accompanied by a map (scale, 1:250,000, or 4 miles to the inch), which shows the main drainage lines and the chief features of the topography of the northeastern part of the peninsula.

A study of the gold deposits of the northeastern part of Kenai Peninsula was made in 1911, the preliminary results of which have been published as "Gold deposits of the Seward-Sunrise region, Kenai Peninsula," by B. L. Johnson (Bull. U. S. Geol. Survey No. 520–E, 1912). In 1911 a topographic survey was carried over the northern part of the peninsula, including the route of the Alaska Northern Railway as far as Turnagain Arm. The map based on these surveys is now being prepared, to be published on a scale of 1:250,000, or 4 miles to 1 inch, with 200-foot contours.

The topography and mineral resources of the region traversed by the railway route from Turnagain Arm to Talkeetna River are discussed in a publication having the title "Geologic reconnaissance in the Matanuska and Talkeetna basins," by Sidney Paige and Adolph Knopf (Bull. U. S. Geol. Survey No. 327, 1907, 71 pp.). A topographic map (scale, 1:250,000, or 4 miles to the inch, with 200-foot contours) accompanies this report.

The Matanuska coal fields, which are tributary to this route, have been described in a report entitled "A reconnaissance of the Matanuska coal field in 1905," by G. C. Martin (Bull. U. S. Geol. Survey No. 289, 1906, 36 pp.). A more detailed account is contained in "Geology and coal fields of the lower Matanuska Valley," by G. C. Martin and F. J. Katz (Bull. U. S. Geol. Survey No. 500, 1912). A detailed topographic map (scale, 1:62,500, or 1 mile to the inch, with 100-foot contours) and a detailed geologic map, showing distribution of coal, accompany this report. In 1911 the Bureau of Mines investigated the conditions of coal mining in the Matanuska field, but the report on this investigation has not yet been issued. A study of the gold-bearing lodes of the Willow Creek district, which lies adjacent to this railway route, was made in 1910 and the results were published as "A reconnaissance of the Willow Creek gold region," by F. J. Katz (in Bull. U. S. Geol. Survey No. 480, 1911, pp. 139–152).

The general features and resources of the Susitna Valley are described in "The Mount McKinley region," by Alfred H. Brooks (Prof. Paper U. S. Geol. Survey No. 70, 234 pp.). A topographic map, which includes that part of the route lying between Turnagain

Arm and Fairbanks, accompanies this report (scale, 1:625,000, or 10 miles to the inch, with 200-foot contours).

The auriferous deposits of the Yentna basin were investigated in 1911 and a preliminary statement of results has been published as "Gold placers of the Yentna district," by S. R. Capps (Bull. U. S. Geol. Survey No. 520-F, 1912, 31 pp.).

In 1910 a survey and investigation was made of the region east of and adjacent to that part of this route lying north of the Alaska Range. A report on this work, called "The Bonnifield region," by S. R. Capps (Bull. U. S. Geol. Survey No. 501), is in print. It is illustrated by a topographic map (scale, 1:250,000, or 4 miles to the inch, with 200-foot contours). The publications relating to resources and topography of the Tanana Valley have already been listed elsewhere (pp. 81–83).

The following congressional committee hearings pertain largely to the Seward-Fairbanks Railway route:

Hearings before the Committee on Territories of the House of Representatives on S. 2534, "An act to extend the time of completion of the Alaska Northern Railway, and for other purposes," December 9, 1911.

Hearings of the Committee on the Territories of the House of Representatives on Conditions in Alaska, February 10, 1912.

Hearings before the Committee on the Territories of the House of Representatives on Transportation in Alaska, March 5 and April 6.

"Government Railroad in Alaska": Hearing before the Committee on Public Lands, United States Senate, Sixty-second Congress, second session, May 22, 1912.

The Alaska Central Railway Co. and its successor, the Alaska Northern Railway Co., have made numerous surveys along this railway route. These are probably for the most part on file in the General Land Office.

ROUTE FROM COOK INLET TO KUSKOKWIM.

The upper part of Cook Inlet is shown on chart No. 8553 and Iliamna Bay on chart No. 8665 of the Coast and Geodetic Survey. Sailing directions for this part of the coast are contained in "Alaska Coast Pilot Notes from Yakutat Bay to Cook Inlet" (Coast and Geodetic Survey, 1910). The geography, geology, and mineral resources of the region lying between Cook Inlet and Lake Clark are described in "A geologic reconnaissance of Iliamna region," by G. C. Martin and F. J. Katz. This is accompanied by a topographic map on a scale of 1:250,000 (4 miles to the inch), with 200-foot contours.

No surveys have been made between Lake Clark and the Kuskokwim. Some account of the geography of the Mulchatna Valley is included in "A biological reconnaissance of the base of the Alaska Peninsula" (North American Fauna No. 24, Dept. of Agriculture, 1904), which is accompanied by a sketch map. The Middle Kuskokwim Valley and the Innoko placer district, which are tributary to this route, are described in "The Innoko gold placer district, Alaska," by A. G. Maddren (Bull. U. S. Geol. Survey No. 410). This is accompanied by a map (scale 1:625,000, or about 10 miles to the inch). A more recent account of the gold placers of this region has been published under the title "Gold placer mining developments in the Innoko-Iditarod region," by A. G. Maddren (Bull. U. S. Geol. Survey No. 480, 1911, pp. 236–370). The topographic survey of the Innoko-Iditarod region has been made (scale 1:250,000, or 4 miles to the inch, with 200-foot contours), but the resulting map has not yet been published.

The Alaska Short Line Railway Co. has made preliminary surveys of a route from Iliamna Bay to the Yukon. Its plats and notes are undoubtedly on file in the General Land Office, but the writer has not examined them.

TIN RESOURCES OF ALASKA.

By Frank L. Hess.

The peculiar deficiency of the United States in tin deposits and the great quantity of tin used in the country, amounting to between 40 and 50 per cent of the world's production, make the possible domestic sources of supply a subject of perennial interest.

Tin was first discovered in Alaska on Buhner Creek, near York, on Seward Peninsula, in 1900. It occurred here as stream tin, or rolled pebbles of cassiterite, and was found in sluicing for gold. The next year stream tin was found on Buck Creek, which is separated from Buhner Creek by a low divide.

In 1903 cassiterite (tin oxide) was found in place in granite porphyry dikes cutting limestones on Cassiterite Creek, a tributary of Lost River, about 100 miles northwest of Nome. Later, stream tin was found in small quantity in the gold placers on Gold Bottom Creek, 20 miles north of Nome; at Ear Mountain, in the northern part of Seward Peninsula; with rutile in the gold placers of Cleary, Fairbanks, and other creeks near Fairbanks; with wolframite in the placers of Deadwood Creek, near Circle; and in the placers on Sullivan Creek, near Hot Springs, on the lower Tanana River.

About the time that tin was discovered on Lost River, float ore was found on Cape Mountain, near Cape Prince of Wales, and later was found in place. Constant prospecting effected the discovery of tin in place at the head of Buck Creek; in small quantity on Ear Mountain; and in 1907 Adolph Knopf,[1] of the United States Geological Survey, discovered on Brooks Mountain, near the head of Lost River, two new tin-boron minerals which he named paigeite and hulsite. Paigeite occurs also on Ear Mountain.[2]

Of the placers, none have shown importance except those of Buck Creek, and, in a much less degree, those of Sullivan Creek. From the tin in place the Bartels Tin Mining Co. produced 10 tons of concentrates in 1906 after expending a disproportionately large amount of money, and on Lost River a fair quantity of tin ore is reported to have been exposed.

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[1] Knopf, Adolph, Geology of the Seward Peninsula tin deposits, Alaska: Bull. U. S. Geol. Survey No. 358, 1908, p. 23.

[2] Op. cit., p. 32.

Buck Creek, on which are the best tin placers now known in Alaska, is about 4 miles long and is about 16 miles north of York and a little greater distance northeast of Cape Prince of Wales. The creek flows southeastward throughout most of its course. The country rock is a dark sedimentary rock ordinarily called slate, though scarcely as highly altered as the term would imply, and in places contains beds which are rather coarsely sandy. The slate is cut by a few quartz porphyry and greenstone dikes. Into these rocks Buck Creek has cut a comparatively broad valley, which has a long tundra-covered slope on its southwest side. On its northeast side the ground is steep and the creek flows close against the hills along much of its course.

The gravel is probably nowhere over 9 feet deep, and extends under the tundra for some distance from the creek. It is all small as compared with that of many placer fields. Very few pebbles are over 4 or 5 inches in diameter, and most of them are much smaller. Here and there is a bowlder of greenstone a foot or more in diameter, but such bowlders probably form less than one twenty-fifth of 1 per cent of the whole number.

In the creek bed the content of stream tin carrying in the neighborhood of 65 per cent metallic tin has been found to be as high as 400 pounds per cubic yard in rich spots, though the average is much lower. The writer saw one trench dug which gave 28 pounds per cubic yard, and Mr. F. P. Kendall, who was at one time in charge of operations on the creek, stated that a season's work gave about the same figure. One large pit gave 25 pounds per yard. In figures furnished the United States Geological Survey the gold in the gravels has been estimated at 40 cents per cubic yard, at $60 per ton of stream tin, and at other amounts. Nuggets of gold in value up to $20 have been found. When compared with the Australian and Malayan gravels, where the "black tin" content is in many places from 1½ pounds to 5 pounds per cubic yard, with perhaps a heavy overburden not only of soil but, as in Tasmania, of basalt, the gravels of Buck Creek appear very rich, but the climate makes the conditions hard for placer working. The season is short, little or nothing can be done before June 15, and the freeze-up is apt to come by September 15, although the season may open early enough and close late enough to allow between four and five months' work. There are many storms, with cold, heavy rains, but, on the other hand, the country is very healthful.

From the time of their discovery until 1911 the gravels were worked first by hand or horse scrapers, then by steam drag shovels, and again by hand until 1911, when a small dredge was put in by the York Dredging Co. The conditions are wholly against hydraulicking, and dredging seems to be the best means of working the gravels.

The dredge, which was specially built for shallow digging, has buckets holding 2½ cubic feet; has gasoline engines for power, and digs from 950 to 1,000 cubic yards each 24 hours. It is equipped with two sluice boxes, so that one can be operated while the other is being cleaned up. The dredge was started on September 10 and, as the season was unusually open, ran until October 15. The ground dug is said to have been partly worked before, and the present yield was between 6 and 7 pounds of stream tin per cubic yard. The total output was 92 tons of stream tin averaging 66 per cent tin, or an equivalent of 101 tons carrying 60 per cent tin, and sold for $52,000.

This brings the total production of tin from Buck Creek up to about 320 or 325 short tons of stream tin on a basis of 60 per cent tin.

During the short run of the dredge a strip 115 by 950 feet was cut out, and it is estimated[1] that there is 3½ miles of such channel. It is also estimated that about three times as much work can be done (100 days' run) in future seasons. Should these figures prove good, and they seem reasonable from the observations of the Survey's representatives, the dredge should have profitable work for a number of years. There is also tin-bearing ground below the point where the dredge started and probably some under the tundra that can not be worked with the dredge..

Placer tin has been reported from a number of the small creeks running into the Arctic Ocean from the hills on the northeast side of Buck Creek and from the creeks draining the west side of Potato Mountain, at the head of Buck Creek, but so far no great quantity has been shown to exist.

From present showings, no production is to be expected from the veins around Buck Creek.

On Cape Mountain, behind Tin City, a granite boss intrudes limestones, and cassiterite is found in quartz veins; in veins in granite, accompanied by tourmaline and arsenopyrite; and in narrow veins, almost or wholly cassiterite, cutting the limestones. The quantity of tin present has been greatly overestimated by some of the persons mining, and there is no immediate prospect of great production. In 1906 the Bartels Tin Mining Co. milled 10 tons of concentrates, the only production up to this time.

On Lost River tin occurs in veins accompanying intrusions of granite porphyry and impregnates the porphyry itself. There is much variation in the veins. Some cut limestones and show nothing but cassiterite and quartz; others carry cassiterite, fluorite, and quartz; fluorite and molybdenite; cassiterite, muscovite, and fluorite; stannite, wolframite, topaz, and quartz; cassiterite, tourmaline, danburite, and calcite; and there are also other combinations.

[1] Eddy, Lewis H., Dredging for placer tin in Alaska: Eng. and Min. Jour., New York, vol. 92, Dec. 23, 1911, p. 1227.

Options for the sale of the property have been given several times, and much work and money have been expended upon it. It is now said to show several thousand tons of ore that will pay to work. There has been no production except a few hundred pounds of tin from unimportant placers formed by the breaking down of the veins.

On Brooks Mountain, at the head of Lost River, hulsite and paigeite are found in limestone metamorphosed by granite intrusions. They are iron-tin borates, containing 15 to 20 per cent of tin. Some prospecting has been done upon the deposit, but the minerals themselves are low in tin, and only a small quantity has been found, so that the deposit does not seem likely to prove of value as a producer of metallic tin. Even were the minerals in large quantity, it is probable that the metallurgical treatment of an iron-tin mineral would prove very difficult.

The only other deposit which promises to be productive is that found in connection with the gold placers on Sullivan Creek, Tofty Gulch, and Cache Creek, in the Hot Springs district of the lower Tanana. The pebbles are very smooth and show the effects of a great amount of water wear. The alluvium is widely and deeply spread over the rocks, and their source has not yet been found.[1]

The occurrence is of great interest mineralogically. The pebbles show that the cassiterite has been deposited in cracks in a quartz vein. The cassiterite has also replaced fragments of some rock of which nothing is now left but a cloudy material resembling clay, suspended in the cassiterite. The cassiterite is very fine grained, appearing so even under the microscope. In this respect it is totally different from any other American tin ore and resembles some of the ore from the Itos mine, near Oruro, Bolivia. Green and brown tourmaline, topaz(?), in exceedingly fine needles piercing the grains of cassiterite and later quartz accompanying it, and fluorite are associated with the cassiterite.

Most of the stream tin has been thrown away, but 1,200 pounds, carrying 55 per cent tin, was shipped at the end of 1911 by Joseph Eglar, and is said to have netted $209. It seems probable that a small production may be made from the deposits.

[1] See article by H. M. Eakin, in this bulletin.

THE TARAL AND BREMNER RIVER DISTRICTS.[1]

By Fred H. Moffit.

GEOGRAPHY AND GEOLOGY.

The search for gold and copper which began in the mountains south of Chitina River with the rush of prospectors to the Copper River basin in 1898 has been carried on spasmodically since that time. As a result copper was found in the mountains east of Taral during the first summer and a few years later (1901) the gold placers of Bremner River were discovered. Of course, no copper has yet been produced in this district, but the facilities for transportation offered by the Copper River & Northwestern Railway during the last year have stimulated interest in the development of copper properties, so that considerable prospecting has been carried on.

Bremner River is the largest tributary to Copper River between Chitina River and the coast. Its valley and Hanagita Valley, north of it, extend eastward from Copper River to the Tana divide, a distance of about 50 miles.

This is a region of high mountains, lying on the border of the great St. Elias ice cap. Numerous glaciers feed its streams and its topography bears evidence of recent and severe glaciation. Its climate is intermediate between that of the coast and that of the interior Copper basin. On the lower Bremner the weather is more like that of the lower Copper and the coast than that of the upper Bremner and Hanagita valleys. Vegetation, particularly in the Bremner Valley, is luxuriant. The valleys are timbered with spruce to 2,500 or 3,000 feet above the sea. Thus Bremner and Little Bremner valleys are well timbered, but the higher parts of Hanagita Valley, particularly in the vicinity of Summit Lake and the head of Tebay River, are above timber line. Some of the spruce is of good size and suitable for lumber. Many trees with a diameter of 18 to 24 inches were seen and a few were found that measured over 3 feet, but these largest trees were not over 35 or 40 feet in height. The finest timber is on the lower part of Little Bremner River and the eastern end of Hanagita Valley.

[1] This paper is a preliminary statement of the results of a geologic reconnaissance by Fred H. Moffit and Theodore Chapin in Hanagita and Bremner River valleys in 1911. The work will be described more fully in a later publication of the Geological Survey.

One small stream, Golconda Creek, a tributary of Bremner River, has yielded most of the gold so far produced in this district, although Little Bremner River has contributed a part. Gold in commercial quantities has not been found near Taral nor between the Chitina and the Bremner in Hanagita Valley. The total production of the district is not known, but probably several thousand dollars have been produced each year since mining began. It should be said, however, that the very high cost of supplies and difficulty of access have done much to discourage prospectors.

The region between Chitina River and the coast (Pl. V) is part of the Chugach Range and is characterized by an exceedingly rugged topography having great relief. It is drained by several streams, of which Bremner River is much the largest and, except the more accessible streams of Hanagita Valley, the best known. Hanagita Valley and the valley of Bremner River furnish the main routes of travel through this region. They will be considered more fully in connection with the descriptions of the placers.

The most important geologic features of the district can be stated briefly as follows: A belt of metamorphic sedimentary beds, including schist, slate, and limestone, extends eastward from Copper River to Tana River and includes the prevailing rocks of the mountain on both sides of Hanagita Valley except in the vicinity of Taral and the upper part of Klu River. These sedimentary beds are intruded by igneous rocks, chiefly dioritic in character, but near Taral they either include or are associated with masses of greenstone. The diorite is of at least two periods of intrusion. Locally, as in the vicinity of Tebay River, the sediments are so intricately intruded and so much altered that they have taken on a banded structure and appear as gneiss. The two periods of diorite intrusion are well shown here, for in many localities the older schistose diorite is cut by younger unaltered dikes. This belt of altered sediments and intrusives includes beds of fossiliferous limestone and is, in part, of Carboniferous age. It is succeeded on the south by a wide area of slate and graywacke, which includes nearly all the Bremner River drainage, so far as it is now known. The beds of the slate and graywacke succession are folded but are less metamorphosed than the sediments on the north. Like them, they are intruded by dioritic dikes and sills, which are most common near the boundary between the two groups and are locally abundant. The slate and graywacke represent the eastward continuation of the rocks found in the vicinity of Valdez. Their relation to the sediments north of them is unknown and their age has not been definitely determined.

A massive conglomerate, which contains pebbles and cobbles of greenstone and diorite in a tuffaceous matrix, and which is associated with fossiliferous tuffaceous sediments, forms the western base

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of the mountain just east of Taral on the south side of Chitina River. The relation of the conglomerate and tuff beds to the narrow schist belt between them and Copper River is that of unconformity, but whether of faulting or of deposition or of both is uncertain at this locality, although adjacent regions give evidence of depositional unconformity. The fossils contained in them are of Jurassic age. These three groups of rocks—the belt of metamorphic sediments and intrusives prevailing in Hanagita Valley, the larger area of slate and graywacke to the south of it, and the tuffaceous sediments near Taral—represent the geology of the region adjoining Chitina River on the south, so far as it is known.

The known mineral resources of this district, as already stated, include gold and copper. Copper is confined to the greenstone areas east and south of Taral, including Canyon Creek, and gold in commercial quantities has been found only in the slate and graywacke area comprising Bremner River basin.

GOLD.

DISTRIBUTION.

All the gold so far produced in the Bremner River valley has been obtained from stream gravels. Little effort has been made to find lode deposits and none to develop such as have been discovered. The success of the Cliff mine at Valdez sent many prospectors into the mountains between Valdez and Copper River in 1911, especially into the more accessible country adjacent to the military road and the Copper River & Northwestern Railway. A large number of small gold-bearing quartz veins was found along the west side of Copper River between Tasnuna River and Chitina, but very few of the prospectors crossed to the east side of Copper River, although the geologic conditions are the same as on the west side. Bremner River valley may be said to be practically unprospected, so far as lode deposits are concerned.

The three parts of the Bremner River valley of present or prospective importance because of known placer gold deposits are Golconda Creek, Little Bremner River, and the lower part of Bremner River above the Little Bremner.

GOLCONDA CREEK.

GENERAL FEATURES.

Golconda Creek is tributary to the north fork of Bremner River, which it joins 5 miles below the great glacier whose waters are the principal source of that stream. It heads in the high mountains between Hanagita Valley and the Bremner but, unlike most of its neighbors, is a clear stream, although melting snow furnishes much of its water in the spring and early summer. It runs southwestward and is between 8 and 9 miles long. In its course from the little lake at its head to its mouth it falls 2,600 feet, or at an average rate of about 300 feet to the mile.

Golconda Creek valley is typical of the valleys in the region. Glaciation has left unmistakable marks in the U-shaped cross section and straightened valley walls, and the stream channel shows the deep narrow canyon in the lower course and broad gravel flood plain toward the head which would be found in almost any important valley in any of the mountain districts of the Copper River basin. A broad, low pass leads from the head of Golconda Creek to Monahan Creek, thus affording a route of travel either westward into the Hanagita Valley or northward to Chitina River. This pass is the gateway by which Golconda Creek valley is entered the year around, for the trail down Bremner River is not available either for winter freighting or summer travel. Bremner River above "the forks" does not afford a highway to Golconda Creek, for the "12-mile canyon" is impassable for sleds in winter and for boats in summer. Monahan Creek, therefore, is at present practically the only route for reaching the upper Bremner River and its tributaries. It flows into Chakina River, which in turn empties into Chitina River 4 miles above the mouth of the Nizina and thus makes it possible to reach the line of the Copper River & Northwestern Railway with comparatively little difficulty. Freight for Golconda Creek, including a small hydraulic plant, followed this route in 1910. The pass has an elevation of about 4,000 feet above the sea, but is only 1,000 feet above timber on the Monahan Creek side and only 1,200 feet above the principal placer workings on the Golconda Creek side. Furthermore, the approaches on both sides offer little difficulty to travel, that from Golconda being the better.

Golconda Creek lies wholly in an area of slate belonging to the Valdez group (see Pl. V), but the slate is cut by numerous light-colored, fine-grained dikes of diorite porphyry, whose presence is distinctly shown in many places on the bare mountain sides. The slate exposed along the creek is hard and siliceous and in places is almost schistose. Its cleavage, which appears to correspond closely in dip and strike with that of the bedding, is nearly horizontal, for the most part dipping slightly to the south, but in places showing a low northerly dip. Perpendicular joints cause the slate to break into angular blocks and slabs, and as disintegration has not advanced far enough since the recent glaciation to soften the rock and make it crumble, great piles of these large slate fragments are seen on the dumps of the placer workings.

PLACERS.

The stream gravels of Golconda Creek are shallow, for in only a few places are they known to have a thickness greater than 8 feet.

They consist chiefly of slate but contain a small proportion of diorite. Diorite bowlders, the largest several feet in diameter, are included in the heaps of slate slabs on the mine dumps, yet fortunately for the miner they are much less common than the slate. Most of the slate can be broken with a sledge and then carried away, but the diorite is too hard for this treatment and requires powder to break it into pieces small enough to handle. For the most part the stream gravels are reworked material from the high bench gravels in which the creek has incised its present channel and formed its narrow flood plain.

Gravel benches, which are prominent in many places on both sides of the channel, may prove to be a source of gold in the future, although no mining has been done in them and they have not been prospected. However, they are known to contain gold in some places and there can be little doubt that the gold content of the creek gravels is in part if not almost entirely a reconcentrated deposit from the benches. These placers thus resemble those of many other Alaskan districts, such as these on Chititu, Dan, and Valdez creeks, where the rich gold-bearing gravels are a reconcentration product from earlier, more widely disseminated deposits that are now being dissected and laid down anew by the present streams.

Golconda Creek gold is described by the miners as "shot gold." Thin, flaky pieces are uncommon, although many pieces are worn quite smooth, yet in general the gold is rough and little worn and many pieces of it carry included quartz. A nugget found on the creek in the early days and valued at $52 is the largest piece of gold yet taken from the gravels.

Most of the mining on Golconda Creek during the seven or eight years following the discovery of gold in 1901 was carried on a short distance below Standard Creek, or about 4 miles below the head of the stream. Pick and shovel were used at first but later a small hydraulic plant was employed in connection with a dam and a "boomer" for disposing of the tailings. During this time the ownership of claims was gradually gathered into the hands of two men. In 1911 the Golconda Mining Co. obtained an option on eighteen claims and installed a hydraulic plant on the stream about a mile below Standard Creek. Most of the summer (1911) was devoted to putting this plant in place and getting it into shape for work. The company now has a mile of ditch line, which takes water from Standard Creek and other small eastern tributaries of Golconda Creek and delivers it at the penstock with a head of approximately 250 feet. From the penstock the water is conducted to the giants by an iron pipe 1,800 feet long. Over 100 feet of 30-inch flume was in place on the 1st of August and bedrock had been reached at its upper end. Unfortunately the condition of the ground prevented the company from placing the boxes so as to take advantage of an excellent dump furnished by the canyon and there may be trouble in disposing of the tailings under the present arrangement. This difficulty can be remedied, however, if it shall arise.

Mining on a more extensive scale would require increased water supply, for the water now available is barely sufficient for present needs. Additional supply could be obtained by extending the ditch so as to take water from the head of Golconda Creek and by collecting it from other tributaries, such as Shovel Creek. Golconda Creek flows at an elevation so high that it will be difficult to bring water from sources outside its valley. This elevation also increases the cost of lumber, for the productive part of the creek is above timber line, and it is therefore necessary to bring logs for lumber and general mining purposes from Bremner River or from Monahan Creek.

LODE DEPOSITS.

Little attention has been given to prospecting for lode deposits on Golconda Creek and in its vicinity. The slate country rock is cut by numerous porphyry dikes and by less conspicuous veins of quartz or quartz and calcite. No direct connection between the intrusives and quartz veins was proved, but they are closely associated at numerous places. Some of the quartz veins are mineralized, but none of them are known to carry gold in commercial quantities. Two claims, the Golconda and the Mammoth, have been staked on the slope of the mountain north of the pass between Golconda and Monahan creeks. The slate is here intruded by several prominent dikes of fine-grained diorite porphyry and is cut by a perpendicular fault running north and south. This fault is traced with little difficulty throughout most of the length of the two claims, for the shattered slate near the fault breaks down more easily than the harder rock on each side, leaving a well-defined depression. Discovery stake, which is on the end line between the two claims, is several hundred feet higher than the summit of the pass. At this point a mass of quartz and calcite, cut longitudinally through its center by the fault, shows evidence of movement after the vein filling was introduced. The west half of the vein consists of cavernous iron-stained quartz, but the east half is made up of calcite containing veins and crystals of quartz. This exposure of vein material is about 60 feet long. Some distance below it, along the fault plane, is another lens of quartz, 6 to 8 feet thick, associated with a fine-grained dike. The vein is found again in a little gulch above the Discovery stake, but the intervening space is barren, although the fault itself is plainly seen. It is evident that the vein filling occurs in a well-defined fault fissure and that it pinches and swells markedly, so that the quartz and calcite masses take the form of lenses irregularly scattered along the fault. Pyrite and zinc sulphide are present in the vein, and a small amount of gold is reported in assay returns. No work had been done on the property at the time of visit in August, 1911, so that only the surface exposures could be examined.

BREMNER RIVER.

Bremner River is now of little importance as a gold-producing stream. No mining was in progress on the north fork in August, 1911, and work on the main river was confined to one locality just above the head of "threemile canyon." The valleys of the lower river and its branches bear evidence of intense glaciation, and at present practically all the important tributaries that make up the Bremner River system head in glaciers, some of which, like those giving rise to the three principal branches, are of large size. The north and middle forks of the river and also the main stream below the forks lie in an area of slate and graywacke, but the quantity of diorite pebbles and bowlders on the river bars shows that there must be important bodies of igneous rock in the mountains between Bremner and Tana rivers, and particularly at the head of the north fork.

The retreat of the ice in these valleys gave opportunity for the deposition of large masses of gravel, which in many places form high benches along the river. Doubtless some of these benches once extended continuously across the valley floor and have been cut into by the river and removed in part.

It was in lower benches of this kind, bordering the river, that mining was carried on in 1911 near "threemile canyon." Here a ridge of slate and graywacke once dammed the river, probably forming a lake and causing a great quantity of sand and fine gravel to be deposited. As the river gradually cut its channel into the slate and formed the canyon it also attacked the gravel deposit above the developed a succession of benches. Fine gold occurs in these benches and may be panned from almost any of the river bars. The amount, however, is so small that it has not offered particular encouragement to prospectors.

In the early part of the 1911 season two men were at work on the north side of the Bremner about half a mile above the canyon. A cut, averaging approximately 10 feet in depth, had been carried down to bedrock in the first bench bordering the river and extended 100 to 200 feet back from the river. The bench at this point consists of sand and fine gravel, probably laid down in quiet water, resting on a slate or graywacke bedrock with smooth undulating surface produced by glacial erosion. Water for sluicing was brought from a small stream near by, and although the head was small it was possible to move a large mass of material in a very short time owing to the fineness of the sand and gravel. Work was interrupted about the middle of summer by failure of the water supply, in consequence of which the gold production was disappointingly low.

Too little prospecting has been done to furnish any proper estimate of the gold content of these gravels. The gravel deposits are extensive and a vast amount of material can be handled easily because of its fineness, yet there are doubtless some bowlder beds present that would offer difficulties.

If systematic prospecting should prove the presence of gold in commercial quantities an excellent water supply with good head can be had at slight expense from the small streams on the north, for the topography at this locality is favorable to the combination of a number of them with comparatively little labor.

A branch of Bremner River which joins the main stream near the lower end of "threemile canyon" was the object of some interest in 1907. An option on a number of placer claims was secured and a party of men with supplies was sent in to exploit the ground, but the returns were so unsatisfactory that the project was abandoned in the middle of the summer. In 1911 only one man was at work on the stream.

The lower part of Bremner River is easily reached in winter from the Copper River & Northwestern Railway near the mouth of Tasnuna River, for there are no canyons on the lower Bremner with water too swift to freeze and the river ice affords good sledding.

In summer small boats can be used as far up as the junction of the north fork and main river, but the water above "threemile canyon" is swift. Near the head of the canyon is a rapid and small fall that makes boating dangerous but not impossible at certain stages of the water. The current is less rapid below the canyon and near Copper River is almost sluggish.

A good summer trail ascends Bremner River from the Little Bremner to Golconda Creek. It is on dry ground all the way and offers no more difficulties than are usual to mountain trails in new and little traveled regions. Horses have never been taken down Bremner River below the Little Bremner, for the river flood plain is quicksand and the steep mountain slope on the river's north side is covered with thick alders and in places with spruce.

LITTLE BREMNER RIVER.

Little Bremner River was the first stream in this district to receive attention from placer miners and was the scene of considerable mining activity before the richer placers of Golconda Creek drew a part of the population to the upper Bremner country. Interest in the Little Bremner, which for several years nearly died out, was revived somewhat in 1910, but late in the summer of 1911 only three men were at work on the stream.

The Little Bremner is a glacial stream about 12 miles long, deriving most of its water from melting snow and ice in the mountains southeast of Spirit Mountain on Copper River. A broad, low pass connects it with the head of Tebay River and thus with Hanagita Valley.

The valley of Little Bremner River, although strongly glaciated, does not show such a pronounced U-shaped cross section as is seen on Bremner River and its other branches. The river flows through a succession of short canyons and intervening gravel flats that occupy overdeepened basins produced by ice erosion of the valley floor.

Slate and graywacke form the country rock of all that part of the stream to which the name "Little Bremner" is applied, but Falls Creek, a large upper tributary, heads in the schist area between Bremner River and Canyon Creek on the north. Toward the head of the river, as the schist boundary is approached, numerous light-colored porphyritic dikes make their appearance. The dip of the slate cleavage, which in most places, although by no means everywhere, corresponds approximately with that of the bedding, is from 30° to 40° N. on the lower river, but gradually decreases.

Prospecting on the Little Bremner in 1911 was confined to the lower end of the flat between the uppermost canyon and the glacier from which the river rises. The flat is between 1 and 2 miles long and about one-quarter mile wide. It was formed by the filling of a shallow basin with outwash material from the glacier, whose stream now shifts back and forth across the surface. The presence of coarse gold in the gravel has been known for some years, and a small amount has been obtained by the pick-and-shovel method of mining.

In 1911 a drill was brought in to prospect the ground, in order to determine whether it would be profitable to install mining machinery. Three holes were put down, reaching bedrock at a depth of 47 feet. The section revealed was 7 feet of coarse surface gravel, underlain by 40 feet of glacier mud, containing rounded and angular rock fragments. Gold is reported to have been found only in the surface wash.

Conditions are favorable for placer mining at this place if the gold content of the gravel proves sufficient to encourage it. Falls Creek would furnish the water necessary for hydraulic operations, or it is possible that the upper Tebay Lake could be diverted to the south side of the divide. Either would supply the necessary head. Furthermore, the Little Bremner possesses a good supply of excellent timber, suitable for all ordinary mining purposes.

COPPER.

DISTRIBUTION AND CHARACTER OF THE DEPOSITS.

A number of copper claims have been staked in the mountains between Canyon Creek and Chitina River and at the head of Canyon Creek. One of these, the Blakney property, near Taral, is patented. On three or four others considerable work has been expended, but the work done on the remainder has consisted only of the assessment work necessary to hold the property. Most of the copper prospects are in shear zones or fractures of various kinds in greenstone, and thus resemble the copper deposits in the Nikolai greenstone of the Kotsina-Chitina district. The only known exception to this mode of occurrence is on Canyon Creek, where the copper minerals are associated with a dark basic dike cutting limestone and schist.

The Blakney property is near the head of Taral Creek, 5 miles east of Taral and approximately 3,400 feet above it. Greenstone, probably derived from an original diabase intrusion or a surface flow, forms the country rock, but is succeeded only a short distance to the east by diorite.

The diorite is believed to be younger than the greenstone and intruded into it. The greenstone has been subjected to great pressure, and as a result is much shattered. Locally the rock is so much crushed that it is difficult to obtain a good hand specimen. Furthermore, the rock has undergone extensive chemical alteration, which is greatest in places where the rock is most crushed.

At the Blakney property a fault zone, made up of numerous parallel fractures and filled with copper and iron sulphides, is exposed on the south side of the creek. The ore body is made up of parallel veins of pyrite and chalcopyrite, ranging in thickness from one-half to 18 inches, separated by thin sheets of greenstone. This mineralized belt in the fault zone is about 3 feet thick. It strikes N. 75° W. and dips 45° SW. An incline was sunk in the ore at its lowest exposure on the creek. From that place the vein extends up the creek for 200 feet till it is cut off by a cross fault striking N. 40° W. and dipping high to the northeast. This ore body is much larger than any other yet discovered in the vicinity of Taral, and so far as the writer knows is as large as any chalcopyrite body not of a disseminated character yet found among the copper deposits of the Chitina region.

SURPRISE CREEK.

Surprise Creek, a short tributary of Nerelna Creek, occupies one of the principal gulches on the east side of that stream, which it joins about 2 miles from Chitina River. Near the mouth of the creek the bedrock is greenstone, intruded by a great mass of diorite, but farther upstream the prevailing rock is greenstone, associated with schist and much-altered siliceous limestone.

About 1½ miles from the mouth of Surprise Creek a short tunnel has been driven in a shattered zone in greenstone containing copper minerals. The fractures in this zone are veined with an intergrowth of quartz and epidote. Particles of chalcopyrite, pyrite, chrysocolla, chalcocite, and bornite are found in the quartz and also disseminated through the greenstone, their relative amounts in the rock corresponding with the order in which they are named, chalcopyrite being greatest. The occurrence of these minerals is similar to that so common in the Nikolai greenstone.

FALLS CREEK.

Falls Creek is a tributary of Canyon Creek, rising in the mountains northwest of Summit Lake. Most of the stream lies in a small basin more than a thousand feet above Canyon Creek, to which it descends in a succession of falls through a narrow, precipitous gulch. This creek is reached from the trail between Taral and Canyon creeks by a branch trail leading up Divide Creek and over the ridge between Divide and Falls creeks. The rock exposures of the basin show a confusing association of greenstone and altered sedimentary beds, including slate, schist, and highly siliceous thin-bedded limestone. Greenstone is the prevailing rock of the mountain slopes south of Falls Creek. Altered sediments prevail on the north side.

Two tunnels, one 105 and the other 150 feet long, were driven into the mountain, on the south side of Falls Creek, in 1911. They are approximately 400 feet apart and about 250 feet above the level of the camp near the creek. Specimens of ore from the longer tunnel show disseminated bornite, covellite, and chalcopyrite in greenstone.

Copper minerals are also found near the trail on the ridge between Divide and Falls creeks. A small open cut in the jointed and fractured greenstone shows chalcopyrite and bornite as veins filling fractures in the rocks and disseminated through it. Covellite and the carbonates resulting from oxidation are present in small amount.

CANYON CREEK.

Canyon Creek, whose head lies in the mountains southwest of Summit Lake, in the Hanagita Valley, is fed by several small glaciers leading down from the snow fields between Canyon Creek and Little Bremner River. In its upper courses, near the main trail running past Summit Lake, it flows through a narrow gravel-floored basin surrounded by high mountains composed of intensely folded and much altered sedimentary beds, among which a massive limesotne, several hundred feet thick, is conspicuous. This limestone is seen on both sides of the valley but is not continuous, for it has been extensively faulted, so that schist intervenes in places between limestone outcrops.

Indications of copper were found on the west side of the creek about a mile from the main valley of Canyon Creek and Summit Lake. A tunnel was driven into the limestone along a copper-stained fault plane just at the top of the talus slope and about 500 feet above the valley floor.

The limestone is highly siliceous. It dips 35° to 45° N. The fault plane strikes N. 40° E. and dips about 45° NW. Smaller perpendicular faults showing slickensided rock faces, nearly at right angles to the main fault, are also present, but they show no copper stains. Near and a little below the tunnel is a dark, fine-grained dike in schist, which probably is faulted into the limestone. The dike rock contains pyrite or pyrite and chalcopyrite and is seemingly the source of the copper stains along the fault plane in the limestone above. It is reported that assay shows nickel as well as copper to be a constituent of the ore.

A large open cut and a tunnel, 20 feet under cover, together with a trail leading to the property, represented the development work done on the claim at the end of August, 1911. The showing was then sufficient to encourage the owners to the expenditure of a considerable further sum in proving up the property, and the construction of a trail down Canyon Creek to Copper River was begun early in September.

SUMMARY.

In summarizing it may be said that the copper deposits east of Copper River in the vicinity of Taral are all associated with altered igneous rocks. Those north of Canyon Creek appear to be closely related in origin and are found in distinct veins and in disseminated deposits in greenstone closely resembling the copper deposits of the Kotsina-Chitina region. The deposit near the head of Canyon Creek differs from these in that it is probably derived from a dike of more basic character than the greenstone and occurs within a mass of limestone.

THE CHITINA COPPER DISTRICT.

By Fred H. Moffit.

PROGRESS IN 1911.

The most important event of the year 1911 affecting the mineral resources of the Chitina Valley was the completion of the Copper River & Northwestern Railway to Kennicott, followed by the first shipment of copper ore from the Bonanza mine to Cordova. A train-load of chalcocite, the first commercial shipment of copper ore from the Copper River basin, arrived in Cordova on April 7, and the day was immediately christened "Cordova Day" by the citizens of that town and given over to a celebration of this important event. The road reached the new town of Chitina, opposite the mouth of Chitina River, early in the summer of 1910 and construction work was pushed as rapidly as possible from Chitina to Kennicott during the fall and winter. Train service between Cordova and Chitina was interrupted at times by snowslides and frozen overflows on the tracks, but during last summer additional snow sheds were built and the tracks were elevated in the troublesome places, so that hereafter there will be no great difficulties in keeping the road clear.

The permanent bridge over Copper River above Chitina has not yet been put in place, but the temporary bridge has fulfilled all the requirements in spite of high water, which loosened some of the piling. Another source of trouble during the summer arose from the occurrence of small landslides in the new cuts along the river, requiring close attention from those in charge of the tracks. Notwithstanding all difficulties and annoyances, however, no serious accidents took place and regular shipments of ore were made over the road all summer.

COPPER.

The Kotsina-Chitina district was not visited by members of the United States Geological Survey in 1911, but some information concerning it was obtained from miners who had been at work there and from other sources.

It is evident that although the region received less publicity than in some former years it was the scene of a large amount of development work in 1911. This work was not confined to one or two properties, but was in progress in all parts of the district. Up to this time no copper ore other than that from the Kennicott Bonanza has been produced. Shipments of chalcocite were made from the Bonanza once or twice each week throughout the summer. The ore is sacked before it is loaded into the cars and is hauled to Cordova, where it is transferred to steamers and carried to the Tacoma smelter. A first dividend has been paid to the owners of the mine, and it is reported that the managers are preparing to proceed with the development of other claims, such as the Jumbo and the Independence, which form a part of the property including the Bonanza.

Prospecting was active in several near-by localities. A force of men was employed in developing the Mother Lode claims, which lie on the same fault zone as the Bonanza mine, about three-fourths mile north of it, on the McCarthy Creek side of the ridge. Construction of a road up McCarthy Creek to these claims was begun preparatory to the installation of mining machinery during the coming summer.

Development was also resumed on the "Nikolai mine," near the head of Nikolai Creek. Nothing had been done on this property since it was patented, about 10 years ago. During that time the old shaft had become filled with ice and the open cuts had been nearly covered by loose débris. About 500 feet of tunnel was driven in 1911. An adit was started near the creek and crosscuts and tunnels were driven in the ore body, revealing a larger amount of copper ore than the surface exposures and shaft had indicated.

A tunnel was also driven in the ore body of the Westover claim, on Dan Creek. Earlier development work, done when the claim was visited by the writer in 1909, consisted of an open cut which did nothing more than to clear away the talus material from the ore body. The tunnel was driven along the fault plane, cutting the ore, and is reported to have proved that the ore extends to some distance.

A promising body of copper is being explored at Copper Mountain, north of Kuskulana River. Work began on this property four or five years ago and a long tunnel has been driven. It is reported that an ore body has been cut by one of the tunnels over 1,000 feet below the outcrop. This is a fact of great importance to those interested in this copper district, since it gives the best indication so far discovered of the depth to which the copper deposits may extend. A survey for a branch road connecting the Copper Mountain camp with the railroad has been made, and construction work will probably begin in the near future.

Development of copper properties in this part of Alaska has gone on slowly, owing to the unusual difficulties to be overcome, yet it appears that a change is taking place and that more rapid progress will be made from this time on.

It is evident that an earnest effort has been made during the year to develop mining properties so as to put them on a producing basis. Stock companies have not been formed or shares sold during the last year or two for two reasons—first, the transportation facilities offered by the railroad have been better, and, second, the copper market has been depressed.

GOLD PLACERS.

A prosperous year is reported from the Chititu Creek and Dan Creek gold-placer district. Nearly all the mining on the Chititu took place on its northern tributary—Rex Creek. A few men were working at the mouth of this stream, shoveling into sluice boxes. The hydraulic plant which has been operated for several years on the lower claims of Chititu Creek above the canyon was moved to the lower part of Rex Creek and installed there. A dam was constructed and several hundred feet of flume and 2,000 feet of iron pipe were put in place in the early part of the season. Frozen gravel was encountered, but the giants were so placed as to avoid difficulty, and a successful season resulted. A much larger plant, to take the place of the one moved from Chititu Creek to Rex Creek, will be taken in during the winter of 1911–12.

Mining was also in progress on the upper part of Rex Creek, and it is reported that some gold was produced. An hydraulic plant will be placed in operation there during the summer of 1912.

On Dan Creek preparations for the installation of an hydraulic plant on the lower part of the creek below the canyon were continued, and in addition work was done on the benches south of Dan Creek and on Copper Creek, its southern tributary. It is also reported that some work was done on Young Creek near Calamity Gulch, but the Nizina district was not visited by members of the United States Geological Survey in 1911 and the extent of operations on Young Creek was not learned.

GOLD DEPOSITS NEAR VALDEZ.

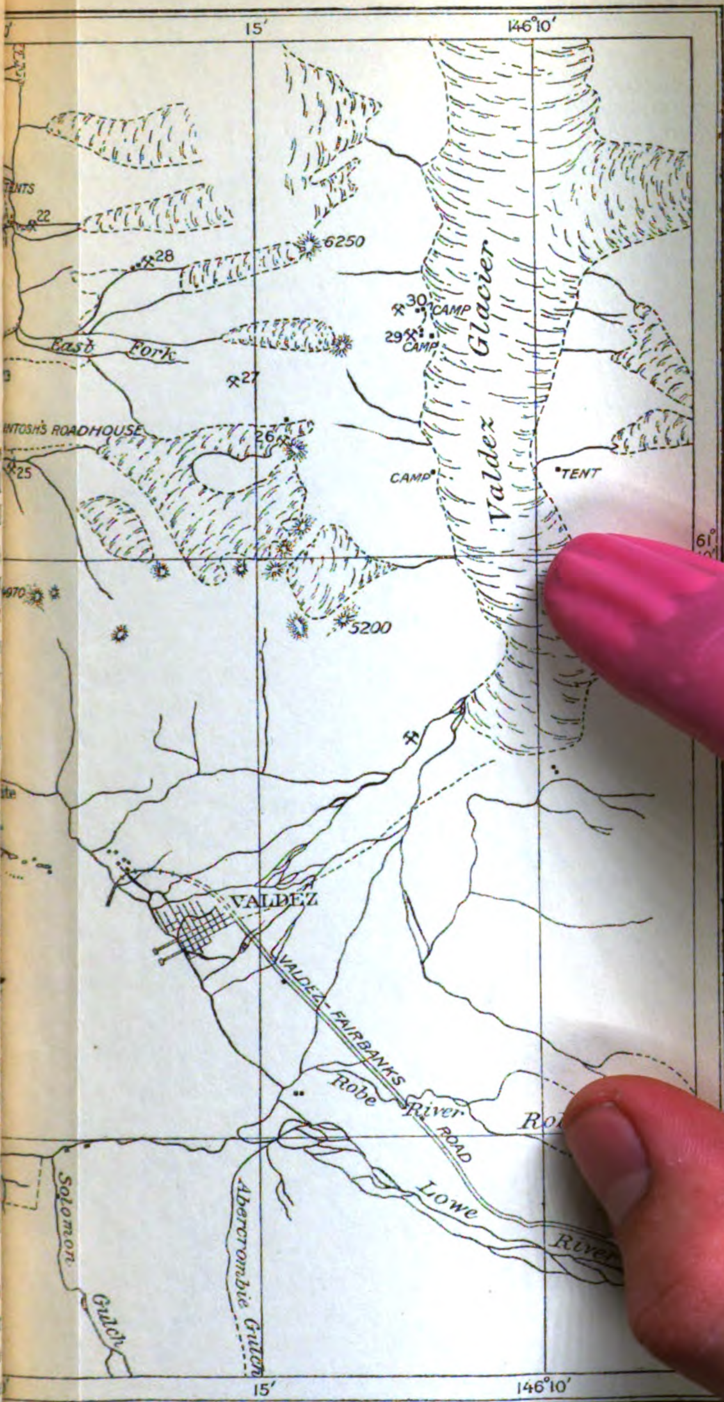
By Alfred H. Brooks.

INTRODUCTION.

As early as 1898 some of the streams tributary to Port Valdez were known to contain auriferous gravels, which had been mined in a small way. In spite of this evidence of auriferous mineralization, as well as that suggested by the presence of quartz veins stained with iron, the Valdez district for many years received relatively little attention from the prospector. The thousands who joined in the mad rush over the Valdez Glacier during the Klondike excitement paid no heed to the possibility of finding mineral wealth in the region which they rapidly traversed on their way into the interior. Many of these gold seekers must have passed in sight of the quartz vein outcropping on the north shore of the inlet which 12 years later was developed as the Cliff mine. A few men, however, persistently kept up the search for gold quartz, and some veins were staked as early as 1898, but as they remained undeveloped, definite proof of the presence of workable ore bodies in this region was lacking. The Cliff mine became productive in 1910 and proved a very profitable mining venture. Its success very greatly stimulated prospecting by local miners and also attracted the attention of nonresidents, who quickly recognized the possibility of developing here a new auriferous lode district. As a result, several hundred lode claims were staked and considerable development work was undertaken during 1910 and 1911. These activities first centered in the region immediately adjacent to Port Valdez, lbut ater both the eastern and western extension of what was believed to be an auriferous belt received attention. The search for auriferous lodes was carried westward to Columbia Glacier and later to Port Wells and eastward along the Valdez-Fairbanks road.

In 1910[1] the writer paid a brief visit to the Cliff mine and also obtained sufficient data about the mining advancement at other localities to be convinced that an immediate detailed survey of the district was justified. As an accurate topographic base map is the

[1] Grant, U. S., and Higgins, D. F., Reconnaissance of geology and mineral resources of Prince William Sound, Alaska: Bull. U. S. Geol. Survey No. 443, pp. 72-75, 1910.


15'
146°10'
NTS
22
28
6250
30
CAMP
29
CAMP
East Fork
27
Valdez Glacier
NTOSH'S ROADHOUSE
26
25
CAMP
TENT
61°
4970
5200
VALDEZ
VALDEZ-FAIRBANKS ROAD
Robe River
Rob
Lowe River
Solomon Gulch
Abercrombie Gulch
15'
146°10'

first requisite to a study of the geology and mineral resources of any region, a topographic survey of what was then believed to be the most important part of the Valdez district was made by J. W. Bagley, assisted by C. E. Giffin, in the summer of 1911. A map based on these surveys is now in preparation. It was impracticable to make the geologic survey during the same season, but in view of the great interest taken in this field by the mining public, it seemed imperative to make at least a preliminary study of the district.

The ten days devoted to this purpose were sufficient only to collect some random notes on the geology and to visit about 25 claims out of the several hundred which had been staked, none of which was exhaustively studied. Therefore those who expect to find a description in this report of all the many properties in this region, or even a comprehensive account of any one property, will be disappointed. Four days were spent on the west side of Shoup Bay and in the adjacent inland region, five days in the Mineral Creek basin, and two days on the west side of Valdez Glacier. This distribution of time made it possible to visit some of the typical occurrences of auriferous lodes as well as most of the best developed properties. Unfortunately, it was possible to see none of the properties in the Columbia Glacier region, on the east side of Shoup Bay, in the Gold Creek basin, or on the shores of Port Valdez (except the Cliff mine), and only a part of those in the Mineral Creek basin.

Much information was obtained from the engineers, miners, and prospectors of the district, to whom the writer hereby expresses his obligations. Among the many who aided the work Eugene Allen, B. F. Millard, Thomas Blakeney, C. M. Nicholson, and M. M. Reese deserve special mention.

This report could not have been prepared if the results of the previous work in this field had not been available. F. C. Schrader studied the geology of Prince William Sound in 1898, and again, in association with A. C. Spencer, in 1900, and in 1905 U. S. Grant and D. F. Higgins traversed the same field in greater detail and in 1908 and 1909 made still other observations. References will be made to the published reports of these investigations. In addition to these reports the unpublished notes of these geologists have been freely drawn upon.

GEOGRAPHY.

SHORE FEATURES.

The town of Valdez, to which the mining district here described is tributary, is located at the head of Port Valdez, a northeastern arm of Prince William Sound. (See Pl. VI.) Port Valdez is one of the many deep fiords that penetrate the mainland of this part of Alaska. It has a lenticular outline, trends about east and west, is about 12½ miles long, and averages about 3 miles in width. It is connected with Prince William Sound by a passage only a mile wide. The fiord averages over 100 fathoms in depth and, except at its head, is deep close to the land. Much of the larger part of the shore line is remarkably even, long stretches being almost unbroken straight lines. Shoup Bay is a small indentation on the northwest shore of the inlet, and several other minor indentations form small coves, notably along the southern shore line.

Throughout most of the inlet the land rises abruptly from the water or from a narrow, rocky beach. An exception is found in the broad gravel floor lowland that sweeps around the east end of Port Valdez. This lowland has been formed by the merging of the deltas of the streams draining Valdez Glacier with the delta of Lowe River. There are also some gravel flats at the mouths of other streams tributary to the bay. Of these the one at the mouth of Mineral Creek, embracing abut 1½ square miles, is the largest.

MOUNTAINS.

Port Valdez occupies a depression in the southern part of the rugged Chugach Mountains, which form a barrier trending east and west between the sea and the Copper River basin. The main range lies north of the inlet, south of which is a less rugged mass, forming a spur, separated from the main range by the bay and by the valley of Lowe River. The mountains north of Port Valdez and adjacent to it include an irregular aggregate of sharp pinnacles connected by narrow, steep-walled ridges and broken by numerous amphitheaters of glacial origin. The summits of these mountains vary in altitude from 4,200 to 6,300 feet. The mountains to the south form a part of a well-defined range, which constitutes the watershed between Port Valdez and Jack Bay. Here the slopes are less abrupt and the summits are more rounded than those in the northern mountains, and the extreme altitudes are only 3,000 to 5,400 feet above the sea.

DRAINAGE.

The region contains many small streams that flow down the mountain slopes in narrow gulches and also some large streams that occupy deep-cut U-shaped valleys. Most of the streams tributary to Port Valdez are less than 3 miles long. Many of the large watercourses head in glacial cirques and some spring directly from ice fronts. The typical valleys have steep walls and narrow floors, which descend with steep gradients to the sea.

Lowe River is the largest stream in the district. It rises on Marshall Pass, 25 miles east of the bay, flows through a steep-walled valley, and discharges into the east end of Port Valdez. Near its mouth a number of streams that flow over a broad flood-plain from

Valdez Glacier, which lies to the northwest, about 5 miles from tidewater, also flow into the bay. Mineral and Gold creeks, Solomon Gulch, and several other streams flow through gravel-filled basins that are connected by stretches of box canyons. Several of the streams, of which Mineral Creek is the best example, are sharply deflected to the west on approaching the sea.

GLACIERS AND GLACIATION.

Valdez Glacier, which is fed by snow fields far back in the Chugach Range and debouches on the gravel plain at the head of Port Valdez, is the largest ice mass of the region. Second in size is Shoup Glacier, which also reaches far back into the mountains and discharges into Shoup Bay. Many other small glaciers, which also lie north of Port Valdez, are drained by streams flowing into the bay. The great Columbia Glacier lies about 4 miles west of Port Valdez and discharges into the sea at Columbia Bay, a northern arm of Prince William Sound.

The present glaciers are but the disappearing remnants of an ice sheet that once filled Port Valdez and the tributary valleys up to an altitude of 3,000 or 4,000 feet. This ice sheet scoured deeply, and eroded many channels and waterways as well as the numerous cirques and U-shaped valleys. The topographic features of the region were well developed before this ice erosion, which, however, deepened and modified them.

VEGETATION.

Timber is rather scant except in part of the flat east of the head of Port Valdez, where there is a growth of spruce, hemlock, and cottonwood, some trees measuring several feet at the butt. Along the shores of the bay there is almost no valuable timber, though a scant growth of spruce and other kinds of trees is found up to an altitude of a few hundred feet above the sea. Good grass grows in the flats, where also some arable lands are found.

CLIMATE.

The climate of Port Valdez is characterized by cool summers with abundant rainfall and by winters which are cold but which have none of the extremes of temperature that are usually associated with Alaska. The records, though meager, indicate an average snowfall of about 12 feet. The total mean annual precipitation is about 75 inches. The data at hand indicate an average temperature of about 51° F. for the three summer months and 20° F. for the three winter months. An average of 176 days of rainy or snowy weather during the year is reported. Records covering two years show a minimum temperature of −14° F. in January and maximum of 79° in June.

GEOLOGY.

GENERAL CONDITIONS.

The Port Valdez region lies within the southern margin of the Chugach Mountains, which, so far as known, are made up of closely folded and faulted sediments, chiefly clay slates and graywackes, both schistose and massive, with some conglomerates. These rocks have been in part altered to phyllites and mica and quartz schists. In the northern part of the range there are also limestones. The axes of folding trend about east and west, and the dips are prevailingly to the north. Some igneous intrusives of various types cut these sediments.

For lack of detailed knowledge of the stratigraphic sequence within this great mass of sediments, which is probably in the aggregate many thousand feet thick, they have all been thrown together as the Valdez group.[1]

The Valdez rocks are believed to be unconformably overlain by another great series of sediments that are of similar lithologic types but that are less altered and include a lower member, made up of ancient volcanic rocks, which has been named the Orca. Intrusive igneous rocks cut the sediments of the Orca group. Grant and Higgins have mapped the boundary between the Orca and Valdez at the entrance to Port Valdez. The Orca group therefore does not occur within the area here under discussion.

The age of the Orca and Valdez rocks has not been determined, but they have been provisionally assigned to the Paleozoic and Mesozoic eras. G. C. Martin and B. L. Johnson in their recent work in the Kenai Peninsula found Mesozoic fossils in a slate-graywacke series that resemble the sediments of Prince William Sound. F. H. Moffit, in 1911, investigated the Bremner River region and there obtained evidence that rocks probably equivalent to the Valdez are of Carboniferous or early Mesozoic age.

Quartz veins are not uncommon in both the Valdez and Orca groups, and some of them are metallized. Some of these veins have long been known to carry gold, but before the Cliff mine was opened none had been exploited on a commercial scale.

SEDIMENTS.

The sediments of the Port Valdez region are chiefly slates and graywackes in proportions that vary greatly from place to place. Local variations from these dominant types include siliceous and carbonaceous slates and feldspathic quartzites.

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[1] Schrader, F. C., Reconnaissance of Prince William Sound and the Copper River district, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, part 7, 1900, pp. 408-410. Schrader, F. C., and Spencer, Arthur C., The geology and mineral resources of a portion of the Copper River district: Special publication U. S. Geol. Survey, 1901.

Grant, U. S., and Higgins, D. F., Reconnaissance of the geology and mineral resources of Prince William Sound Alaska: Bull. U. S. Geol. Survey No. 443, 1910, pp. 22-24.

The weathered surface of the graywacke varies in color from light brown to gray, the brown usually indicating the presence of pyrite. A finely pitted surface is characteristic of the rock where it is exposed to weathering, but the pits are generally so small as to be distinguishable only with a lens. The rock cleaves irregularly and in the fresh fracture is gray or blue. Even the massive graywackes may show on the fresh fracture a minute banding caused by a parallel arrangement of the minerals. The graywackes are composed essentially of minute angular and subangular grains of quartz and feldspar embedded in a cement of quartz, mica, and chlorite. In many specimens, however, these minerals can be definitely recognized only with the microscope.

Many of the graywackes have been wholly or in part recrystallized. Some specimens are difficult to distinguish from igneous rocks except by microscopic analysis. Grant mentions graywackes that have been so altered as to become schists, but none of these was seen by the writer. These graywackes are of sedimentary origin and were probably deposited at a time when a large amount of material was furnished by the erosion of igneous rocks.

A common variation from the above type is a schistose graywacke; that is, one in which secondary cleavage has been developed. In some places this cleavage amounts only to an irregular system of fracturing; in others it is almost slaty cleavage. Another variation is a feldspathic quartzite, in which the percentage of quartz is increased at the expense of the feldspar. With the development of secondary structure the quartzite passes into a quartz slate, and with still greater alteration into a mica schist.

The graywacke occurs most commonly in alternation with beds of slate, but appears locally in masses aggregating in thickness at least several hundred feet. The data at hand indicate that such masses are large lenses in the graywacke and slate series rather than beds or formations that perserve their continuity over considerable areas.

The rocks here classed as slates are fine-grained argillites which have a more or less regular secondary cleavage. The weathered surface of these rocks is in places gray, but where the slate contains pyrite it is more often brown. On the fresh fracture it is gray-blue to black in color. In none of these rocks is the cleavage as perfect as that of roofing slate. In composition the slates are chiefly argillites, which are in places altered to phyllites by the development of muscovite along planes of foliation. Some of the slates are very siliceous, grading into slaty quartzites. These siliceous slates locally contain some feldspar, thus passing into slaty graywackes. At several localities the slates carry a large amount of carbonaceous material and are finely fissile, resembling a carbonaceous shale, but in all these slates the foliation seems to be a secondary structure. Many of the slates carry considerable disseminated pyrite.

Some belts of green chloritic shale found near the head of Mineral Creek seem to form an integral part of the sedimentary series. This rock is made up entirely of secondary minerals, and its original character has not been determined. Grant found similar rocks on the south side of Port Valdez and has suggested that they might be altered volcanic tuffs. Grant also found a belt of greenstone on the northwest side of the entrance to Port Valdez.

IGNEOUS ROCKS.

No outcrops of igneous rocks were examined in the district, but some crosscutting dikes were seen from a distance. One of these, in the Shoup Glacier region, was clearly visible and could be traced up the slope to the crest of the ridge for 200 to 300 feet. A similar dike was seen in the Mineral Creek basin. These dikes are almost white and contrast strongly with the gray sediments which they crosscut. What appeared to be material derived from similar intrusives was found in the débris of both Shoup and Valdez glaciers.

These intrusives are included in those termed by Grant[1] acidic dikes. The specimens collected from the glacial débris are fine-grained crystalline rocks, pale green to white in color. They appear to be altered porphyritic rocks in which the phenocrysts were probably feldspar. The groundmass seems to be chiefly feldspar, but the specimens obtained were so much weathered that no exact determination could be made of the original character of the rock. They can be provisionally termed diorite porphyries. Schrader[2] has noted the presence of dikes of granodiorite or aplite and diorite porphyry cutting the sediments of the Valdez group. He has mapped a large dike of granite near the head of Valdez Glacier and two smaller dikes of aplite on some small islands near Valdez. The latter have been studied by Grant and Higgins,[3] who also found some crosscutting dikes of diabase on the south side of the entrance to Port Valdez.

STRUCTURE.

The general trend of the bedrock structures is about east and west and therefore parallel to the axes of Port Valdez and the bordering mountains. On the south side of the bay strike lines measured by Grant vary from N. 70° W. to N. 70° E., but the average is about east and west. North of the bay the average strike line is about N. 70° E. The observed dips are almost entirely to the north, at angles varying from 45° to 80°. Minor folds observed at several localities indicate that the monoclinal dips are the result of com-

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[1] Op. cit., pp. 47-48.

[2] Schrader, F. C., Reconnaissance of part of Prince William Sound and Copper River district, Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, part 7, 1900, pp. 409-410.

[3] Grant, U. S., and Higgins, D. F., Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska: Bull. U. S. Geol. Survey No. 443, 1910, p. 50.

pressed folds overturned to the south. The best indications of faulting observed were the evidences of the movements that formed the fissures in which the quartz veins were deposited. In the Shoup Bay region these fissures fall into at least two well-defined systems, one trending N. 40° to 60° W. and the other N. 20° to 40° E. The data at hand indicate that in the Mineral Creek region the fissuring is not so pronounced, but here also two systems can be recognized, one of them trending from N. 70° W. to east and west, the other from about N. 30° W. to N. 50° W. No measure was obtained of the extent of the movement along these fissures, but the facts that some can be traced for considerable distances and that many show slickensides and much crushed material indicate that it was considerable.

A later period of deformation is shown by faulting of some of the quartz veins which occur in the fissures already described. The only examples of this faulting which could be measured showed displacements not exceeding 3 to 5 feet. There is, however, some evidence of more extensive faults. In the outcrops seen the cleavage of slates and slaty graywackes was mostly parallel to the bedding. Some exceptions to this were noted, and the observations were not sufficient to establish any general law. In some localities there is a well-marked system of jointing, which trends about N. 10° to 30° W. These joint planes, being lines of weakness to erosive agencies, are marked in places by steep-walled gulches on the hill slopes. A second system of jointing, which trends about N. 20° to 30° E., was noted. Quartz stringers were seen along some of these joint planes, and the joints may represent the results of the same epoch of movements as do the fissures.

The facts stated indicate that the bedrock has undergone at least three periods of disturbance. During the first, which was the period of greatest movement, the folding that gave the sediments their present structures took place. At a later date there was a period of deformation during which the fissuring occurred. After the fissures had been filled with quartz there was another and probably minor disturbance, which faulted some of the quartz veins.

AREAL DISTRIBUTION OF ROCKS.

Although the field observations are insufficient for the preparation of a geologic map, they indicate that the sediments of the region occur in more or less well-defined belts, each of which is characterized by the dominance of one kind of rock or association of rocks. Thus, in certain areas the rocks are predominantly graywackes, with subordinate amounts of slate; in others they are chiefly slate, with but little graywacke; and in still others they consist of graywacke and slate in about equal proportions. These lithologically similar areas, as would be expected from the dominant structure, form belts trending east and west. It is probable that these belts will be the basis for geologic mapping at some future time, when it will be determined which represent distinct formations and which represent duplications brought about by folding and faulting.

In extent of areal distribution the slate-graywacke belts dominate in the region. According to Grant's notes this association of sediments characterizes nearly the entire south shore of Port Valdez, both sides of the entrance, and the west shore as far north as Shoup Bay. Grant has noted that a belt of slates skirts the shore of the bay east of Fort Liscum. The strike of these slates would carry them into the Lowe River Valley, where there is a pronounced development of slate.

On the north shore of Port Valdez slates appear to dominate, but for the most part they have been considerably altered. At the Cliff mine the slates are highly silicified, and near the mouth of Mineral Creek secondary mica has been developed, so that the rocks are properly termed "phyllites." Grant reports that mica schists occur on the small islands lying between Mineral Creek and Valdez. These are to be regarded as a more highly metamorphosed phase of the slate. The slate and phyllite belt at Mineral Creek is about 2 miles wide, but includes some bands of graywacke. It is bordered on the north by a belt of graywacke and slate, which appears to be the same one observed on the west side of the lower part of Valdez Glacier.

The northern boundary of the graywacke-slate belt has not been determined, but considerable slate is found about a mile southeast of McIntosh Road House, and the slates occurring near the Valdez-Bonanza property and near the Valdez and Ibex properties on Valdez Glacier are probably in the same belt. Half a mile north of the Valdez-Bonanza is a series of massive graywackes, which probably bound this slate belt, but have not been traced to the east or west.

The bedrock of the upper part of the Mineral Creek Valley above the mouth of the East Fork is chiefly slate, with some bands of graywacke.

Slates and graywackes in many alternating bands occur on the west side of Shoup Bay. Between McAllister Creek and Shoup Glacier slates dominate. These slates are bordered on the north by massive graywacke, which attains a thickness of several hundred feet. Slates are found again north of this graywacke. Greenstone and chloritic schists were observed by Grant on the south shore of Port Valdez, a mile west of Fort Liscum, where they are in part interbedded with slates. Chloritic schists were also found east of Mineral Creek Road House and 2 miles north of it, along the main stream. The evidence at hand indicates that the greenstone schists are limited to small areas and do not extend for any considerable distance along the strike line.

MINERAL RESOURCES.

OUTLINE.

Up to the close of 1911 one auriferous lode mine, the Cliff, had been developed in the district, and a little gold ore from other properties had been treated at a customs mill erected at Valdez in the fall of 1911. A shipment of copper ore is said to have been made from a chalcopyrite deposit which has been developed on Solomon Gulch since the writer's visit. The only other productive mining in the district consists of the exploitation of some gold placers at various times during the last 10 years. These operations were, however, on only a small scale, and the output was insignificant.

CHARACTER OF ORE DEPOSITS.

The gold-ore deposits of the district that give promise of commercial importance are all fissure veins; that is, they are fillings of fissures or fractures in the country rock. A variation from this type, though of the same genesis, is seen in mineralized zones of fracture that have no well-defined walls. Local pyritization of the country rock is also not uncommon in the district, and it is not impossible that some gold deposition accompanied this action, but even if this is proved there is no evidence that the rock contains commercial ore bodies of this type.

In some parts of the district the fracturing is pronounced, and individual fissures can be traced for long distances. In the region adjacent to the west side of Shoup Bay, for example, two well-defined systems of fissures are recognizable, one striking about N. 10° to 40° E. and the other N. 40° to 60° W. In addition to the veins following these systems, there are veins that are nearly parallel to the bedding striking about N. 70° E., and others whose trend does not fall into any of these systems. The Cliff vein strikes about N. 30° W. and the others nearby are probably about parallel to it, though no definite measurement was obtained on any of them.

The system of fissuring in the upper Mineral Creek basin does not appear to be nearly as well defined as that at Shoup Bay. Observations were made in the upper Mineral Creek basin on eleven veins, five of which trended about east and west, two from N. 70° to 80° E., one N. 50° E., and two N. 20° W. So far as the observations go, they indicate that the prevailing strike of the veins is from N. 70° to 90° E. Too few observations have been made near Valdez Glacier to justify any deductions as to trend of fissures, but those made indicate one system striking about east and west and another striking about N. 30° W.

The fissures are mostly marked by a zone of brecciation and slickensiding. In many of the veins the fragments of country rock form much the larger part of the material included between the walls, the foreign matter brought in being very subordinate in amount. Slickensides are almost everywhere present on one wall, with more or less gouge. In a few fissures slickensides were found on both walls. Some of the fissures are remarkably persistent for long distances. A number have been traced for more than a quarter of a mile, and there is good reason to believe that one or two have been identified at intervals for a mile to a mile and a half. Unfortunately the vein filling by no means shows such persistency. In several fissures which could be traced by slickenside and gouge for a long distance the vein matter practically gives out in a hundred feet or less. In some fissures the vein matter is in places almost entirely absent for considerable distances, and reappears farther along.

Any statement as to the thickness of the workable ore body in a field where only one productive mine has been developed can have little value, for workability is evidently dependent on the cost of mining and the amount of the valuable minerals in the vein. Most of the veins that have been staked are narrow, and though some larger veins have been found, few of them exceed 2 to 3 feet in thickness. The common impression among the miners of the district is that the promise of this field is in small, rich veins rather than in large deposits carrying lower values, and this view is justified by the facts in hand. Some of the lodes in the district, though they occur along lines of more or less well-developed fissures, seem to be very local accumulations of quartz. These masses of quartz are very irregular and seem to have no persistency along either the strike or the dip. As some of these have extensive outcrops and show a large content of gold, thay have given hopes of large workable ore bodies—hopes that were not realized when development was attempted. Some of these quartz masses are local swellings along veins which in their normal thickness may furnish workable ore bodies. Others are simply irregular masses of mineralized quartz whose continuation at depth or along strike is found only in very small stringers.

There is little evidence at hand regarding the continuity of veins at depth. Veins have been found at sea level and at altitudes of over 5,500 feet. This variation in the altitude of the veins and the fact that the rocks stand nearly vertical and the veins are cross-cutting indicate that the ore bodies are not confined to any particular level. At the Cliff mine the vein has been followed to a depth of 400 feet below its outcrop. There is therefore no reason to believe that the ore bodies will exhibit any greater irregularity at depth than they show along the strike line in their surface outcrops. Although many of the veins occur in fissures which are traceable for considerable distances, it is not to be supposed that all or even the larger part of the veins are of this character. Many of those located pinch out or disappear in a short distance along the strike or along the dip. On the other hand, some lodes have been discovered during underground exploration that did not outcrop and yet seemed to be well defined.

DISTRIBUTION OF ORE DEPOSITS.

Considerable prospecting has been done on the south side of Port Valdez, where some promising ore bodies are reported to have been found. None of these were examined, but they are said to be larger and of lower grade than those to the north. Be this as it may, the fact remains that most of the development work has been confined to the region lying north of Port Valdez.

The accompanying map (Pl. VI, p. 108), on which many of the most important prospects are indicated, shows that the area in which the ore bodies have been found lies in a belt paralleling the inlet and extending from Columbia Glacier on the west to and beyond Valdez Glacier on the east, a distance of about 20 miles. It should be added that prospects have been found both east and west of the area thus defined. The most northerly prospects within this area are those on upper Mineral Creek, which are about 8 miles from tidewater. It appears that the inland limit of the occurrence of ores, as above defined, seems to be determined by accessibility. Thus far the prospectors have extended their search only to the headwaters of the streams flowing into Port Valdez, rightfully regarding the region beyond, with its high ranges, as too inaccessible at present to permit the development of any ore bodies that might be found there. The gold-bearing area as thus outlined must in light of present knowledge therefore be regarded as a topographic province in which ores have been found rather than as a geologic province within which the conditions for the occurrence of mineral deposits are more favorable than they are elsewhere. The actual limits of the prospective mineral district will remain to be discovered in the future, when the knowledge of the geology is more nearly complete.

Little is known of the geologic association of the ore bodies thus far discovered. In view of the intimate relation[1] which exists in most of the Alaska metalliferous districts between the occurrence of ores and of igneous intrusives it is natural to look for similar relations in the Valdez district. Here, however, the evidence is largely negative. Intrusive rocks are by no means common in the areas examined, nor does the glacial drift indicate the presence of any large masses of intrusives in the high ranges to the north. The facts in hand do not warrant the conclusion that the mineralization of the district had any connection with igneous intrusion, but a detailed survey may show more intrusive rocks in the district than is now supposed. Gold ores have been found in the areas of slate, of slate and graywacke, and of graywacke. It appears, however, that the country rock adjacent to the ore bodies usually has a more or less well-developed cleavage. In other words, no promising ores have been found in the massive

[1] Brooks, Alfred H., Geologic features of Alaskan metalliferous lodes: Bull. U. S. Geol Survey No. 480, 1911, pp. 57-58.

graywacke. Beyond this fact there is no evidence of any direct relation between the lithology of the country rock and the occurrence of ore. On the other hand, it is to be expected that the various types of sediments found in the district may fracture in different manner and thus affect the continuity of the ore bodies. The data in hand are insufficient, however, to establish any generalizations concerning the character of the fractures in the different rocks.

CHARACTER OF THE ORES.

The mineralogy of the ores, so far as it is known, is simple. In most of the ores pyrite, gold, and argentiferous galena are the only metalliferous minerals recognized. Grant found some pyrrhotite and chalcopyrite in a small vein about three-quarters of a mile west of Fort Liscum. Chalcopyrite has also been found on Solomon Gulch, on the south shore of the bay. Arsenopyrite ores are reported from this part of the district. Pyrrhotite is said to occur on the Blue Bird claim, located near the west entrance to Shoup Bay.

The gangue mineral is almost entirely quartz. Microscopic analysis of many of the ores reveals the presence of some calcite, but in only a few places did this mineral form more than a small proportion of the gangue. Feldspar, chiefly albite, was observed in several of the veins which were studied under the microscope. The typical ore of the district is pyritiferous gold-bearing quartz, in many places carrying a little galena. Pyrite, always the most abundant metalliferous mineral, occurs both in granular aggregates and in small cubical crystals. The galena is present either in small isolated particles or in association with the pyrite.

In the unoxidized vein material visible free gold is relatively rare. When present it occurs in small filaments and particles. Most of the free gold observed was in the weathered portions of the vein, where it is associated with iron-stained quartz.

The quartz varies in color from white to bluish and in places is vitreous. Most of the veins show quartz crystals. In many veins are druses lined with crystals of vitreous quartz. The calcite, which was seen only under the microscope, occurs in small, irregularly outlined masses. The feldspar generally occurs in well-developed crystals. In some of the veins the feldspars constitute a surprisingly large percentage of the gangue material. Masses of country rock form a large proportion of the vein material in many of the lodes. These vary from horses several feet in diameter to small fragments which can be seen only under the microscope. The larger fragments, which show relatively less alteration than the small, are silicified, sericitized, and usually heavily charged with pyrite. Small veinlets of quartz forming networks through the fragments are common. The small fragments of country rock are in many places entirely recrystallized and are made up of quartz mosaics, calcite, and sericite, with much pyrite.

Many of the veins are banded, dark and light layers alternating. These seem to be made up of bands of country rock consisting of quartz, mica, and pyrite, alternating with bands of quartz carrying pyrite and in many places calcite. Some veins that cut across carbonaceous rocks contain carbonaceous matter, probably graphite.

Most of the specimens of ore collected by prospectors are taken from the surface outcrops and show considerable oxidation, which does not seem to extend to great depth. At the Cliff mine evidence of oxidation was seen to a distance of about 100 feet from surface but was distinctly marked for only about half this distance. Oxidation of about the same depth was noted at the few other localities where observations were possible. In other places the decided decrease in gold at a depth of a few feet indicates that oxidation was in such places very superficial.

The important question of the gold content of the veins does not admit of a categorical answer. There has been relatively little sampling of a kind to yield definite information concerning gold values of the lodes of the district. Current reports indicate that the Cliff vein has averaged about $50 to the ton, mostly in free gold, with very little change in depth. The concentrates are said to run about 7 per cent and carry about $100 worth of gold to the ton. This is probably a fair measure of the gold content of the ores of the district, though many property owners report values ranging from $75 to $200 and even higher. It is needless to state that many veins carry very little gold—only $2 to $3 to the ton. Rich spots in some of these veins have misled prospectors who have not done careful sampling.

GOLD PLACERS.

Some of the streams of the Valdez district were known to carry auriferous gravels long before any workable quartz was discovered, but up to the present time there has been no important placer mining. The surface gravels on Mineral, Gold, and some other streams of the district have been sluiced in a small way, but their gold content was not high enough to warrant profitable exploitation by the simple methods used.

On Mineral Creek, Gold Creek, and in Solomon Gulch, as well as on some of the other streams, there are gravel-filled basins that seem to afford about the only hope for placer mining in the district. These gravels are known to be auriferous on the surface at least, but few, if any, attempts appear to have been made to test them to bedrock. A hydraulic plant which is being installed on Gold Creek affords presumptive evidence that the exploiters have made some tests of the extent and value of the alluvial deposits they propose to mine.

NOTES ON MINES AND PROSPECTS.

Cliff mine.—The following account of the Cliff mine is based on notes taken in 1910, when only the main level and workings above had been opened up, and on one very brief visit to the lower level made in 1911. The mine is on the north side of Port Valdez, about a mile east of the eastern entrance to Shoup Bay (Pl. VI, p. 108). An outcrop of the vein was discovered in 1909 in a cliff close to tidewater. The vein was subsequently found on a hill slope about 100 to 200 feet above, and has been traced probably over 600 feet and reported beyond. Since 1910 it has been systematically developed.

The country rock at the mine appears to be chiefly dark siliceous slate or phyllite, locally carbonaceous and with a blocky cleavage. This slate carries mica and in places is heavily charged with finely divided pyrite, which occurs in veinlets cutting the foliation and is also disseminated along cleavage planes. Slickensided surfaces occur along these veinlets, showing that there has been movement since the pyrite was formed.

The vein follows a well-defined fissure, which strikes from N. 30° to N. 45° W., probably averaging about 35°, and cuts across the foliation of the slate. At the outcrop and in the workings above the main tunnel it dips to the southwest at an angle of 50° to 70°, but exhibits some rolls. Throughout the mine workings, which now reach a depth of about 100 feet below sea level and extend for about 600 feet along the vein, the fissure is plainly recognizable, but in places the vein material is represented by only half an inch of gouge. Where mined the lode probably averages from 14 to 30 inches, but it locally widens to about 4 feet. In some places the lead is made up of a single vein of quartz; in others of a network of quartz stringers separated by masses of country rock.

A smaller vein, which has a course about parallel with the main lead and which is about 45 feet distant from it has been opened up on the lower level. The ore seems to be of about the same character as that of the main vein and is said to be of about the same value. There is some evidence that this may be an offshoot from the main vein.

The ore consists of bluish to white vitreous quartz, with inclusions of country rock. The ore contains pyrite in disseminated grains or crystals and some galena. It is free-milling, but gold visible to the naked eye is comparatively rare. Microscopic analysis shows that it carries some albite and some calcite.

The three-stamp mill which had been installed and successfully operated for about a year was burned in 1911. With characteristic energy the management at once began to erect a new mill of five stamps, which was completed and in operation before the end of the year. Meanwhile mining was continued and the ore was shipped to Tacoma.

Several properties along the north shore of the bay east of the Cliff mine have been more or less developed. The most work has been done on the Imperial, about 2 miles east of the Cliff, where an adit tunnel has been driven in at sea level and an air compressor installed. The property was idle at the time of the writer's visit in September, 1911, and the underground workings were not examined. Judging by the direction of the adit, the vein appears to be parallel to that of the Cliff.

Shoup Bay and Columbia Glacier regions.—The Alice claim is located on a well-defined fissure on the north shore of Shoup Bay. This fissure trends about N. 62° W. and dips 70° to 80° S., crosscutting a series of interbedded slates and graywackes. It is traceable across a point to the water's edge, a distance of about 1,100 feet. The foot-wall side is well defined by slickensides and in places the hanging wall also shows similar evidence of movement. Only a little work had been done here at the time of the writer's visit, but the vein seemed to have a thickness of 7 to 22 inches. The vein material, which is heavily iron stained, consists of a mass of brecciated and silicified country rock cemented with pyritiferous quartz and carrying considerable visible free gold.

About half a mile northwest of the Alice claim there is another fissure, which trends about N. 10° W., and dips to the west at an angle of about 70° or 80°. This fissure is traceable from tidewater for over half a mile and its hanging wall side seems to be well defined and slickensided throughout this distance. The vein matter shows a varying composition and thickness, ranging from a few inches of crushed slate with but little quartz or other evidence of mineralization to 12 to 18 inches of quartz and slate fragments carrying pyrite and galena. This vein is said to carry very little gold, but it is reported to contain considerable silver. The Silver Gem claim is staked on the north end of this fissure, where an adit tunnel about 400 feet long has been driven. Some work has also been done by the Shoup Bay Mining Co. at a point more than half a mile to the south.

It is reported that a quartz vein has been found about 500 feet above the sea on the west side of the entrance to Shoup Bay. This vein has been staked as the so-called Blue Bird property. It was not visited by the writer. The vein is said to strike about east and west, parallel to the slate bedrock in which it occurs. It is reported that the lode has been exposed by open cuts for a distance of about 100 feet. The ore is said to carry pyrite, a little pyrrhotite, and free gold. Near at hand also is the Whistler lode, in which the vein material consists of silicified slate fragments and quartz, both carrying pyrite and some free gold.

The Sealy-Davis property, located on the east side of Shoup Bay, was not visited. Here a vein is said to have been opened up by three crosscut tunnels. From the position of these tunnels as seen from a distance, the trend of the vein appears to be northerly, but no measurement was obtained. The Gold Bluff claim, near the east entrance of Shoup Bay, was not visited either.

The Spanish and the I. X. L. claims are located near McAllister Creek, about a mile from tidewater, and lie on the same fissure, which strikes from N. 70° to N. 85° W. Slickensides are found on both walls. The vein so far as exposed is about a foot wide and includes brecciated slate, quartz, and pyrite with, it is said, free gold. The I. X. L. claim joins the Dorothy vein, which strikes about N. 45° W. At their junction a cut shows nearly 3 feet of vein matter, made up chiefly of fragments of country rock, cemented by quartz with much pyrite. Here both walls are well defined.

The Shoup Glacier Co. is developing a vein on what is known as the Palmer claim. It is about a mile from tidewater and is said to be on the same fissure as the I. X. L. A tunnel has been driven for about 100 feet on the vein, which strikes about N. 60° W. and stands nearly vertical. The hanging wall is well defined by a slickenside, but the footwall is not so well marked. The movement has crushed a zone of the country rock from 2½ to about 4½ feet wide. There is a gouge on the hanging wall side. This zone of crushed rock, said to carry free gold, is permeated by quartz stringers that carry pyrite.

The Big Four claim has been staked on a vein outcropping in one of the tributaries of upper McAllister Creek, about 2 miles from the beach. This vein strikes about N. 35° E., dips 70° to the northwest, and crosscuts a slate bedrock. It has clean walls, and in 20 feet varies in width from 1 to 3 feet. The ore is banded, includes pyrite and galena, and is said to carry only a little gold. This vein carries more calcite than is normal for the veins of the district. About 30 feet away there is another vein, striking about east and west, having a width of 1 to 2 feet.

A shear zone in slates, which strikes about N. 40° W., occurs on the divide between the head of McAllister Creek and Shoup Glacier. This zone contains some iron-stained quartz stringers which have been staked as the Alder claim. About a mile to the west are the Hecla No. 1 and Hecla No. 2 claims. They are located on parallel shear zones which trend about N. 40° W. and crosscut a graywacke and slate series. The zone of shattering on Hecla No. 2 is about 7 or 8 feet wide, and includes irregularly distributed masses and stringers of quartz. The quartz carries pyrite, some arsenopyrite, and galena. It is reported that the same shear zone has been recognized on the mountain about half a mile away from the cut, and that it is there 10 to 15 feet wide. The vein material is said to carry some gold and higher values in silver.

The Ford & Thomson Mining Co. is reported to have done work on a group of claims located near the Gold Creek divide about a mile from Shoup Glacier. A quartz vein 18 to 36 inches wide is said to have been traced over 100 feet on the Silver Falls claims. This vein strikes about N. 60° W. and stands about vertical. The quartz is well crystallized and carries pyrite, galena, and free gold.

The Hogan property, belonging to the Mayfield Mining Co., is located near the Columbia Glacier, about 6 miles from Shoup Bay and 8 miles from Columbia Bay. It was not visited, but the vein is said to strike about east and west, to have been traced about 1,000 feet, and to be from 4 to 8 feet wide. An offshoot trending northwest goes out from the main vein. Developments in September, 1911, consisted of a tunnel about 50 feet long, intersecting the vein 55 feet below the outcrop. The ore is an iron-stained, well-crystallized quartz with much pyrite and is said to carry high gold values.

Gold Creek.—Gold Creek was not examined nor was any information obtained about the prospects on it. A trail has been built up to the lower basin of the creek, where a hydraulic plant for placer mining was being installed during the summer of 1911.

Mineral Creek.—The Buster, Sunshine, and Hercules claims are located on the west slope of Mineral Creek valley 2,800 to 3,400 feet above the sea and about 8 miles from tidewater. They can be reached by a horse trail from Mineral Creek. At the Buster claim about 18 inches of quartz which strikes about N. 50° E. is exposed on the surface. The Sunshine vein has been developed by a 25-foot tunnel in which a vein 2 inches to 1 foot in thickness is exposed. This vein varies in trend from about N. 60° E. to east-west. The ore reported to carry some free gold is pyrite and galena, with a white quartz gangue. The Hercules vein outcrops for about 50 to 70 feet, with a width of 18 to 30 inches. It strikes about N. 80° E. and dips 70° N. High free gold values are reported in this vein.

The Big Four claim is located near the divide at the head of Brevier Creek, a western tributary of Mineral Creek. The vein outcrops on a steep talus slope broken by small cliffs at an altitude of over 5,000 feet above the sea and only about 200 feet below the crest line of the ridge. Its trend varies from N. 55° to 80° E., and it dips 70° to 80° N. Its width varies from about 1 to 3 feet, but in places it swells out to 5 feet. The vein can be traced on the surface for about 200 feet, but is offset by several faults whose trend is N. 10° E. In two places the vein is entirely cut out by faulting. It is made up of iron-stained vitreous crystallized quartz and said to carry considerable gold.

The Millionaire claim is also located on upper Mineral Creek, almost a mile north of the Buster. It is an irregular quartz vein from about 4 to 24 inches wide, which is said to carry much gold. It strikes about east and west and dips 70° to 80° N. The country rock is slate and graywacke, striking about N. 70° E. and dipping 60° N.

The Monte Carlo claim is about half a mile north of the Millionaire. It is staked on an irregular body of quartz, which branches in several directions. What seems to be the main lead strikes N. 50° W., but another shoot trends N. 50° E. This lode can be traced only about 50 feet, but in places is 8 to 9 feet wide. The vein matter is iron-stained quartz and includes some druses showing well-developed crystals. Pyrite is disseminated through this ore, which also carries some galena. It is said that specimens taken from surface cropping of the vein carry considerable gold.

A 30-foot tunnel has been driven on the Mineral King claim on the south side of Brevier Creek, about one-quarter of a mile above its mouth. A quartz vein about a foot wide outcrops here. It strikes about N. 40° W., and stands about vertical. About half a mile north of this is the Chesna claim. Here a 3 to 4 foot quartz vein outcrops, which pinches down to a foot in the tunnel and finally, at a distance of 50 feet, can no longer be recognized as a distinct vein. Beyond this point the tunnel penetrates a zone in which a stockwork of quartz stringers occurs in the slate country rock. This stockwork has a well-defined wall on the south but on the north has no definite boundaries. These lodes strike nearly east and west. Just south of the tunnel a network of veins is exposed in the creek bed. Some specimens from the quartz at the entrance of the tunnel and from the network of veins are said to have yielded high values in gold.

The Mountain View claim is on the east slope of the Mineral Creek valley at an altitude of about 2,000 feet and just opposite the mouth of Brevier Creek. Here there is a quartz vein east and west trending and dipping about 70° to 80° N. At its point of discovery it has a width of about 3 feet, of which 1½ feet, next the hanging wall, consists of massive iron-stained quartz with some slate fragments. The balance of the lode is made up of slate fragments with, however, a large amount of vein quartz. A tunnel intersects the vein at a depth of 30 feet, where its widest part is about 30 inches thick. In driving the tunnel the lode was lost, but later a small vein, which may be the main lead or may be a stringer, was found in a crosscut. The vein material is quartz, accompanied by some feldspar and carbonaceous matter and much yellow pyrite. It is reported that the gold content of the vein at the outcrop is much higher than in the vein in the tunnel.

There is a shear zone in the slate graywacke series on the east side of Mineral Creek about a mile above the roadhouse. This zone, which strikes about N. 65° E., is 2 to 2½ feet wide. Within the crushed zone are a number of quartz veins, the largest of which is 3 inches in thickness. These veins, as well as the crushed rock, are iron stained. The Gold Sunlight claim has been staked at this locality. A similar zone was observed on what is known as the Oleson & Woods property in a series of slates at an altitude of about 2,000 feet above the sea and about a mile southeast of the roadhouse. This zone trends about N. 25° W., and dips 70° E., and has been permeated by iron-stained quartz veins, the largest about 1 foot thick. It is reported that a quartz vein 2 to 3 feet wide has been staked near this locality as the Golden Dollar claim. This claim was not visited by the writer.

A claim, known as the McIntosh property, has been staked on the west side of Mineral Creek, nearly opposite the roadhouse. At this locality there is an irregular shear zone, which traverses some graywacke, trending as near as can be determined about N. 70° W. This zone includes from 1 to 3 feet of shattered rock and some quartz veins. This lode has no well-defined walls.

The Valdez Bonanza claim is located close to the divide between Mineral Creek and the Valdez Glacier. It lies at an altitude of about 4,350 feet, and is about 3¼ miles due east of the Mineral Creek roadhouse, from which point it can be reached by a horse trail. The ore body, which outcrops as an irregularly shaped mass in a cliff, is from 2 to 5 feet thick and is traceable for about 50 feet. Its strike varies from east and west to N. 75° E., and is about parallel to the cleavage of the slate that forms the country rock. A tunnel has been driven for about 100 feet just below the outcrop of the vein. In this tunnel the vein first shows a thickness of 18 to 24 inches, and then narrows down to 2 inches of ribbon quartz, which finally also disappears. The footwall is well defined by a slickenside and continues beyond the point where the quartz has pinched out. A crosscut revealed another large body of quartz, which carries some iron pyrite but is said not to contain much gold.

The Blue Ribbon claim is about a mile northwest of the Bonanza, where an east and west quartz vein, which is parallel to the foliation of the associated slates, has been traced about 1,000 feet. At the west end the quartz filling appears to pinch out, but the fissure is continuous. At the widest place seen it included about 8 inches of ribbon quartz, said to carry considerable free gold, and 4 to 6 inches of white quartz, which carries pyrite but no free gold.

The William Genzler prospect is located on the north slope of the East Fork of Mineral Creek at an altitude of about 4,000 feet. It was not visited, but the vein is said to be from 18 to 24 inches wide, to have good walls, and to carry considerable gold.

Valdez Glacier region.—The Valdez Mining Co. owns a group of claims on the west side of Valdez Glacier about 8 miles from tidewater, at an altitude of about 2,700 feet. It can be reached from Valdez by a horse trail which traverses the glacier for some distance. The country rock consists of interbedded schistose graywacke and slate, which strike about N. 75° E. and dip about 75° N. The vein, which at the outcrop is about 5 to 6 feet wide, strikes about N. 60° W.

and dips 70° S. An adit, which reaches the vein at a depth of about 60 feet, has been driven 110 feet. A winze has been sunk 50 feet below this level, at which depth a drift has been run on the vein for some 40 feet. The vein at this depth is well defined, having good walls and a gouge on the hanging wall. The vein is from 3 to 8 feet wide in the underground workings. It is made up of ribbon quartz, which carries the gold in high values and measures from 2 to 4 feet in thickness, and of massive white quartz. On the lower level the ribbon quartz is from 24 to 50 inches wide. The white quartz also carries some gold. The ribbon quartz includes coarse pyrite masses and crystals. The vein includes druses containing well-developed quartz crystals. Another adit, which has been driven about 115 feet, is intended to crosscut the vein at a depth of 330 feet in a distance of 300 to 325 feet. The Ibex group of claims lies about one-fourth mile northwest of the Valdez tunnel, where a 4-foot vein outcrops at an altitude of about 2,600 feet. Both walls of this vein are well defined. Banded quartz in this vein is said to carry gold in high values. A tunnel has been driven about 200 feet, but the vein was lost at a distance of 100 feet. The Ibex vein is believed to lie on an extension of the Valdez.

A number of other claims have been staked in the region adjacent to Valdez Glacier, some of them east of the glacier. There was no opportunity to examine any of these claims.

COMMERCIAL CONDITIONS.

Valdez, a town of 700 or 800 people, is about 1,230 nautical miles from Seattle. Two steamship lines maintain a service of six trips a month between Valdez and Seattle, the voyage usually taking about five days. Valdez is the coast terminal of the military road to Fairbanks, and until the Copper River Railroad was completed most of the inland travel was by this route. Valdez is connected by cable with other Alaska ports and with Seattle, and by telegraph line with points in the interior. The town is well built, has wharves, banks, a number of hotels, good stores, and telephone and electric-light service. It is the headquarters of the Alaska Road Commission and of the Copper River section of the military telegraphic service. Fort Liscum, an Army post, is on the south side of the bay, where there is also a wharf. The only other wharves on the bay are one near the mouth of Mineral Creek, where there is a small settlement, and one at the Cliff mine. A road and trail lead up Mineral Creek for a distance of about 8 miles. At low tide, wagons can be driven from Valdez to the mouth of Mineral Creek. There is a new trail part way up Gold Creek. Aside from these, there are only a few foot trails in the entire district. Travel along the coast is easy by gasoline launches, of which there are a number at Valdez.

The town affords a good outfitting point for work in the district. Provisions and supplies are not high, except coal, most of which is brought from Vancouver Island and sells at $12 to $16 a ton. The district contains some trees which can be used for mine timber and rough lumber, but most of the good lumber is brought from Seattle.

The strong relief and steep slopes favor the opening of lodes by crosscut tunnels. The heaviest item of expense is usually the transportation of supplies and equipment from tidewater to the place of utilization.

SUMMARY AND CONCLUSIONS.

The bedrock of the region is made up of closely folded and faulted slate and graywacke and a little greenstone schist, with, so far as known, only a few igneous dikes. Auriferous quartz veins constitute the important known mineral deposits of the district. Part of those developed follow well-marked fissures, which can be traced for considerable distances. In parts of the district there are two systems of fissures. There is no reason to suppose that these fissures will exhibit any greater irregularity at depth than they do along the surface. Although many of the fissures are traceable for considerable distances, the vein filling of some of them locally pinches out completely, in some fissures to reappear farther along on the strike.

The principal metallic minerals of the veins are pyrite (locally auriferous), free gold, argentiferous galena, and in a few localities pyrrhotite, chalcopyrite, and arsenopyrite. Quartz is the chief gangue mineral and in many veins appears in more or less crystalline form. Calcite occurs sparingly in most of the lodes, and in a few constitutes a considerable proportion of the vein matter. Feldspar, chiefly albite, was observed in several veins. Where veins cut carbonaceous rocks, graphite is found in the gangue.

Many of the ore bodies that have been opened up are zones of brecciation along fault lines, which have been permeated by quartz and pyrite. In these the fragments of country rock are usually more or less recrystallized. The country rock and ores are similar to those of the Sitka district.[1]

There is no reason to believe that the gold content of the pyritiferous quartz veins will show any greater variation at a considerable depth than it does at a moderate depth, but in many places the weathered outcrop shows marked surface enrichment. Assays of samples of quartz veins from surface outcrops, even if carefully taken, are likely to be very misleading. Many samples taken from outcrops show a gold content of $100 or more to the ton, whereas samples taken 10 or 20 feet below the surface at the same places contain less than $10 in gold to the ton.

[1] Knopf, Adolph, The Sitka mining district: Bull. U. S. Geol. Survey No. 504, 1912.

The most encouraging feature of the district is, of course, the fact that one lode has been profitably mined to a depth of about 400 feet and for about 500 feet along the strike. So far as can be seen there are no geologic conditions at the Cliff mine which are not found elsewhere in the region. Although, as in all mining camps, much the larger number of the claims staked give little promise of developing into mines, yet there a number show results that fully justify further exploitation. The facts at hand indicate that it will be a district of small rich veins rather than of large low-grade deposits. Some larger deposits of low grade, which were not visited, are, however, reported to occur on the south side of the bay.

The geographic limits of auriferous mineralization, as indicated by discovery of gold-bearing veins, seem to be determined by accessibility rather than by geologic conditions, and no evidence in hand indicates that the ore bodies are limited to the particular district in which they have thus far been found. The outlook for further discoveries is therefore good and is made more hopeful by the fact that auriferous quartz has been found on the east, along the Fairbanks road near Beaver Dam, and on the west, near Port Wells.

On the whole, the commercial conditions in the district are favorable to economic development. The prices for most commodities except coal are reasonable. Much of the district is readily accessible from tidewater and most of it could be rendered accessible by roads and trails at no great cost. Economies could be introduced in mining by making available the water powers which are not now being utilized.

GOLD DEPOSITS OF THE SEWARD-SUNRISE REGION, KENAI PENINSULA.

By Bertrand L. Johnson.

INTRODUCTION.

The following paper is a preliminary report on the main features of the distribution and occurrence of gold-bearing lodes and placers in the northern part of Kenai Peninsula and the adjoining Crow Creek district. The discussion of the mineral resources is preceded by a short résumé of the principal factors bearing on their economic development. A more complete report on the mineral resources of this region is in preparation. Many of the data on which this report is based were obtained by the writer during an examination of the lode and placer prospects of the region in the summer of 1911, but free use has been made of field notes and reports of others.

The mineral resources of this district were first examined by the Geological Survey in 1895, when Becker[1] visited the placers near Hope, then recently discovered. Early in 1898 Mendenhall[2] made a hasty examination of the Mills, Canyon, and Sixmile creek placers. Six years later, in 1904, a more detailed examination of the mineral resources of the northern part of the peninsula was made by Moffit,[3] who gave particular attention to the gold placers, then the only source of gold in the district. In the fall of 1906 Paige and Knopf[4] visited the placers of Crow, Canyon, and Sixmile creeks and the East Fork. Grant and Higgins[5] have briefly described the gold lodes which were visited by them in 1908 and 1909, and Brooks[6] has made numerous summary notes on the mining industry of the region. In the work of the last season special attention was

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[1] Becker, George F., Reconnaissance of the gold fields of southern Alaska, with some notes on general geology: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, pp. 1–86.

[2] Mendenhall, W. C., A reconnaissance from Resurrection Bay to the Tanana River, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 265–340.

[3] Moffit, F. H., The gold placers of Turnagain Arm: Bull. U. S. Geol. Survey No. 259, 1905, pp. 90–99; Gold fields of the Turnagain Arm region, in Mineral resources of Kenai Peninsula, Alaska: Bull. U. S. Geol. Survey No. 277, 1906, pp. 7–52.

[4] Paige, Sidney, and Knopf, Adolph, Reconnaissance in the Matanuska and Talkeetna basins, with notes on the placers of the adjacent region: Bull. U. S. Geol. Survey No. 314, 1907, pp. 104–125.

[5] Grant, U. S., and Higgins, D. F., jr., Notes on the geology and mineral prospects in the vicinity of Seward, Kenai Peninsula, Alaska: Bull. U. S. Geol. Survey No. 379, 1909, pp. 98–107; Preliminary report on the mineral resources of the southern part of Kenai Peninsula, Alaska: Bull. U. S. Geol. Survey No. 277, 1906, pp. 7–52.

[6] Brooks, Alfred H., Bulls. U. S. Geol. Survey Nos. 284, 314, 345, 379, 442, and 480.

given to the deposits of gold quartz, which have become increasingly important during recent years. The writer wishes to acknowledge the many courtesies shown him and the data furnished during the progress of the investigation by persons interested in the development of the mineral resources of the region.

GENERAL FEATURES OF THE REGION.

GEOGRAPHY.

Kenai Peninsula, which has an area of about 9,000 square miles, lies in the northern portion of the great southward-facing bend of that part of the Pacific coast line which incloses the Gulf of Alaska. Most of the peninsula lies between meridians 148° and 152° west longitude and parallels 59° and 61° north latitude. The bounding waters are Prince William Sound, the Pacific Ocean, Cook Inlet, and Turnagain Arm. (See Pl. VII.)

The surface of the peninsula exhibits two widely different physiographic features. Mountains 5,000 to 7,000 feet high and valleys deeply cut by glacial action, remnants of the former ice sheet still remaining in the higher parts of the range, occupy the eastern, central, and southern parts of the region, covering approximately three-fourths of its area. The remaining fourth consists of a broad lowland, 25 miles wide, extending along the entire western side of the peninsula from Kachemak Bay to Turnagain Arm. The gold quartz lodes are restricted to the mountainous area, as are most of the placers, although beach placers occur at Anchor Point, on Cook Inlet, and auriferous gravels are reported to occur on the lower Kenai River.

The watershed between the Cook Inlet drainage and that of the Pacific Ocean and Prince William Sound lies close to the southeastern side of the peninsula, so that most of the drainage of the peninsula enters Cook Inlet or Turnagain Arm. Kenai River, discharging into Cook Inlet at Kenai, is the largest stream on the peninsula and drains its entire central portion, including lakes Skilak and Kenai. Kasilof River, which flows into Cook Inlet a short distance south of Kenai, drains Lake Tustumena, the largest body of fresh water on the peninsula. Lakes Skilak and Tustumena lie on the borderland between the Kenai Mountains and the Kenai lowland. Two smaller streams, Chickaloon and Big Indian rivers, drain a portion of the Kenai lowland and discharge into Chickaloon Bay near the west end of Turnagain Arm. The principal streams tributary to Turnagain Arm within the mountainous area are Placer, Portage, and Twentymile rivers and Resurrection, Sixmile, and Glacier creeks. The streams of the Pacific and Prince William Sound slopes are short, none of them, except Resurrection River, being over 15 miles in length. The discharge of most of the streams varies greatly in different seasons of the year because they derive a considerable part

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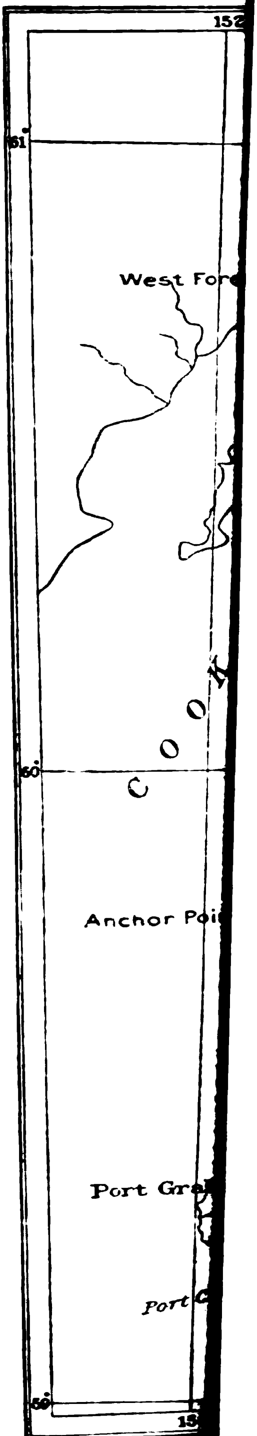

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of their waters from glaciers and melting snows. In the mountainous area the steep gradients of many of the streams and the numerous waterfalls offer possible sources of power for use in mining.

CLIMATE.

The following table affords a means of comparing the climatic conditions on the north and south sides of the peninsula. The data were obtained from the annual reports of Alaska agricultural experiment stations for 1908, 1909, and 1910. The observations at Seward were made by W. A. McNeiley; those at Sunrise by A. Lawson. The climatic conditions at these two places are obviously somewhat different, the Turnagain Arm section having much colder winters and considerably less rainfall, although the number of days with precipitation is slightly greater. Both the recording stations are only a few feet above sea level. In the interior of the peninsula, where the elevation is considerable, the winters are much more severe.

TABLE I.—*Summary of meteorologic records at Seward and Sunrise, Alaska.*

Month.	Temperature (°F.).						Precipitation in inches.		Weather conditions.			
	Maximum.		Minimum.		Daily mean.				Clear days.		Days with precipitation.	
	Seward.	Sunrise.	Seward.	Sunrise.	Seward.	Sunrise.	Seward.	Sunrise.	Seward.	Sunrise.	Seward.	Sunrise.
1908.												
February	42	42	9	−8	30.56	23.96	10.43	4.68	8	11	16	12
March	45	40	15	−2	32.14	24.01	2.35	2.00	14	12	9	12
April	53	51	23	16	38.01	32.29	4.00	3.37	12	6	16	14
May	65	66	32	27	44.51	42.87	1.63	2.63	14	9	12	12
June	80	79	36	30	50.98	50.29	.45	.21	15	15	5	5
July	73	70	41	36	51.80	52.49	3.25	2.28	12	7	13	12
August	71	70	41	35	52.77	50.86	6.34	2.91	10	5	16	21
September	65	60	27	17	45.81	40.71	4.29	5.00	13	10	9	16
October	51	53	11	2	34.96	29.24	9.73	2.59	17	16	11	14
November	49	48	11	−7	33.40	27.89	[b]20.99	4.49	9	4	19	20
December	41	42	−1	−13	29.20	23.50	12.38	3.37	9	9	18	16
1909.												
January	43	29	−5	−25	13.88	−1.01	.52	.54	24	22	4	6
February	44	39	2	−17	22.20	10.60	.47	1.05	18	14	2	9
March	49	49	10	−9	31.20	24.90	3.72	2.71	14	8	12	16
April	54	51	18	11	36.50	33.10	3.03	.68	16	13	8	8
May	73	68	32	26	43.30	43.56	4.47	2.27	12	13	15	13
June	84	78	35	28	48.80	48.10	4.39	1.96	15	10	12	13
July	77	73	43	39	55.10	54.50	.72	1.79	12	11	6	13
August	75	70	40	35	55.00	52.54	3.71	3.06	15	8	14	17
September	[a]60	61	[a]45	17	[a]50.10	42.50	[a]1.41	2.64	([a])	9	[a]6	18
October	50	45	22	10	37.20	29.90	8.92	2.56	17	12	12	15
November	48	42	9	−14	27.7	13.6	.37	.40	25	21	2	5
December	40	43	4	−12	25.9	15.8	12.80	3.36	12	10	15	18
1910.												
January	37	36	−8	−21	18.8	7.9	3.32	3.22	17	5	9	18
February	39	38	−12	−27	24.4	15.2	4.52	4.39	13	8	8	11
March	49	50	......	−16	29.2	22.5	2.50	1.66	16	8	8	16
April	53	50	10	1	34.2	28.4	.55	1.55	20	6	4	11
May	75	73	26	24	43.6	41.7	1.43	.86	17	9	7	10
June	63	63	33	27	46.0	[c]26.4	2.59	1.44	15	7	11	15
July	80	73	40	37	55.1	52.7	2.15	1.79	18	9	8	14
August	76	68	39	35	55.1	51.1	2.45	1.74	18	10	8	12
September	84	72	35	26	51.4	45.2	7.12	2.80	14	11	14	15
October	55	53	19	8	30.2	33.4	5.72	4.34	10	3	15	20
November	45	40	12	−8	30.1	19.9	1.55	2.29	14	13	1	11
December	......	36	......	−26	......	9.2	......	4.06	......	15	......	15

[a] Record for 6 days only. [b] Accuracy of this figure questioned. [c] Probably intended for 46.2.

Records were also kept at Kenai for several years, the extreme temperatures for 4 complete years and additional periods aggregating 12 months being given in the following table. The annual precipitation at this place ranges from 13.50 to 18.53 inches, being considerably less than at either Seward or Sunrise.

TABLE II.—*Summary of temperatures (°F.) at Kenai, Alaska.*

[Lengths of record, 4 complete years, 12 months.]

Month.	Maximum.	Minimum.	Months.	Maximum.	Minimum.
January	45	−40	July	82	30
February	45	−32	August	73	28
March	52	−30	September	65	16
April	58	4	October	60	−10
May	63	20	November	44	−26
June	79	26	December	45	−43

TIMBER AND VEGETATION.

Kenai Peninusla, which is heavily timbered from sea level to elevations of 1,200 to 2,000 feet, is in large part included in the Chugach National Forest. The conifers are far more abundant than the broadleaf deciduous trees, spruce predominating, although considerable hemlock grows in the Turnagain Arm region. Cottonwood, willow, poplar, birch, and alder are the principal deciduous trees. Commercial timber is reported only on Turnagain Arm and in the vicinity of Seward, but lumber adequate for many uses can be obtained at reasonable cost near most of the camps. Spruce is the best timber available for use in mining. Spruce timber from this region was tested for use in bridges on the Alaska Central Railway, and although the results obtained were not quite so good as those afforded by Washington fir, the spruce was made satisfactory by using slightly larger timbers than would have been used with fir, in order to offset the difference in the strength of the two kinds of lumber. Some scattered spruce trees near the lower end of Kenai Lake will trim to 12 inches square, but only a few will afford 18-inch pieces. Larger trees and better stands grow in the Seward and Turnagain Arm regions. The hemlock found in the Turnagain Arm region is reported to be unfit to withstand much strain. Sawmills have been erected at Seward, Hope, and Girdwood. In Seward the price of the native spruce dimension lumber in 1911 was about $25 per 1,000 feet. The better grades of lumber are brought from Seattle.

Native grasses are abundant, especially around timber line and in the upper timberless parts of the valleys, furnishing good feed for horses during the summer. Considerable hay is now being made in the peninsula, especially in the vicinity of Hope and Sunrise. Native hay in stacks in the Sunrise country brings from $10 to $12 a ton, occasionally late in the winter going as high as $20 a ton. Near Seward, Sunrise, and Hope, where conditions are the most favorable for gardening, vegetables are raised in considerable quantities for local consumption. Cranberries, currants, blueberries, huckleberries, and a few salmonberries grow wild. An experiment station was established by the United States Department of Agriculture at Kenai in 1899 and maintained until 1908, when, on account of the isolation of the location, the work was transferred to Kodiak.

GAME.

Kenai Peninsula is well and favorably known as a big-game country. Both brown and black bear are native to the peninsula, the black bear being by far the most abundant. Fur-bearing animals other than bear include lynx, ermine, some mink, and a very few marten. Land and sea otters are found around Turnagain Arm. Foxes are scarce, wolverines are only occasionally seen, beavers are very rare, and wolves are practically extinct. Ground squirrels are fairly numerous and rabbits are beginning to reappear. Porcupines are abundant and form an easily obtainable food for the numerous dogs.

Moose are abundant in the central and western parts of the peninsula. Mountain sheep are numerous, but mountain goats are rare. Caribou are very scarce. Grouse, ptarmigan, and shore birds, as well as waterfowl, such as ducks, geese, brant, swan, snipe, and curlew, are found in most parts of the peninsula. Trout are found in many of the mountain streams, and lake trout, whitefish, and a few grayling are reported in the large lakes. In summer salmon in great numbers run up most of the streams that flow into Resurrection Bay and Cook Inlet.

POPULATION AND SETTLEMENTS.

The census of 1910 gives the population of the Kenai Peninsula as 1,692. The principal towns were Seward, 534 inhabitants; Kenai, 250 inhabitants; and Seldovia, 173 inhabitants. The population of this region, as of other parts of Alaska, fluctuates greatly during the year, being at its maximum during the summer. As the census of 1910 was taken in winter, the above figures represent probably the least number of people on the peninsula at any time during the year.

Seward is the principal distributing point for this region. Situated at the head of Resurrection Bay, it has an excellent harbor, is the terminus of the steamship lines to the States and to the Alaska Peninsula, and the coastal terminus of the Alaska Northern Railway. Seldovia is of considerable importance at present in any economic discussion of this district, as it is the transfer point of supplies from the large steamers to the numerous smaller boats (60 to 70 tons) running on the inlet for transportation to points on Cook Inlet, Turnagain Arm, and Susitna River. Sunrise and Hope, at the mouths of Sixmile and Resurrection creeks, respectively, and Girdwood, at the mouth of Glacier Creek, are small settlements, important as distributing points for the placer and lode diggings in their vicinity. The population of these places is small, Sunrise having but 12 inhabitants in September, 1911, and Hope only 35 or 40 in the winter of 1910–11. Kern Creek, the present terminus of the Alaska Northern Railway, is a transfer point of supplies from Seward to Turnagain Arm points and Knik.

TRANSPORTATION.

WATER TRANSPORTATION.

Steamships of the Alaska Coast Co. and the Alaska Steamship Co. run regularly between Seattle and Seward throughout the year, for navigation in Resurrection Bay is never interrupted by ice. Water transportation on Cook Inlet, however, is possible only during a part of the year, for ice prevents navigation on the upper part of the inlet for about five months. During the summer of 1912 the western terminus of the Alaska Coast Co. will be at Kodiak and the steamers of this company will make several trips to Knik Anchorage, serving upper Cook Inlet points directly or by barge from Knik Anchorage instead of making the transfer of passengers and freight, as formerly, at Seldovia and Port Graham to the smaller boats plying on the inlet. The larger boats can not enter Turnagain Arm, however, and small gasoline boats, of 80 to 100 tons, which can reach the various settlements at high tide, will still have to be used between Kern Creek, Girdwood, Sunrise, and Hope and the ocean-steamer terminus in Knik Anchorage.

The Alaska Northern Railway offers a possible freight route from Seward to Turnagain Arm, but because of the high freight rates charged by the railroad most of the freight from Seattle to points on Turnagain Arm has come by water, by way of Seldovia and Cook Inlet, a rate of $8 a ton being the usual charge between Seldovia and Sunrise, Hope, or Girdwood. Water transportation on the peninsula is restricted at present to Kenai Lake, where several small gasoline launches were in operation last summer. This lake is reported to freeze over about January 1 and to open up late in May.

LAND TRANSPORTATION.

The Alaska Northern Railway Co. has built 71 miles of standard-gage track from Seward to Kern Creek, near the head of Turnagain Arm. This line was in operation in 1911, gasoline passenger cars being run almost every day during the summer. The passenger rates in 1911 were 20 cents a mile, or 15 cents a mile on round-trip tickets. Freight trains were run only occasionally. The service was maintained on this line only during the summer and fall.

Wagon roads have been built from Sunrise to Mile 34 on the Alaska Northern Railway, from Hope for several miles up Resurrection Creek, and from Girdwood to the Nutter-Dawson placer camp on Crow Creek. Roads have also been built from the mouths of Bear and Lynx Creeks to prospects near the heads. The Alaska Road Commission has cut good trails from Hope to Sunrise and from Mile 29 on the Alaska Northern Railway through Moose Pass to Slate Creek. During the summer of 1911 the commission finished the portion of the Seward-Iditarod trail between Kern Creek and Knik, by way of Crow Creek Pass and Eagle River. A trail has also been laid out down Canyon Creek from Moose Pass to the Sunrise road.

Most people living away from the towns in the winter use their own dog teams for transportation of supplies. In the summer pack trains are run at irregular intervals from Mile 34 on the Alaska Northern Railway to Hope and Sunrise and from Mile 29 through Moose Pass to Mills Creek. The following rates, averaging approximately $0.0025 per pound per mile, were charged in 1911:

Freighting charges in Seward-Sunrise region.

	Cents per pound.
Sunrise to Hope	2½
Sunrise to Gulch Creek	2
Sunrise to Lynx Creek	4 and 5
Sunrise to Mile 34, Alaska Northern Railway	7
Gulch Creek to Mile 34, Alaska Northern Railway	5 and 6
Mile 29, Alaska Northern Railway, to Mills Creek	5

MAIL SERVICE.

Mail from the outside arrives in Seward about six times a month throughout the year. From December 1 to March 31 mail for Sunrise and Hope is carried overland twice a month, usually through Johnson Pass, but in exceptionally bad weather by way of Moose Pass. From April 15 to October 31 mail for settlements on Cook Inlet and Turnagain Arm goes to Seldovia, whence it is forwarded by small gasoline boats. During the early spring the mail deliveries at points on Turnagain Arm are infrequent on account of the poor transportation facilities.

POWER RESOURCES.

The possible sources of power for use in mining in this region are the abundant timber below 2,000 feet elevation, the steep gradient and numerous falls of many of the streams, the lignite of the Cook Inlet region, and the higher-grade coals of the Matanuska Valley.

Few power plants were in operation in 1911 in the Seward-Sunrise region. The Kenai Alaska Gold Co.'s stamp mill on Falls Creek was operated by a small steam engine with a wood-burning boiler. The California-Alaska Mining Co.'s stamp mill was run by water power furnished by a Pelton water wheel. The town of Seward was furnished with electric light and power throughout the year by a 225-kilowatt Allis-Chalmers (Bullock) alternating-current generator, driven by a Pelton water wheel operating under an effective head of 360 feet. The coal resources of this region are at present unavailable. British Columbia coal (Nanaimo coal), which alone is used, costs at Seward about $10 to $12 a ton wholesale and about $17 a ton retail.

GENERAL GEOLOGY.

SEDIMENTARY ROCKS.

The sedimentary rocks of the Seward-Sunrise region consist principally of interbedded dark-colored graywackes and black or bluish-black slates and argillites, with a few interstratified beds of conglomerate and quartzite and still fewer beds of dark-gray limestone. The thickness of the slate and graywacke beds varies from a few inches to many feet. The relative proportions of the slates, argillites, graywackes, and conglomerates differ considerably from place to place, conglomerates being the least abundant. The slates and argillites need no particular description. The graywackes are massive sedimentary rocks, composed chiefly of angular fragments of quartz and feldspar, usually orthoclase and acidic plagioclase. Flat angular fragments of slaty rock appear in many of the beds. Because of their uniform width and longitudinal extent these graywacke beds are often called "dikes" by prospectors. In local usage they are also often referred to as diorites, but the sedimentary origin is in most places readily discernible. The conglomerates contain well-rounded pebbles of argillaceous rocks, granite, quartzites, and quartz.

The general strike of the rocks on the peninsula is from north to N. 20° E., but north of Turnagain Arm more easterly strikes prevail. The dips are generally not far from vertical. In places the rocks show close folds, most of which have vertical axes, though in one place folds overturned toward the west were seen. The finer-grained sedimentary beds exhibit varying degrees of metamorphism, resulting in the development of slaty cleavage or schistose structure, in many places parallel to the stratification. Faults are numerous, but the uniform lithologic character of the rocks makes it difficult to determine the extent of the displacement.

This slate-graywacke series, called the Sunrise series by Mendenhall, forms the mass of the Kenai Mountains in central and northern Kenai

Peninsula and between Knik and Turnagain arms, and also extends along the coast from Prince William Sound to the west side of Nuka Island Passage. Considerable doubt exists as to its age. The evidence available indicates that it includes at least two formations, which are unconformable but similar in lithologic character, the younger containing fossils of Jurassic or Cretaceous age.

The unconsolidated sediments of the district are of interest because they are in places auriferous. These deposits may be classed as glacial and water-laid. Purely glacial deposits, such as moraines, are comparatively rare. Terminal moraines have been found only on Crow and Canyon creeks, but ground-morainal deposits have been seen on several creeks. Valley trains are still being formed on Placer and Snow rivers and on other streams, and remnants of earlier valley trains can be seen in the high-bench deposits along many of the streams. In numerous valleys where no glacier exists the streams have cut down through these fluvioglacial gravels and have deposited 2 to 10 feet of sands, gravels, and clays, usually poorly stratified, on top of bedrock or earlier gravels.

IGNEOUS ROCKS.

DEEP-SEATED INTRUSIVE ROCKS.

Several isolated masses of granitoid rocks, most of them coarse-grained biotite granites, are intrusive into the sedimentary rocks of the Kenai Mountains, especially in the eastern and southern parts. A large granite area, which extends from Hive and Rugged islands, in Resurrection Bay, to and beyond Aialik Bay, makes up all the adjacent islands and much of the headland on both sides of the southern half of the bay.[1] Another large granite mass forms Pye Islands and the adjacent mainland, and prospectors report a granite area in the vicinity of Russian River and Lake Skilak. At the head of Crow Creek several small, closely grouped bosses of fine-grained light-colored quartz diorite have intruded sediments of Jurassic or possibly Cretaceous age. Grant,[2] in his discussion of the igneous rocks of the Prince William Sound region, describes in detail the granites of the eastern portion of the peninsula—on Port Nellie Juan, Passage Canal, Ewan, and Eshamy bays—and concludes that "the lack of intense anamorphic changes and the occurrence of porphyritic peripheral phases of the granites, as well as the absence of the complicated aplite and pegmatite dike systems characteristic of deep-seated intrusions, indicate that these granites solidified considerably nearer the surface than is common with granitic intrusions." The

[1] Grant, U. S., and Higgins, D. F., Preliminary report on the mineral resources of the southern part of the Kenai Peninsula: Bull. U. S. Geol. Survey No. 442, 1910, p. 167.

[2] Grant, U. S., and Higgins, D. F., Reconnaissance of the mineral resources of Prince William Sound, Alaska: Bull. U. S. Geol. Survey No. 443, 1910, pp. 33–48.

only evidence available as to the age of the intrusions is that furnished by the Crow Creek locality, which places them in the middle or later part of the Mesozoic.

DIKE ROCKS.

On Crow Creek numerous light-colored acidic dike rocks of fine-grained to aphanitic texture occur as offshoots from the quartz diorite bosses, to which they are similar in composition. Similar acidic dike rocks, dioritic in composition, many of them of porphyritic texture, occur in different parts of the peninsula, as on Palmer, Bear, Porcupine, and Groundhog creeks and in the Moose Pass district. Along the shores of Turnagain Arm these dikes are easily distinguished by their light color from the dark-gray colored graywackes and black slates into which they are intruded. The dikes of Moose Pass and Palmer Creek are rather remarkable for their length and comparatively slight width. The largest, the so-called Moose Pass ledge, is a dike of much-altered, very fine-grained diorite porphyry, over 12 miles long and averaging only 8 feet wide. Knopf,[1] in describing somewhat similar dikes in southeastern Alaska, has pointed out their occurrence in a graywacke-slate formation far from known areas of diorite intrusions and their uniformity of appearance in widely separated localities. This is also true of the region under consideration, where, except in the Crow Creek section, the acidic dikes are found many miles from the nearest diorite masses and throughout the area show little variation either in their mineralogy or their texture.

ECONOMIC GEOLOGY.

GENERAL FEATURES.

Only the gold deposits are described in this report. The region contains deposits of copper, antimony, and argentiferous galena, but these are small and are of little present commercial importance, and have already been briefly described in earlier reports.

The gold produced in the district comes from both lode and placer deposits. The placers have attracted the most attention and they still lead in production, but the increasing activity of the quartz prospector and the increasing list of producing properties is steadily emphasizing the importance of the gold-quartz deposits.

Gold was first discovered in Alaska in 1848, in the gravels of streams tributary to Kenai River, by P. P. Doroschin, who was then making an examination of the mineral resources of the district for

[1] Knopf, Adolph, The Sitka mining district, Alaska: Bull. U. S. Geol. Survey No. 504, 1912, p. 17.

the Russian-American Co. The low gold content of the auriferous gravels found in that year and in 1850 discouraged prospecting and little is known of any that may have been done between 1850 and 1894, though gold is reported to have been discovered on Cooper Creek about 1884, on Resurrection Creek in 1888, and at Anchor Point in 1889. Placer discoveries were made on Bear and Palmer creeks in 1894 and on Canyon, Mills, and Lynx creeks in 1895. These discoveries were followed, in 1896, by a stampede of several thousand men to this field. Crow Creek was staked at this time but did not yield any gold until two years later. In 1898 a second rush, partly an overflow from the Klondike stampede, was made to the Turnagain Arm section. Since 1898 placer mining has been in progress on many of the creeks of the district, chiefly on Quartz and Cooper creeks and in the region adjacent to Turnagain Arm.

Practically all the richer and more accessible creek gravels that are workable at a profit by pick-and-shovel methods have been worked out and the exploitation of the bench gravels by hydraulic methods has begun. Attempts to work the gravels of Resurrection Creek by hydraulic elevator and later by dredge were not satisfactory. During all or part of the season of 1911 hydraulic work was in progress on Resurrection, Crow, Cooper, Mills, Canyon, Quartz, Gulch, Sixmile, and Silvertip creeks. The hydraulic plants on Resurrection, Silvertip, and Cooper creeks were working the creek gravels, a Ruble elevator being used on Cooper Creek. The other plants in the district were at work on bench deposits. A little pick-and-shovel work is also reported from the upper part of Mills Creek. On upper Kenai River a small dredge was installed and the installation of a larger dredge was begun; and on Kenai River near the mouth of Killey River ground was systematically drilled to determine its adaptability to dredging. Ground on Trail Creek between Kenai Lake and Lower Trail Lake was also prospected by drilling.

Gold-bearing lodes were discovered in the Turnagain Arm region soon after the placers were first worked. Gold-quartz float was found on Summit Creek, in the Moose Pass district, by John C. Gilpatrick in 1896, but the ledge was not found until 1906. Locations were made on Palmer, Bear, and Sawmill creeks in 1898, and some development work was done on these properties in that and the following year. In 1903 and 1904, after the settlement of Seward, gold-quartz veins were discovered in the hills close to the town, but were not much developed for several years. On Falls Creek gold-bearing quartz was first discovered in 1905 by F. P. Skeen and John Lechner on property now owned by the California-Alaska Mining Co. The property was bonded to C. D. Lane in October of that year, and about 110 feet of development work was done. From 1905 to 1909 no development work was in progress on the peninsula, although many prospects were located. In June, 1906, J. W. and C. E. Stephenson located the Black Butte ledge on Falls Creek, and in August of that year John C. Gilpatrick made the first locations in the Moose Pass district. The veins now being developed on the properties of the Seward Bonanza Gold Mines Co. and the Skeen-Lechner Mining Co. were located in 1907. Considerable development work was done on the Gilpatrick property in the Moose Pass district in 1909, and many new locations were made in that vicinity. New lodes were also discovered on Crow Creek and Resurrection River. Arrastres were installed on the property of the California-Alaska Mining Co. on Falls Creek and were operated for a short time during that year and the next. In 1910 development work was carried on at a few properties, notably on Crow and Falls creeks and in the Moose Pass district. During the season of 1911 the California-Alaska Mining Co. replaced the arrastres on its property by a two-stamp mill, and the Kenai-Alaska Gold Co. erected a five-stamp mill on the north side of the valley of Falls Creek. Both mills were in operation during a part of the summer. Development work was actively carried on at several properties and assessment work done on many others. A large number of prospectors visited the region in 1911, and numerous gold-bearing veins were discovered.

The auriferous area considered in this report lies within the third judicial division of the District of Alaska and includes portions of Kenai, Knik, and Valdez districts. The boundaries of these three recording districts were recently slightly changed by an order of E. E. Cushman, district judge of the third division, dated April 24, 1911, and taking effect May 1, 1911. The Crow Creek deposits are in the Knik mining district, the recording office of which is at Knik. The recorder's office of the Kenai mining district is at Seward. The revised boundary of the Kenai mining district is described as follows:

Beginning at Cape Douglas on the north shore of Shelikof Strait, running thence northeast up the center of the waters of Cook Inlet to a point opposite the center line of Turnagain Arm; thence east along the center of the waters of Turnagain Arm to the easterly extremity of said arm; thence in an easterly direction to the summit of the watershed, between the waters flowing into Turnagain Arm on the west and the waters flowing into Prince William Sound on the east; thence in a southerly direction following the summit of the watershed between the waters flowing into Prince William Sound on the east and the waters flowing into Kenai Lake on the west to the southernmost extremity of Cape Junken on the Gulf of Alaska; thence southwesterly to a point south of Cape Elizabeth, the southernmost point of the Kenai Peninsula and midway between said cape and the Barren Islands and including all islands contiguous and adjacent to the mainland of the said Kenai Peninsula; thence west to Cape Douglas and point of beginning.

GOLD LODE DEPOSITS.

DISTRIBUTION.

The gold lodes of the northern portion of Kenai Peninsula may be grouped tentatively as (1) fissure veins, (2) stringer lodes, and (3) mineralized acidic dikes. The largest number of the deposits, including those now of the greatest commercial importance, are fissure veins. Two of these rank as gold producers and others will probably soon become producers. The stringer lodes are few and have been but little developed. The mineralized dikes of the Moose Pass district attracted considerable attention in 1909–10, when extensive development work was done on one of them. The areal distribution of the fissure veins, stringer lodes, and mineralized dikes is outlined in the descriptions of these types. A linear arrangement of the lode gold prospects in parts of the area considered is indicated on the map (Pl. VII, opposite p. 132). In the Moose Pass and Palmer Creek districts this arrangement is due to the location of most of the prospects along the strike of mineralized acidic dikes. It appears probable, however, that the area between Seward and the Trail Lakes, near the main line of travel (the Alaska Northern Railway), has been more carefully prospected than other parts of the region, so that the numerous prospects show on the map a linear arrangement. However, no reason is known for the localization of the gold lodes in any one part of the mountainous region between Seward and Turnagain Arm.

FISSURE VEINS.

CHARACTER AND DISTRIBUTION.

The term fissure vein is usually applied to ore deposits, tabular in form as a whole, though commonly irregular in detail, occupying a fracture or set of fractures in the country rock. Most of them are characterized by regular and straight walls, by a fairly constant width, and by a definite direction of both strike and dip. As a rule they show no conformity to lines of structure. In form and occurrence these veins show great variety, those in the more massive and rigid rocks being generally the better developed.

Deposits referable to this general type have been found in many parts of Kenai Peninsula. The outcrops of most of the larger veins are traceable for but a few hundred feet and many of the fractures are short and gashlike. Some of the veins follow closely the structure of the country rock, but those that are now most important commercially occupy transverse fractures. Two distinct sets of fissures, approximately at right angles to each other, are conspicuous in the region examined. The strike of one set trends in general from north to a little west of north; that of most of the other set lies between east and northeast, only a very few trending a little south of east. Both sets of fissures are, in general, ore bearing, and are probably of about the same age, although the latest movement appears to have been along the east-west set of fractures. The veins dip at angles ranging from 45° to 90°, and some individual veins show considerable variation in dip.

The ores are simple in composition. The gangue is quartz with here and there a little calcite, and the ores contain sulphides in various amounts. The principal sulphide is arsenopyrite, but galena, pyrite, and sphalerite occur in subordinate quantities. Pyrrhotite, molybdenite, and chalcopyrite are also present in some of the ores, and gold tellurides have been reported. The ores are free milling. The gold occurs free in the quartz and also in close association with the sulphides, some of it being included in the galena and arsenopyrite grains. The wall rocks show metasomatic alteration, and disseminated crystals of arsenopyrite and pyrite have been noted in the altered rocks. In the Moose Pass district the shattered diorite porphyry dikes have been sericitized by the action of ore-bearing solutions that traversed them and the associated fissures.

Brief descriptions of a few of the characteristic fissure veins of the Seward-Sunrise region will be given. There are many other prospects on deposits of this type, but they show no important differences from those here to be described, and individual descriptions of all these would result only in a duplication of examples of the type of deposit under consideration, which would be unnecessary in a preliminary report. The properties in the southern part of the area are described first and the other properties are considered in order northward. The prospects near Seward having already been briefly described by Grant[1] need only be mentioned here. Bodies of gold-bearing quartz are reported by prospectors to occur on Resurrection River, but have not been visited. Fissure veins occur also in association with the mineralized dikes in the Moose Pass region. (See p. 156.)

SEWARD BONANZA GOLD MINES CO.

The Seward Bonanza Gold Mines Co.'s property is situated on the west face of the mountain between Victor and Ptarmigan creeks. The vein was discovered in 1907 by C. E. and J. W. Stephenson, but underground development work was not begun on it until July, 1911, after the property had been taken over by the present owners. The lower tunnel was started 1,250 feet above Kenai Lake on a well-defined fissure vein striking N. 75° W. and dipping 80° S. in black slate, the cleavage of which strikes N. 17° W. On September 29 this tunnel had been driven 110 feet along the vein, whose thickness

[1] Grant, U. S., and Higgins, D. F., Notes on the geology and mineral prospects in the vicinity of Seward, Kenai Peninsula: Bull. U. S. Geol. Survey No. 379, 1909, p. 107.

ranged from 1½ to 5 feet, and averaged about 2½ feet. The vein outcrops along the bottom of a small gulch and has been uncovered for about 300 feet above the mouth of the tunnel, and at one point near its upper end it narrows to a thickness of only a few inches. It is reported to have been traced eastward up the slope for the length of five claims. At an elevation of approximately 5,000 feet above sea level a crosscut tunnel has been driven 40 feet in a northerly direction, cutting the reported continuation of this vein at its east end. The rocks near the upper workings are mostly slate with small amounts of graywacke and dark-gray limestone. The cleavage strikes N. 7° E. and dips steeply to the east at angles ranging from 55° to 80°. The strike of the bedding is indeterminate, but appears to be about north.

In an open cut above the crosscut tunnel parallel jointing occurs in the slates, the joints striking N. 59° W., dipping 55° N., and carrying narrow quartz veins. The main vein at this point is 10 inches wide and parallels the joints. A few quartz lenses also occur in the slate. Numerous parallel, approximately east-west joints, with steep dips, are characteristic of this deposit. These joints are exceedingly well developed at the open rounded head of Stevenson Gulch, but also show near the lower tunnel and at several places along the trail joining the two workings. The ore body apparently occupies one of the larger and more persistent of these fractures, along which there was considerable movement after the quartz was deposited, as is shown by the secondary banding of the vein parallel to the walls, best seen at the lower tunnel. The joint planes in the vein are in places closely spaced, but the bands range in width from 1 to 18 inches. The joints appear to be closer and more abundant along the hanging wall. The quartz is coarsely crystalline in some of the bands, but no open cavities were seen. Sulphides have been deposited along these joint planes, and the vein is more highly mineralized where the joint planes lie close together. The quartz breaks free from the walls but shows little or no gouge. The hanging wall is better defined and freer than the foot wall.

Between 75 and 90 feet from the tunnel mouth the vein grades outward on the foot-wall side into a mass of shattered slate cemented by intersecting, generally thin, quartz stringers. These stringers are irregular in length, width, and distribution, although a few thin ones follow joint cracks in the slate. The later development work reached a point where the foot wall is well defined, the vein being 16 inches wide and carrying gouge on both walls. Some quartz stringers extend out from the vein into the country rock on the foot-wall side. Numerous quartz stringers occur in the adjoining country rock, in places showing parallelism with the vein.

The owners figure on $20 to $30 a ton on the ore from this vein, although individual assays run as high as $85, and assays of ore from the vein near the upper tunnel give higher figures. The ore is free milling and contains abundant sulphides. Arsenopyrite, the dominant sulphide, occurs as crystals in the quartz along the joint planes in the veins and as disseminated crystals in the slate. Pyrite occurs principally in small stringers in the slate, with or without quartz gangue. Galena, sphalerite, and a small amount of chalcopyrite also occur. The gangue is quartz with some calcite. Gold occurs free in the quartz. It is reported fine at the lower but coarser in the upper workings, 10-cent nuggets having been found in Stevenson Gulch.

CALIFORNIA-ALASKA MINING CO.

The property owned by the California-Alaska Mining Co. on Kenai Peninsula is at the head of the canyon on Falls Creek, about 4 miles from its junction with Trail Creek. The mine workings are on the north bank of Falls Creek, the tunnel mouth being only a few feet above the creek level. Gold-bearing quartz was first discovered in the Falls Creek region on this property by F. P. Skeen and John Lechner in 1905. The property was bonded to C. D. Lane in October, 1905; but after about 90 feet of tunnel had been driven on the Betty claim and a winze, started 60 feet in from the mouth of the tunnel, had been put down to a depth of 20 feet, the bond was allowed to lapse, the property reverting to the original locators. No further development work was done until after the property had been deeded to the present owners, the California-Alaska Mining Co., in January, 1908. The winze has since been deepened to 40 feet, and from its bottom 140 feet of drifts have been run on the vein. Flooding of the lower level caused a cessation of further development work. About 30 men, principally Greeks, were employed on the property in June, 1911, but this number was much decreased later in the season. A ditch of 500 feet was put in, 600 feet of pipe line was laid, and a two-stamp mill and concentrator were installed during 1911.

But little of the country rock is exposed in the vicinity of the tunnel, the lower slopes of the valley being heavily covered except where bedrock has been exposed along Falls Creek by the erosive action of the stream. The rocks here consist of closely folded slates and graywackes striking a little east of north and dipping 75° to 90° E. A 12-foot bed of graywacke, striking N. 7° E. and dipping 75° E., occurs at the tunnel and also opposite, a little upstream. This bed carries small quantities of iron sulphides, and weathers rusty. No igneous rocks are known to occur in the vicinity of the ore body.

The vein occupies a nearly vertical fissure that strikes N. 51° E. Near the face of the tunnel the strike swings farther east and the dip changes to 75° SE. The vein varies in width from 8 inches to 4 feet. Twenty-five feet from the tunnel mouth the fissure filling is 43 inches wide, mostly gouge, but carrying quartz stringers. Six feet beyond is an 18-inch vein of quartz, which gradually widens to 46 inches, then narrows to 1 foot about 8 feet from the winze, and then widens until, directly over the winze, it is 31 inches wide, filling the entire fissure. Narrow gash quartz veins occur in the graywacke walls, which are in many places impregnated with arsenopyrite. Beyond the winze the vein fissure splits up into three small fissures, 3 to 12 inches wide, and the graywacke has been shattered and recemented with numerous small quartz veins and impregnated with considerable arsenopyrite. The lower level could not be examined, because the workings were flooded. The vein on this level, however, is reported to be well defined and to have a width of 3 to 4 feet.

The vein material is quartz, massive and clear white in most parts of the main vein. A small amount of calcite also occurs as gangue. A bluish quartz lies in narrow stringers in the mineralized fractured graywacke and is reported to occur in the main vein. No drusy cavities were noticed in either kind of quartz. Free gold occurs in the blue quartz in close association with the fine sulphides and less abundantly in intimate association with scattered sulphide groups in the white quartz. Arsenopyrite is the principal sulphide, galena being subordinate. Numerous striated crystals of arsenopyrite are embedded in the wall rocks next to the veins and narrow stringers. Gold tellurides have also been reported from this ore, but their presence in appreciable amounts has not been proved. The ore is free milling and is reported to average $30 to $40 to the ton in gold.

Two arrastres were installed in 1909 and were run for a short time in that and the following year. Early in 1911 they were dismantled and a two-stamp mill was installed. This was the first stamp mill to begin actual operations on the Kenai Peninsula, the stamps dropping for the first time early in June, 1911. The mill was run intermittently during the season and about 90 tons of ore are reported to have been treated. The present ore-dressing equipment consists of a Ford crusher, a stamp-driven automatic feeder, standard type, supplying ore to a two-stamp mill, and a Deister No. 2 concentrator. The power for the plant is furnished by a Pelton water wheel, connected by belt to the stamp mill and crusher and operating under an 80-foot head of water from Falls Creek.

KENAI-ALASKA GOLD CO.

The property of the Kenai-Alaska Gold Co. is on the north side of Falls Creek. The mill buildings are close to timber line, approximately 1,700 feet above sea level, on a small stream tributary to Falls Creek. The mine workings, 2,825 feet above the mill, are in the west wall of a small glacial cirque 275 feet above a small glacier. The vein now being developed is on the Black Butte No. 2 claim, located by J. W. and C. E. Stevenson in June, 1906.

No development work was done until July, 1910, after an option had been taken on this and three adjoining quartz claims by T. W. Hawkins, C. E. Brown, J. R. Hayden, and John Adams. The Kenai-Alaska Gold Co., incorporated under the laws of Alaska in November, 1910, acquired the property December 16, 1910. About 200 feet of development work was done in 1910, including two crosscut tunnels 20 and 100 feet long and 80 feet of drifting. In 1911 considerable development work was done on the property. Early in the spring a road was constructed from the railroad to the mine, and a stamp mill, assay office, and several other buildings were erected. Stamps began dropping on August 25 and ceased October 1, when the mill closed down for the season, after running 276 hours actual time, and milling approximately 185 tons of ore. Work was started at the mine on July 15, a 630-foot aerial tramway being installed from the mouth of the lower tunnel to the end of the wagon road on the lateral moraine of the glacier. The underground developments to October 10, 1911, comprised a 100-foot lower crosscut tunnel, a 20-foot upper crosscut tunnel, 160 feet of drifts, one 69-foot raise connecting the upper and lower levels, and three shorter raises connecting the lower level and stopes. The ore milled was taken principally from the portion of the vein that lies east of the lower crosscut tunnel. Raises were run from the lower level toward the surface and the vein was stoped out for an area 30 feet in height and 70 feet in length. An average of 21 men and two teams were employed to October 1.

Only sedimentary rocks, slates, graywackes, and conglomerates were seen in the vicinity of the prospects on Falls Creek, but it is reported that greenstone ledges occur near its head. Conglomerate beds are found in the slate graywacke series in the cirque walls near the property of the Kenai-Alaska Gold Co. The pebbles are small, most of them less than 2 inches in diameter, well rounded, and firmly embedded in a slaty or siliceous matrix. The general tone of the rock is dark gray. The slates are very fine grained, grayish-black rocks, and the graywackes occurring with them are fine-grained gray to dark-gray rocks, weathering much lighter than the slates. On the east wall of the cirque in which the mine is located are black slates, weathering with brownish bands, interbedded with thin graywacke beds, 2 to 12 inches thick and striking N. 8° W. and dipping 70° E. The rock exposed consists predominantly of slates. On the north and west walls of the cirque the rocks have been closely folded. Some of the folds show a decided overturning toward the west, the axis of one fold dipping 30° E. This folding has been accompanied by considerable shearing and faulting.

Three veins have been discovered on this property, the one now being developed on the Black Butte claim and two smaller ones on the Moon Anchor claim. The ore body on the Black Butte claims occupies a fissure, formed during or after the folding of the slate-graywacke series, and having a general strike of N. 70° E. with a dip ranging from 65° SE. to 90°. The strike of the fissure, as shown by the mine workings, is slightly curved, varying from N. 50° E. to N. 97° E. On the surface the vein has been traced by outcroppings and open cuts for over 1,500 feet. Considerable movement has occurred along the line of this fissure, some of which has taken place since the vein quartz was deposited, as is shown by the presence of slickensided quartz surfaces within the vein, the close jointing in the quartz, and the lenticular nature of some of the quartz masses. Slickensides are also noticeable in the slate close to the vein. The width of the shear zone is variable, ranging from 5 to 48 inches, the average width being from 20 to 30 inches. The fissure filling consists of crushed and decomposed country rock with numerous lenses and stringers of quartz which locally fill the entire fissure. The width of the quartz masses varies from 1 to 30 inches. Twenty measurements on several of the quartz lenses gave an average width of 11 inches. Larger and more continuous bodies of quartz have been opened up in the eastern end of the lower drift than in the western, and most of the development work in 1911 was done in that portion of the mine. No development work has been done on the veins on the Moon Anchor claim and but little is known regarding their size or extent. Their width varies from 1 to 2 feet and one of the veins is traceable for about 200 feet with a strike a little south of east and a vertical dip. Both veins apparently occupy fissures.

The ore has a checked appearance due to the development of roughly rhombohedral jointing in the quartz, which as a rule is massive and compact. Specimens from the Moon Anchor claim, however, show cavities containing well-developed quartz crystals. The jointing makes the ore easy to mine. The quartz is milky-white except where discolored by decomposition products of the sulphides. Many of the joint surfaces are rusty and when cleaned show considerable fine gold, left by the decomposition of the auriferous sulphides deposited on the joint surfaces. The ore is free milling. The gold is all fine and sulphides are not conspicuous, mill tests showing that it requires from 100 to 128 tons of ore to obtain 1 ton of concentrates. The gold occurs native, though in many places in close association with the sulphides, which are fine and widely disseminated.

Only galena and arsenopyrite were noted. Tellurides are reported from some of the veins in this vicinity.

No gold is reported in the country rock adjoining the vein or in the fissure filling outside of the quartz, which alone is sacked for milling. An average of several assays made by the company on the vein quartz gave slightly less than $80 a ton. This, however, included one exceptionally high assay of $718, without which the average would be about $45 a ton. Assays as high as $84, $101, and $718 have been obtained from portions of the vein. The results of the last season's run at the mill showed that the ore plated about $45 to the ton. The concentrates, of which there was approximately 0.66 ton, assayed over $400 a ton. An assumed recovery of 80 to 90 per cent would place the value of the ore at $50 or $60 a ton.

During 1911 the ore sacked at the mine was hauled on go-devils to the mill, where it was passed over a 1½-inch grizzly, the oversize going to a Blake ore crusher. It was then fed to a 5-stamp mill, the stamps dropping 114 times a minute with a 6-inch drop, the pulp being discharged through a 40-mesh screen. After passing over the amalgamating plates the pulp went to a Risdon-Johnston concentrator. The concentrates were shipped to the Tacoma smelter and the tailings were impounded pending the erection of a plant for the recovery of their contained gold.

SKEEN-LECHNER MINING CO.

The Skeen-Lechner Mining Co.'s property is on the north side of Falls Creek about 4 miles above its junction with Trail Creek. Two of the claims, the Portland and the Betty No. 1, were located by F. P. Skeen and L. F. Shaw, respectively, early in 1907. Two veins, one of which was discovered in the fall of 1911, have been uncovered on these two claims. The earlier-known (upper) vein has been opened upon the surface for 375 feet by trenches and open cuts, and the more recently found (lower) vein is reported to be traceable for 300 feet. On February 21, 1912, the underground development comprised 190 feet of crosscut tunneling and 160 feet of drifting, most of it on the upper vein.

The country rock of the ore body is principally massive graywacke. About 20 feet west of the last open cut on the upper vein there is a graywacke-slate contact, striking N. 6° E. and dipping 85° W. A small amount of slate with approximately this same strike occurs along the vein west of the small fault that offsets the upper vein. Slate, graywacke, and conglomerate bowlders are found in the talus.

The upper vein, occupying a fissure in the massive graywacke, strikes N. 15° W. and dips 45° E. About midway of its present-known length (375 feet) it is offset 40 feet on the tunnel level by a vertical fault fissure striking N. 56° E. The sheared zone along the fault plane is 12 to 23 inches wide and is filled with crushed country rock containing fragments of vein quartz. Slickensides are visible both on this included vein quartz and on the walls of the fault fissure. In the tunnel the vein is well defined, varies in width from 20 to 45 inches, and shows 1 to 4 inches of gouge on both walls. The outcrop shows much less quartz, 28 inches being the maximum measurement recorded, and in places the vein fissure filling is a sheared pyrite-impregnated graywacke containing only a few narrow quartz stringers. The lower vein lies about 90 feet southwest of the upper vein and appears to parallel it in strike and to dip in the same direction. It measured 46 inches at the original discovery, near the mouth of the upper tunnel. This vein as exposed at present lies southeast of the fault offsetting the upper vein.

The fissure filling of the two veins is massive white quartz, somewhat shattered and jointed. A slight tendency toward secondary banding is seen in some places. Only a few small crystal-lined cavities are noticeable in the vein quartz. At the western end of the outcrop of the upper vein the quartz occurs as a network of stringers in the shattered country rock, the graywacke being considerably iron-stained. The quartz stringers here are frozen tightly to the graywacke, and narrow rusty bands, showing the former position of iron sulphides, lie along the contact. The country rock is impregnated with iron sulphides at several places along the vein.

Sulphides are somewhat more abundant in these veins than in those of the Kenai-Alaska Gold Co., but they are not nearly so plentiful as in the vein on the adjacent property of the California-Alaska Mining Co. Native gold occurs in association with arsenopyrite and galena and in one specimen gold was embedded in an arsenopyrite grain. The gold and sulphides appear as small grains, no large masses being observed in either vein. The ore in the upper vein is said to average over $35 in gold to the ton, and careful sampling and assaying on the outcrop of this vein is reported to show the presence of two distinct ore shoots. Assays of $50 a ton are reported from the lower vein.

SEWARD GOLD CO.

The property of the Seward Gold Co. is about 4,250 feet above sea level on the crest of the ridge between the forks of Groundhog Creek, a tributary to Bench Creek from the west, crossing the Government road from Sunrise 10½ miles from Mile 34 on the Alaska Northern Railway. The claims were located September 11, 1910, by R. L. Hatcher and C. A. McPherson. Between September 20 and the later part of November about 60 feet of tunneling was done on the vein. On October 20, 1910, the property was deeded to the Seward Gold Co. Development work was done during the summer of 1911, but was brought to an end by the collapse of the tunnel. The total work done since discovery consisted of 90 feet of tunneling, 23 feet of winzes, a 12-foot crosscut, and a 15-foot shaft.

The country rock of the ore body consists of slates and some graywacke, striking a few degrees east of north and dipping eastward at an angle of about 60°. The strike and dip of the cleavage closely correspond to that of the bedding. A vertical jointing near the vein and almost parallel to it strikes N. 85° E. The joints are irregularly spaced at intervals of a foot or more. A short distance above the workings a pale-greenish porphyritic dike crosses the ridge, striking N. 28° W. and dipping vertically. The dike measures as much as 10 feet at one point, and the rock composing it is much jointed, but appears fairly fresh and unaltered, its porphyritic texture being plainly evident in most specimens. It shows little evidence of mineralization. About 150 feet northeast of this dike is another dike of similar appearance, whose northernmost end lies close to the easternmost extremity of the vein as now uncovered. The outcrop of the vein has not been traced quite to the point where it should intersect this dike, nor is this dike visible on the surface north of the vein. It is of variable width, measuring 28 inches on the first outcrop south of the vein, but in places reaching a width of at least 8 feet. It is approximately parallel to the upper dike, striking about N. 40° W. Both dikes have been fractured and the fractures have been filled with white, glassy-looking quartz, which at one place carries native gold. Arsenopyrite was found in one of the dikes.

The ore body consists of a zone of fractured slates, 5 to 6 feet wide, extending S. 80° E. between the two dikes. The fractures have been filled with quartz, much of it coarsely crystalline, which forms a network of irregular stringers, between which there is considerable crushed slate. The vein material is all more or less decomposed by surface weathering. The vein has been traced about a hundred feet, and so far as present development work shows does not extend beyond either dike. It is nearly vertical, dipping steeply to the south. A narrow streak of gouge lies along the hanging wall. In many places the vein quartz shows drusy cavities, indicating deposition in open spaces. The quartz filling varies from narrow stringers to veins over a foot in width. A small quantity of calcite occurs in the veins. The gold is free in the quartz or in close association with arsenopyrite and galena. Specimens from the outcrop show abundant free gold. Arsenopyrite occurs also in the slate wall rock and in the dikes, its appearance in those places indicating metasomatic alteration by mineralizing solutions. The vein quartz carries the gold, assays of the decomposed slate from the fractured zone showing only traces of gold.

BARNES PROPERTY.

The property of the Alaska Gold Exploration & Development Co., usually referred to locally as the Barnes property, is at the head of Crow Creek, in the Knik mining district. Glacier Creek, of which Crow Creek is the most important tributary, enters Turnagain Arm from the north 4 miles beyond the present terminus of the Alaska Northern Railway. Although the first discovery of gold-bearing quartz on this property was made in September, 1909, by Conrad Hores, little work was done to open up the vein prior to August 1, 1910. Since that date, however, underground development has been actively carried on, practically all of it on the Stella claim. Three veins had already been found at the time this property was visited, and a fourth was discovered on the Ruth claim late in the fall. The outcrops of these veins have been traced only a few hundred feet. The ore body on the Stella claim consists of two parallel veins, a little over 100 feet apart, striking eastward, and a third vein crossing these with a strike of S. 18 E. The vein on the Ruth claim is reported to strike eastward. The developments on the Stella claim to January 1, 1912, consisted of 560 feet of adit levels, 56 feet of crosscut timbering, 14 feet of drifts, and 52 feet of winzes, together with several open cuts on the different veins. These developments include three adit levels, two of which are on the southernmost vein, one 100 feet vertically above the other. This southern vein strikes S. 83 E. and dips 55° N. and varies in width from 8 to 46 inches. The upper of the two tunnels was 267 feet in length, and the lower tunnel, started late in the fall, was only 50 feet long; two winzes, 42 feet and 10 feet in depth, have been sunk on the vein in the upper tunnel. On the northern vein, which is nearly parallel to this one and about 100 feet distant from it, an adit level 243 feet in length has been driven. This northern vein varies in width from 10 inches to 3 feet, strikes N. 87° E., and dips 68° N. The third or crosscutting vein, which ranges in width from 2 to 10 inches, strikes N. 18 W. and dips 80° W. A tunnel, driven N. 47 E., crosscutting this vein 56 feet from the mouth, shows that it is a narrow-fracture zone in the country rock cemented by quartz carrying sulphides. The apex of the Ruth lode is about 860 feet above the level of this crosscut, and it is reported that very little work has been done on this vein, which is said to have a width of 6 to 8 inches.

The country rock of the ore deposits consists of dark-colored slates, banded argillites, fine-grained graywackes, and conglomerates, folded and later intruded by numerous bosses of light-colored, fine-grained granites, and fine-grained to aphanitic acidic dikes, offshoots from the granitic masses. The strike and dip of the sedimentary beds vary, but in general the strike is easterly and the dip northerly.

Fossils are not abundant. Imprints of small Inoceramus of Jurassic or Cretaceous age were found during 1911 on the bedding planes of the banded argillites in bowlders on the moraines of the Crow and Raven Creek glaciers and in place on the west side of the Raven Creek glacier. Inclusions of the banded argillites are found in some of the granite bosses with sharp contacts between the igneous and sedimentary rocks. No development of contact minerals is noticeable. The angularity of the fragments of the talus, the appearance of the weathered surfaces, and the dense character of the rocks, as well as the reddish, rusty discoloration of the sedimentary rocks of the area, suggest considerable heat action and mineralizing activity, which are further indicated by the presence of molybdenite and pyrrhotite in some of the quartz veins and by the occurrence of pyrrhotite and chalcopyrite in narrow quartz seams in the shales. Traces of contact-metamorphic action are visible along these seams. Ellipsoidal or concentric jointing by the metamorphism of some of the thicker argillite beds has also been noticed. Many of the dikes are faulted, the displacement, however, being usually only a few feet.

The predominant gangue mineral of the gold veins is quartz, but they contain also some calcite. The physical character of the vein quartz varies slightly. Secondary banding parallel to the walls is noticeable in places and sulphides have been deposited along some of the fractures. At some places joints occur in the quartz. At others the quartz is coarsely crystalline and the vein contains numerous small vugs.

Pyrite, arsenopyrite, sphalerite, and galena are the principal sulphides. Chalcopyrite also occurs in small quantities. Pyrite and arsenopyrite occur as disseminated crystals in the metasomatically altered wall rock of the veins as well as in association with the other sulphides in the vein quartz. In the open cuts galena is altered to cerusite.

The ores are free milling. Tests on some of the more highly mineralized ore are reported to have saved 80 per cent by amalgamation and 16.4 per cent in the concentrates. The gold is free and also occurs in close association with the sulphides, and is often included in galena and arsenopyrite grains. It is especially noticeable along some of the joint planes where the auriferous iron sulphides have been oxidized. Nuggets worth 63 cents have been found in the veins. The gold of Crow Creek is of rather low grade, having a value of about $15.90 an ounce.

The crosscut tunnel on the Stella claim passed through a small vein containing molybdenite, pyrrhotite, and chalcopyrite in a gangue of vitreous-looking quartz, but no visible free gold. Pyrrhotite and chalcopyrite also occur in narrow seams in the banded shales near the igneous rocks.

The ore from the two larger veins on the Stella claim is reported by the owners to average $35 to $40 a ton for the southern vein and $12 a ton for the northern vein. Much higher assays have been obtained, however, in single samples. The limits of the ore shoots are not yet defined. About midway of the upper tunnel on the southern vein a stringer runs out into the hanging wall, and at this point sulphides are said to have been much more abundant and assay values much higher than in other parts of the vein. Exceedingly high assays are reported from the crosscut vein on the Stella claim and from the vein on the Ruth claim. The wall rocks of none of the veins are said to carry gold, although the amount of pyrite and arsenopyrite would suggest the presence of at least a little.

STRINGER LODES.

Typical stringer lodes are composed of numerous nearly parallel overlapping quartz veinlets occupying irregular openings along cleavage lines or in some places cutting across the structure. Several deposits of this type, which is characteristic of slaty rocks, occur in this region, the best known of which lie in a belt extending northward from the Mile 4 property to the mouth of Porcupine Creek. They include the Mile 4, Pullen-Davis, and Schoonover properties. The Pullen-Davis lode differs somewhat from the others in that the quartz stringers form a network recementing a fractured graywacke bed. The other lodes in this belt are in slate, stand vertical, and strike in general parallel to the structure, although some of them cut the bedding at slight angles. At the Schoonover property near the upper end of Porcupine Creek a compact stringer lode 9 feet in width at the tunnel mouth and traceable for over 125 feet, contains irregular lenses and stringers of quartz from 1 inch to 15 inches in width. Assays up to $100 have been obtained on samples taken across the full width of some of the larger stringers. Other mineralized quartz stringers, 1 to 6 inches in width, are found on this property outside of the zone mentioned. The interbedded slate and graywacke strikes N. 17° W. and has a vertical dip. On the canyon walls, however, surficial creep of the beds has caused an inclination of the upper portion of the lode and country rock toward the creek and has resulted in a false dip away from the creek.

The gangue in the stringer lodes is quartz, coarsely crystalline in some of the larger stringers and showing interlocking crystals in places at the center of the veins. Some calcite occurs with the quartz as a gangue mineral. The gold occurs free in the quartz. Arsenopyrite is the most abundant sulphide; galena, sphalerite, and pyrite are subordinate.

Other occurrences of stringer lodes are known on Palmer, Cub, Groundhog, and other creeks of the district. Most of the veins are small and comparatively short, and only where they are fairly closely spaced and well mineralized can they be considered as possible ore bodies. The small amount of development work done on deposits of this type in this region has not determined either their lateral or their longitudinal extent nor demonstrated their economic importance. Stringer lodes have proved to be of great value in some portions of the Juneau gold belt and commercially valuable stringer lodes may exist in the slate areas of Kenai Peninsula.

MINERALIZED ACIDIC DIKES.

DISTRIBUTION.

The only mineralized dikes in this district of any present economic importance are those of the Moose Pass and Palmer Creek regions. Other acidic dikes occur along Turnagain Arm, on Crow, Raven, Groundhog, Porcupine, Mile Four, Bear, and other creeks, but are so slightly mineralized that they appear of little economic value. The possible existence of other well-mineralized dikes, however, is not denied.

The characteristic feature of the Moose Pass and adjoining Palmer Creek regions is the occurrence of several nearly parallel mineralized acidic dikes striking in a general north-south direction and confined so far as known to a relatively narrow strip of country between Quartz, Canyon, and Resurrection creeks. The largest of these dikes, known locally as the "Blue Lead," is in the Moose Pass district and has been traced for approximately 12 miles from Slate Creek to Donaldson Creek with an average width of 8 feet. Near the southern end of the area several promising gold-bearing quartz veins have been opened. North of Summit Creek the mineralized quartz appears, so far as present developments show, to be confined chiefly to the fractured and mineralized dikes, although small gold quartz veins have been located at the head of Palmer Creek, and on Canyon, Juneau, and Fresno creeks. Further prospecting in this northern portion will probably reveal other gold quartz veins.

STRIKE.

The noticeable parallelism of the dikes of this district and their length is evidence of extensive parallel fissuring prior to the intrusion of the acidic igneous material now filling those former openings. These earlier fissures follow closely the dominant strike lines of the district and dip nearly vertical, as do most of the sedimentary rocks. The strike of the "Blue Lead" changes gradually from N. 12° E. in its southern portion to N. 30° E. on Donaldson Creek, where it disappears under timber cover. The Mascot ledge, near the head of Fox Creek, has a due north strike and a vertical dip, and the Logman ledge on Palmer Creek, traceable for over 6 miles, has a north-south strike. The other dikes of this district parallel these. On Bear Creek numerous large acidic dikes outcrop and some of them have northerly strikes. Subsequent to the intrusion of the acidic dikes further fissuring took place, faulting and fracturing the dikes and opening new fissures for the deposition of gold-bearing quartz. These later fissures are vertical or nearly so. Their strikes fall into two general groups, one group having northeast-southwest strikes and the second a general northwesterly strike. Small transverse slippings are noticeable in the tunnels at the southern end of the big Moose Pass dike, but most of the offsets are small. In places the dike walls are frozen to the country rock, but generally they break clear. The dikes are badly sheared in other places and show gouge streaks and slickensides along the walls in many localities.

MINERAL CHARACTER.

The dikes are very fine grained, badly altered porphyritic rocks, light colored and greenish. Owing to the extensive alteration they have undergone their porphyritic character is discernible in few hand specimens. Under the microscope they show phenocrysts of plagioclase feldspars and a colorless silicate (probably originally biotite) embedded in a fine-grained groundmass of quartz and plagioclase feldspars. Considerable secondary muscovite (sericite) and calcite are present and also a small amount of chlorite, to which last the greenish tinge of the rocks is probably due. Sericitization of the feldspars is well advanced, and the original biotite phenocrysts are completely altered to chlorite, calcite, and sericite. The unaltered rock would best be classed as a very fine-grained diorite porphyry. Small seams of calcite occur in the more altered portions of the dikes, and calcite is present also in many of the quartz veins associated with them. Striated crystals of arsenopyrite are abundantly disseminated through the altered porphyry adjacent to quartz veins and stringers. Dendritic markings of manganese dioxide are found on many of the fractured planes of the dike rocks. In the more mineralized portions the fractured dike rock is cemented by irregular quartz stringers with a little calcite. The gold is free in the quartz gangue as well as closely associated with the sulphides. Arsenopyrite occurs both in the quartz stringers and disseminated in the altered dike rocks adjoining. Galena, sphalerite, chalcopyrite, and pyrite are also present.

The mineralization in the dikes is irregularly distributed, poorly mineralized and barren stretches occurring at irregular intervals. Low-grade mineralized zones of country rock as well as gold-bearing stringer lodes of indeterminate lateral and longitudinal extent intersect the dikes, which are mineralized along the crossings, the crushing and fracturing of the dike rocks having facilitated the circulation of the mineralizing waters. The original dike rock carried practically no gold. Assays on average samples from the less altered portions range from a trace to a little over $1. In the more mineralized portions average samples are reported to assay from $1.40 to $52.80 and picked specimens to run a great deal higher. The portion of the "Blue Lead" between Summit and Colorado creeks is reported by the owners to average $19 to $20 to the ton, this result being obtained on average samples from five open cuts on the ledge between those creeks. Comparatively unmineralized portions, however, occur in this strip as in other portions of the dike, and these would lower the general average considerably. No assays from the Logman ledge on Palmer Creek are available at present save one running $100 to the ton on a picked specimen. An average figure for the value per ton of these mineralized dikes could not be given without careful sampling and assaying. Their length, the probability of their continuance with depth as borne out by their igneous origin, and their mineralization (which, though markedly irregular and in most places slight, extends over a considerable area) suggest that they warrant careful future consideration and some places may pay to work on a large scale even under present economic conditions.

Some of the associated gold quartz veins appear of greater immediate importance under existing conditions. On the Gilpatrick property, between Slate and Summit creeks, at the southern end of "Blue Lead," gold quartz veins occur in close association with the dike. One such vein follows along the west wall of the dike as exposed in the upper tunnel. A crosscut to the west at the face of this tunnel shows 5 feet 2 inches of slate and quartz separated from the dike by 3 feet of slate with small rusty quartz stringers. Within this vertical veins of quartz, 7, 16, and 18 inches wide, are visible, and the slate between these veins carries numerous small quartz stringers. A crosscut to the west about 125 feet from the mouth of this upper tunnel shows a 15-inch vein of quartz in slate 12 feet west of the dike. A crosscut in the lower tunnel does not encounter this vein and it seems probable that it occupies a later nearly parallel fissure that crosses the dike between the two tunnels. The Summit vein, on the crest of the ridge between Slate and Summit creeks east of the dike, lies in sheared graywacke, strikes northwest, stands vertical, and has a width approximating 3 feet. This vein has not been traced to its intersection with the dike. The width of the quartz ranges from 6 to 40 inches. Free gold is plainly visible to the unaided eye, as are also the sulphides, galena, and arsenopyrite. Average assays of from $30 to $68 are reported from this vein. Assays on quartz from the upper tunnel run from $0.80 to $37, although higher results are obtainable on specimen ore. On the ridge between Slate and Boulder creeks several quartz veins have been located, assays on which are reported to run from $3 to $25.

DEVELOPMENT.

Comparatively little development other than assessment has been done on the mineralized dikes of this region. On the Gilpatrick property in Moose Pass there are three tunnels, two of which, 286 and 235 feet in length, with about 45 feet of crosscutting, were driven along the big porphyry dike, and a third, now caved, was driven 117 feet along the quartz vein on the Summit claim. On the adjoining property to the east a tunnel 204 feet in length has been driven along a shear zone striking N. 57° E. On the Logman lode, Palmer Creek drainage, a 40-foot tunnel has been driven on the south side of Cœur d'Alene Gulch. Assessment work only has been done on the other claims and has been restricted to the construction of trails to the properties and the making of a few open cuts across the dikes.

CONCLUSIONS.

The numerous gold quartz lodes and placer deposits scattered through the mountainous portion of the peninsula indicate widespread mineralization, coextensive, presumably, with the area underlain by metamorphic rocks. In the surrounding portions of Alaska, in the Iliamna region, in the Nizina, Chistochina, Yentna, and Willow Creek districts, and in southeastern Alaska, the gold deposits all appear to be genetically related to Mesozoic dioritic intrusive rocks.[1] On the Kenai Peninsula and the adjoining mainland, granitic and dioritic intrusives occur at several places and the evidence available indicates that they are of Mesozoic age. The mineralization of the area took place subsequent to the intrusion of these igneous masses and probably as an after effect of the igneous activity. In age and association, therefore, the gold quartz lodes of this region are similar to most of the auriferous lode deposits of Alaska.

The mineralogy of the gold ores of the Kenai Peninsula—pyrrhotite, molybdenite, chalcopyrite, pyrite, arsenopyrite, galena, sphalerite, gold, etc.—is characteristic of gold veins deposited by aqueous solutions under conditions of moderately high temperature and pressure, at minimum depths of several thousand feet below the surface.[2] The metasomatic alteration of the wall rocks of the ore bodies is also that effected by heated aqueous solutions under deep-seated conditions; and the present known range of auriferous vein filling, over 5,000

[1] Brooks, A. H., Geologic features of Alaskan metalliferous lodes: Bull. U. S. Geol. Survey No. 480, 1911, pp. 43–93.

[2] Lindgren, W., The relation of ore deposition to physical conditions: Econ. Geology, vol. 2, 1907, pp. 113–116.

feet, extending from practically sea level in the prospects near Seward to altitudes of 4,000 to 5,000 feet on the properties of the Kenai-Alaska Gold Co. and the Seward Bonanza Gold Mines Co., is probably a minimum estimate of the range through which the auriferous solutions were capable of depositing their contents. The deep-seated origin of the ore deposits, their probable deposition from ascending thermal waters, the character of the mineralization, and the extensive vertical range of auriferous vein-filling above sea level, all indicate the continuity of the ore deposits to a depth below the limits of profitable mining; and in general it is probable that gold quartz veins are distributed through the rocks to considerable depths, in much the same manner and form as in the rocks that lie above sea level. However, the persistence of the general mineralization with depth is no criterion as to the persistence of mineralization in individual veins.

Secondarily enriched deposits do not occur in this district, the powerful glacial erosion of comparatively recent times having removed any enriched zones that may once have existed. Neither is there a complete zone of oxidation. The original sulphide ore bodies are now exposed at the surface, and no reason exists for suspecting any marked change in depth either in the mineralogic character of the ores or in the value of the lodes as a whole. The outcrops of many of the ore bodies have been modified slightly by the postglacial oxidation of the sulphides contained in the veins, and in the more favorable places partial oxidation of the sulphides has taken place to depths of 200 to 250 feet, these being the greatest depths yet attained in the mine workings. The greater part of the contained gold appears to have been left behind in the oxidized outcrops.

GOLD PLACERS.

GENERAL FEATURES.

Colors of placer gold have been found on most, if not all, of the streams of the mountainous region of northern and central Kenai Peninsula, but in few places have deposits been found sufficiently rich to be of economic importance under present conditions. Consequently, though the present known distribution of the auriferous gravels is widespread, the list of producing creeks is small. In 1911 it included only Resurrection, Crow, Cooper, Quartz, Gulch, Mills, Canyon, Sixmile, Silvertip, Bear, and Winner creeks, and Kenai River, being much the same as it was when the region was visited by Moffit in 1904 and Paige and Knopf in 1906. About 25 claims were being worked at one time or another in 1911, and from 75 to 100 men were engaged in placer mining during the open season. The production of placer gold in 1911 from Kenai Peninsula, including

Crow and Winner creeks, is estimated at 1,540 crude ounces, valued at $26,000 for gold and $150 for silver. The value of the placer gold of this region varies from $15.86 to $17.87 per ounce. Bear and Crow creeks furnish the lower grades, the assay value per ounce (after melting) of dust from these two creeks ranging from $15.86 to $15.90. Bear Creek gold is usually taken in trade locally at $15 per ounce.

The placer deposits of this region may be grouped as (1) creek placers, (2) bench placers, (3) river-bar placers, (4) lake-bed placers, and (5) beach placers. The data regarding the principal characteristics of each of these classes, with examples of each and the methods at present used in working them, are tabulated here for convenience in reference.

Classification of gold placers of Kenai Peninsula and vicinity.

Class.	Nature and location.	Examples.	Method of working in 1911.
Creek	In, adjacent to, and at the level of small streams.	Resurrection Creek Cooper Creek	Hydraulicking. Hydraulicking over Ruble elevator.
Bench	Fluvioglacial or glacial deposits in valleys but considerably above level of present streams, usually terraced.	Lynx, Crow, Canyon, Mills, Sixmile, Gulch, Resurrection, Quartz, and Cooper creeks.	Hydraulicking.
River bar	Gravel flats, in or adjacent to beds of large streams.	Kenai River	Dredge (installed on upper Kenai River in 1911).
Lake bed	Accumulations in the beds of present or former lakes; generally formed by landslides or glacial damming.	Crow Creek Bench deposits on upper Kenai River.	Not worked.
Beach	Adjacent to the sea or to large bays to which waves have access.	Anchor Point, Cook Inlet Snipers Point, Turnagain Arm.	Rockers and sluice boxes. Not worked.

SOURCE OF THE GOLD.

Most of the placer gold of the region is undoubtedly of local origin and was probably derived from the erosion of gold veins in the slates and graywackes of the Kenai Mountains. Most of it was derived from veins within the area drained by the stream in whose valley the auriferous gravels are found. The present distribution and arrangement of the auriferous gravels results principally from the glacial and fluvioglacial activity of the recent past and from recent stream erosion. No preglacial gravels are known to occur in place in that portion of the Kenai Peninsula under consideration. Preglacial stream deposits undoubtedly existed, but probably all of them have been removed by glacial erosion and reworked by glacial streams. As the ice retreated the shifting overloaded glacial streams laid down valley trains in which the gold was necessarily widely disseminated. Later, with a decrease in load after the disappearance of the glaciers, the streams began to cut down through the valley trains, terracing the older deposits and concentrating the gold contained therein in the creek gravels. Most of the present creek placers are the product of this concentration, although some of the placer gold of a few of them may possibly have been furnished by postglacial erosion of the lodes.

MINING METHODS.

The future of the region as a placer producer depends largely on the introduction of economical methods of handling large bodies of low-grade gravels. The channel gravels yielded most of the gold in the earlier years of placer mining in the peninsula, but the richer spots were soon worked out; and the remaining creek placers have repeatedly proved unprofitable when worked by ordinary pick-and-shovel methods. They are, moreover, in most places shallow and of small extent. Where of greatest extent, as on Cooper and Resurrection creeks, values of only 30 to 50 cents a yard are reported, and methods other than shoveling into sluice boxes must be employed to obtain a profit. As the topographic conditions and abundant water supply of the region are particularly favorable to hydraulicking, most of the placer mining in recent years has been by that method, the material worked in most places being the bench deposits. These bench placers are of much lower grade than the creek gravels; in those of glacial or fluvioglacial origin the gold is widely disseminated. On some of the lower benches where remnants of the reworked high bench deposits have been left by the down-cutting streams slightly richer deposits are found.

The handling of large bodies of low-grade gold-bearing gravels by methods other than those of ordinary hydraulic mining has been attempted at different times in the Kenai Peninsula, but thus far has not been successful. The failure of a Risdon 5-foot open-connected dredge on Resurrection Creek in 1905 is reported to have been due partly at least to the numerous large bowlders contained in the creek gravels. A small dredge, differing markedly from the usual type, was erected on upper Kenai River in 1911 but failed to yield satisfactory results; and it appears probable that nearly everywhere on Kenai River dredges designed to handle heavy wash will be required. Attempts to work the gold-bearing gravels on Resurrection and Sixmile creeks by hydraulic elevators were not successful. In general it may be said that inadequate prospecting of placer ground before a method or plant adapted to the conditions is chosen has caused most of the failures.

Many conditions favor the placer miner; the open season is longer than in either the Yukon country or on Seward Peninsula; perpetually frozen ground does not occur; compared with the interior of Alaska, the country is easier of access, and the cost of labor and supplies is less; topographic conditions and the abundant water supply favor hydraulic methods; and timber suitable for cabins, fuel, and mine work is readily obtainable.

PRODUCTIVE CREEKS.

The general characteristics of the productive creeks have been described in considerable detail by Moffit[1] and therefore only those operations which were in progress in 1911 are here described. The placers are described in geographic order, those in the southern part of the area being placed first and the more northern ones last.

KENAI RIVER.

After the discovery in 1910, by C. D. Cunningham, of placer gold in the gravels of Kenai River about a mile below the mouth of Cooper Creek, practically all the lower ground bordering the river from the lower end of Kenai Lake to Cook Inlet was staked as possible dredging ground. Little careful prospecting, however, has as yet been done. Early in 1911 ground near the mouth of Killey River was drilled to determine its suitability for dredging and later in the season some of the claims between the upper and lower Kenai Lakes were prospected by shafts. Gold values sufficient to justify dredging are reported from parts of the lower river. Specially designed dredges would, however, be required to work these deposits on account of the occurrence of very heavy wash in many places.

Between Skilak and Kenai Lakes Kenai River flows among high rounded hills. Gravel benches flank the stream; their upper surface is at water level at the lower end of Kenai Lake, but is high above the river in the vicinity of Cooper and Juneau creeks, where the river has cut deeply into them. The 200-foot bluff at the mouth of Cooper Creek shows the structure of these high-bench deposits to be that of a typical delta, deposited in ponded waters by a stream flowing westward, as does the present river.

In recent geologic time it is probable that the trunk glacier extending down the valley now occupied by Kenai Lake and Kenai River widened and deepened the preglacial valley and impressed upon it the U-shape characteristic of glaciated valleys. Because of its greater size and erosive power this glacier cut the bottom of its valley considerably below the level of the tributaries' valleys, so that Cooper and Juneau creeks were left as hanging valleys on the retreat of the ice. The delta structure of the bench deposits indicates that a lake of considerable size formerly filled the valley, being probably produced by ice damming Kenai River in the vicinity of Skilak Lake. It appears probable that the ice front of the Kenai River

[1] Moffit, F. H., Gold fields of the Turnagain Arm region: Bull. U. S. Geol. Survey No. 277, 1906, pp. 7–52.

glacier stood near the lower end of the present Kenai Lake during the formation of the delta, which built out and filled the lake to the extent indicated by the development of the present terracing. The removal of the obstruction which gave rise to the lake was followed by the cutting of the present channel through the delta deposits, a process which is still in progress. The depth to which the Kenai River glacier eroded its channel below that of its tributaries is not known, and therefore neither the thickness of the unconsolidated glacial and fluvioglacial filling nor the depth to bedrock in this portion of the river's course is known, although it is probably considerable.

From the delta character of the bench deposits it would be expected that the contained gold would be widely disseminated and that no definite pay streaks would occur. As to the average value per cubic yard of these bench deposits no data are at hand. It is probably exceedingly small, much too small to be worked profitably under present conditions. Panning tests in the delta bluff at the mouth of Cooper Creek failed to show any colors. The fact that these delta deposits are slightly auriferous, however, is shown by the occurrence in the present stream gravels of fine flaky gold, which must have been derived, partly at least, from the concentration of the delta gravels.

Of the present river gravels that are locally considered as possible dredging ground, those in the portion of the river's course between the upper and lower lakes are the result of the reworking and re-sorting of the sands and gravels of the above-mentioned delta, as the stream cut through it down to its present level. Coarser material, derived principally from the erosion of morainic material and bedrock on the tributary streams, also occurs in the gravels of stream flat.

The thickness of these river gravels is unknown. Prospecting shafts reach only a depth from 4 to 8 feet before encountering water. The stream-flat gravels of the lower end of Cooper Creek have a thickness of only 8 to 10 feet, resting on a false bedrock of the delta deposit in which this portion of the creek valley is cut. The river gravels may be somewhat thicker.

The low gold content of the sands and gravels of the delta underlying the present river gravels has been pointed out. In the river gravels, however, colors are obtained from the surface down without any well-defined paystreak. The data available regarding the value per cubic yard of these gravels varies considerably. The Kenai Dredging Co., whose property is about a mile below the mouth of Cooper Creek, is reported to have obtained $167 from 9½ cubic yards of gravel and from 2 to 25 cents from each pan from the river bars. The results obtained from prospecting shafts 4 to 8 feet deep in the stream flat between the upper and lower lakes are much lower. Values of 25 and 38 cents per cubic yard were obtained in two of the shafts, and placer operations on the lower portion of Cooper Creek are reported to show an average gold content for stream-flat gravels of 30 to 50 cents a cubic yard. The average gold content of all material which would have to be handled in dredging operations, as reported from a considerable number of these shallow shafts sunk during the past season, was, however, only a few cents to the cubic yard, less than the cost of dredging operations under more favorable conditions in California. It is doubtful, however, whether any of these shafts reached either the false or the solid bedrock, upon which higher values might be found.

Most of the gold in the gravels of Kenai River is very fine, light, and flaky, and has a value of about $17.58 per ounce. Coarser gold, flat but not flaky, has been introduced into the river gravels from Cooper Creek. Active operations on the upper river have thus far been confined to the original discovery, where, during 1911, the Kenai Dredging Co. erected a small dredge which, however, failed to save the values contained in the gravel worked. A larger dredge of the same type, in process of construction, had not been completed at the close of the season. Should the gravels in the upper river, after careful prospecting, warrant the installation of dredging machinery, it appears probable that dredges capable of handling rather heavy wash will be required. The further possibility that the gold-bearing gravels of the present stream in this portion of its course may be, and probably are, of comparatively slight thickness should not be overlooked.

COOPER CREEK.

Cooper Creek, 10 miles in length, enters Kenai River from the south 3 miles below Kenai Lake. Stetson Creek is its principal tributary. Cooper Creek in most of its course flows in a postglacial rock canyon cut in a broad glacial valley. Its lower half mile, however, is cut in the sands, clays, and gravels of the delta deposit of the Kenai Valley.

The auriferous deposits comprise both bench and creek gravels. The gold content of the delta bench gravels is low (see p. 164), but above the mouth of the rock canyon richer bench deposits of moraine and fluvioglacial origin, containing both coarse and fine gold, rest on the glaciated bedrock floor. The largest nugget thus far found had a value of $3.80. The larger nuggets are very much smoothed.

The creek gravels have been worked both in the canyon and on the flat at the lower end of the creek. The latest work in the canyon was done about 1903. The gravels are said to have varied much in thickness and to have been richer than most of the gravel on the stream flat below. For several years active operations have been confined to the wide flat at the lower end of Cooper Creek, where the creek gravels, 8 to 10 feet thick, form a uniform layer over a false bedrock of fine sand and sandy clay, with some lenses of pebbly gravel. The surface of this bedrock is fairly even, with slight depressions representing temporary channels of the shifting creek as it wandered back and forth, downcutting the present flat through the old delta deposits. The creek gravels are loose and easily handled. Pebbles of dark blue-black slates and graywackes predominate, interspersed with some conglomeratic bowlders. A few bowlders of fine-grained acidic dike rocks are also found. Bowlders over 3 feet through are rare, most of them averaging 1½ to 2 feet. The larger bowlders appear principally in the lower part of the gravels. Considerable fine material forms a matrix for the bowlders, but it is gravelly and crumbles readily. No distinct stratification is noticeable, although most of the pebbles and bowlders are flattish or slabby and lie approximately flat. These stream-flat gravels are reported to average from 30 to 50 cents gold per cubic yard.

The gold is derived from three sources—partly from the delta deposits that flank the stream flat, partly from the auriferous glacial and fluvioglacial deposits in the glaciated valley of Cooper Creek, and to a slight extent, probably by postglacial erosion, from gold-bearing lodes in the bedrock of the valley. Two distinct runs of gold are reported, one a little darker than the other.

The gold is small, flat but heavy, not flaky, and has a value of about $17.60 per ounce. Nuggets up to 80 cents in value have been found, some with quartz attached. Pyrite, arsenopyrite, and magnetite are found in the concentrates from the clean-ups.

The Cooper Creek placers are the property of the Kenai Mining & Milling Co., whose claims extend from Cooper Lake to Kenai River. Hydraulic operations were in progress in 1911 on the stream flat at the lower end of the creek. On account of the low stream gradient a Ruble elevator with a 48-foot body 10 feet wide and a 12-foot extension at the lower end, has been installed. The gold-saving attachments consist of four sluice boxes, 12 feet long by 4 feet wide, set on a grade of 8 inches to the box length. The three lower boxes were set with steel-capped wooden cross riffles, 4 inches by 2 inches by 4 feet in size, 2 inches apart with 1-inch spaces between the steel straps, the dimensions of which were ¼ inch by 3 inches by 4 feet. Water for hydraulicking is obtained from Stetson, Wildhorse, and Kickinghorse creeks by an upper ditch 4 miles long, a lower ditch 1¾ miles long, and 1,300 feet of flume. Two No. 2 Hendy giants with 4-inch nozzles and two No. 4 giants with 5-inch nozzles made by a Portland firm were available, but only one giant with a 5-inch nozzle operating under a 200-foot head was in use in June, 1911. The usual mode of operation is to strip the soil down to the gravel layer and then to wash all the gravel, down to the false bedrock, over the elevator. Most of the gold is caught in the upper boxes.

QUARTZ CREEK.

Quartz Creek, tributary to Kenai Lake from the north near its lower end, has a length of about 16 miles. In 1911 a hydraulic plant was in operation on this creek a short distance above the mouth of Devil Creek. In this portion of its course Quartz Creek winds southward in a narrow, steep-sided valley cut in the bedrock floor of a broad glaciated valley. Bedrock of interbedded slates and graywackes striking N. 17° W. and dipping 60° W. outcrops in many places in the stream course and in the valley walls. The character of the unconsolidated material covering the bedrock on the slopes is shown in the ditch which extends along the east side of the valley. It is cut in a compact clayey gravel, which contains a few rounded and striated bowlders and was evidently waterlaid in places. Small gravel-covered benches lie at different elevations on the valley sides. The creek gravels are reported to have been good pay and to have carried coarse gold. Present operations are confined to a gravel-covered rock-cut bench, the bedrock surface of which is, at the pit, about 15 feet above the present stream. The thickness of the gravel on this bench varies from 12 to 22 feet because of the unevenness of the bedrock surface. The gravels consist of fairly well rounded slate and graywacke. Large bowlders, some as much as 6 feet in diameter, are found, but most of the material is under 3 inches in diameter. An average value of 27 to 32 cents a cubic yard is reported for these gravels. The gold is coarse, pieces up to 73 cents in value having been found, and has an assay value of about $16.90 an ounce.

At the Fairman and Madson plant water is obtained from Quartz Creek, a short distance below the mouth of Johns Creek, by a ditch 1½ miles in length with a grade of one-fourth inch to the rod. The intake is situated on the west bank of the creek and the ditch follows along the west side of the valley to a point about one-half mile below the intake, where the water is carried across Quartz Creek on a 160-foot flume 65 feet above the creek. The pipe line from the penstock to the giants decreases gradually in diameter from 14 inches at the penstock to 10 inches at the giants. Two No. 2 Kendall giants with No. 3 nozzles operate under heads of 95 to 120 feet. The gold-saving apparatus consists of 10 sluice boxes, set with longitudinal pole riffles, 4 poles wide and 6 feet long, 2 sets to each box. The head box was set on a grade of 14 inches to the box length, the second box on a 12-inch grade, the third on a 10-inch grade, and the remainder on a 9-inch grade. Most of the gold is caught in the first two boxes.

Sluicing operations in 1911 began about June 25, when 10 men were at work on the property; later in the season this force was much reduced.

FALLS AND TRAIL CREEKS.

Using an Empire drill with a 4½-inch casing, the Houston Dredge Co. drilled 20 holes in 1911 in the flats along Falls Creek between Lower Trail and Kenai lakes. The unconsolidated material in the flat between the two lakes is composed partly of morainic and fluvio-glacial material deposited by the former Trail Creek Glacier and partly of recent outwash-fan deposits of Falls Creek. The depth to bedrock as determined by the drill holes varied from 10 to 23 feet. The material passed through is reported as principally gravel, but contains some bowlders too large for a dredge to handle. In some of the holes prospects were found all the way from surface to bedrock, but no definite pay streak was located and, from the nature of the deposit, it would be expected that its gold would be widely disseminated.

SIXMILE CREEK DRAINAGE.

Placer mining on Sixmile Creek, a tributary of Turnagain Arm from the south at Sunrise, was in 1911, as in former years, confined to a very few small hydraulic plants, worked by individuals and operating on high-bench gravels bordering the stream. On Canyon Creek, at a small hydraulic plant installed near the mouth of the creek, only six days' sluicing was done in 1911, a No. 2 giant under 150-foot head being used on bench gravels. The remainder of the season was spent in development work preparatory to opening up an old channel in the bench gravels on the west side of the creek. Farther upstream hydraulic operations were continued on the bench gravels on the Wible property. At the lower workings about 3 miles above the "forks" a well-defined rock-cut channel about 650 feet in length, 100 feet wide, and 30 feet deep, crossing a nose in the bedrock 150 feet above the level of the present winding channel and filled with horizontally stratified water-laid gravels, has been nearly worked out. Considerable work was also done on high-bench gravels near the mouth of Pass Creek.

But little active mining was in progress on Mills Creek during the past season. A short distance above its junction with Canyon Creek a hydraulic outfit using two giants, a No. 1 and a No. 2, piped off a small low bench about 15 feet above the creek level. Four men were employed during part of the season. Operations were discontinued in the latter part of August, when the water supply from Moose Creek became insufficient for hydraulic purposes. On Mills Creek, above the junction of Juneau and Mills Creek, a few scattered placer claims were worked and some prospecting done.

On Gulch Creek, a small stream tributary to East Fork, about a mile above its junction with Canyon Creek, two hydraulic outfits were in operation in 1911. The smaller of these two outfits, in operation the entire season, was at work on a low bench, about 20 feet above the creek level, at the junction of Gulch Creek and the East Fork. The gravel, which varies from 10 to 15 feet in thickness, rests on a smooth bedrock surface. The gravels are very compact, with clayey cement and a few clayey streaks, and are roughly stratified. The pebbles and bowlders, besides the usual slate and graywacke, included an assortment of crystalline igneous rocks. The equipment consisted of an 8-inch pipe with 2½-inch nozzle. Water for the piping was collected from the sidehill drainage on the north side of Gulch Creek by a ditch 4,000 feet in length, 2 feet wide on the bottom. In the spring sufficient water is continuously available for a full pipe head, but later the supply decreases and the water is collected in a reservoir for use as required. The gravel is piped into two lead boxes and then into a string of nine 12-foot sluice boxes, 1 foot in width, set with pole riffles. The gold recovered is flat, smooth, and medium coarse to coarse, nuggets worth $70 having been found. At the upper plant, the Dunfranwald gold mines, situated a short distance above the mouth of Gulch Creek, hydraulic operations were begun on high-bench gravels early in June and discontinued about August 15. This plant was not in operation when visited. The deposit worked consisted of horizontally stratified clayey gravels, very compact in places, with beds of sandy clay, resting in an old channel cut in the interbedded slate and graywacke. Most of the bowlders appear to be under a foot in diameter. No data are at hand regarding the gold content of these gravels. Water for hydraulic operations is obtained from Gulch Creek by a large ditch about three-fourths mile in length. The gold-saving apparatus consisted of a string of 11 sluice boxes with 3-foot square cross section laid on bedrock. The two head boxes and the lowest box of all were set with steel-capped wooden cross riffles with 1½-inch spaces. The next eight boxes were set with block riffles, those in the first four boxes having a square and those in the remaining four boxes a circular cross section. One box length from the lower end an undercurrent, 6 feet wide by 12 feet long, fitted with wooden cross riffles with ¾-inch spaces, was inserted.

The shallow creek gravels, 3 to 4 feet deep, on Silvertip Creek, about one-half mile above the road crossing, were worked in 1911 by a small hydraulic outfit. The work was carried on for about six weeks by three men using 6-inch hose with a 2½-inch nozzle under a head of 60 feet. Sluicing began June 28, and ceased in August on account of insufficient water supply. The gold is reported to be similar to that from Gulch Creek, although the nuggets found are not so large. Most of the larger nuggets had quartz attached.

RESURRECTION CREEK.

Resurrection Creek, the earliest producer and the westernmost productive stream of the Turnagain Arm region, flows northward into Turnagain Arm through a broad valley, 21 miles in length, floored with a thick deposit of gravels, in which, throughout the greater part of its course, the stream has cut a deep canyon-like channel. Near the lower end of the valley the stream flat widens and a short distance below the mouth of Palmer Creek it has a width of about 1,000 feet. High gravel benches here flank the stream flat on both sides. Slate bedrock and rimrock outcrop in but few places, the stream not yet having removed all the earlier unconsolidated deposits in its course. The gold-bearing creek gravels cover the stream flat to an average depth of 7 feet, resting on a false bedrock of earlier unconsolidated fluvioglacial deposits. At the placer workings this consists of yellowish horizontally bedded clay containing some streaks of blue clay. The auriferous gravels are loose and stream laid, with but little clayey sediment. Bowlders over 3 feet in diameter are not very numerous, although a few very large ones are found. Graywacke bowlders predominate, granite bowlders and conglomerate bowlders being much less abundant. The gravels are reported to average between 45 and 50 cents to the cubic yard. No definite pay streak exists.

During 1911 these creek gravels were being worked by hydraulic methods by the Mathison Mining Co. The property known as the Texas-Oklahoma Consolidation extends from a point 4 miles above the mouth of Resurrection Creek to within 1,500 feet of tidewater. The work of 1911 was done near the upper end of the property. Sluicing was begun on May 29 and work stopped on October 8, after 127 working days, during which approximately 16,000 cubic yards of gravel were moved. An average of seven men were employed. In August but two men were at work in the pit, on account of low water in the creeks. Three miles of new ditch, 20 inches deep and 36 inches wide, was built, tapping Bedrock and Rimrock creeks and Gold Gulch for water supply, the water running through the ditch for the first time about September 10. Two miles of the ditch were constructed on a grade of one-half inch to the rod and 1 mile on a grade of 1 inch to the rod. Prior to the construction of this ditch the water supply had all been obtained from Bedrock Creek. Approximately 3,000 feet of pipe-line, ranging in diameter from 16 inches down to 11 inches, is used to lead the water from the ditch to two No. 2 Hendy ball-bearing giants with 4-inch nozzles and one No. 1 giant with a 3-inch nozzle, all operating under 315-foot heads. Occasionally a 4½-inch nozzle is used on one of the No. 2 giants. Two of these giants are used in the face of the workings and the third stacks the tailings from the sluice boxes. Only three 15-foot sluice boxes can be used, because of the low stream gradient. These are 3 feet in width and are set on an average grade of 9 inches to the box length. Pole riffles are used in the head box, where most of the gold is caught, and Hungarian vacuum riffles in the remaining two boxes. All of the gold-bearing gravel is driven into the boxes by the giants. Small bowlders are handled by a derrick and stone boat and the larger ones chained.

Near the above plant E. E. Carson has installed a small hydraulic plant on a bench on the west side of Resurrection Creek. Water is obtained from Wildhorse Creek through a ditch 1½ miles in length. The equipment is reported to consist of a No. 1 giant with a 3-inch nozzle operating under a 60-foot head of water. The gravels are similar to the creek gravels; they are horizontally bedded and rest on a clay bench. In 1911 a shortage in the water supply permitted only a short working season on these bench gravels.

CROW CREEK.

At present Crow Creek is the only important gold-producing stream on the north side of Turnagain Arm. It is 4 to 5 miles in length, heading against Raven Creek of the Eagle River drainage in a broad pass (Crow Creek Pass) 3,540 (aneroid) feet above sea level and entering Glacier Creek from the northwest, 5 miles from Turnagain Arm. A considerable part of its water is derived from several small glaciers occupying cirques in the mountains surrounding the head of the valley. From the pass the creek flows southward in a narrow U-shaped valley, bottomed with glacial till in which the stream has cut a small V-shaped gorge, to a point within about 3 miles of its mouth, where it swings sharply to the southeast, the valley broadening suddenly to a gravel-filled basin three-fourths mile long. Below this basin the creek drops into a narrow gravel-walled flat-bottomed valley, in which it flows for a considerable distance. In the remaining half mile of its course the stream flows through a narrow rock canyon in a series of rapids and falls to its junction with Glacier Creek.

Placer operations in recent years have been confined to the moraine-dammed gravel-filled basin in the upper part of the valley, and to an old buried channel at the head of the rock canyon about one-half mile from the mouth of the creek. Hydraulic plants have been installed in both places. During the past season work at the upper plant was suspended to avoid covering unworked gold-bearing gravels with tailings. The recent geologic conditions at this property have been described in detail by Moffit[1] and Paige and Knopf[2] and need not be repeated here.

Near the middle of the rock canyon of the present stream mining operations in 1904 disclosed an earlier well-developed gravel-filled channel, cut in bedrock, crossed by the present channel and apparently headed toward the gravel flat at the upper end of the present rock canyon. Most of the later development work has been confined to the removal of the unconsolidated deposits filling this channel. The property has changed hands several times. The present owners, the Nutter-Dawson Mining Co., completed in 1911, after several seasons' work, a cut through the high-bench deposits from the original point of discovery of the channel in the canyon to the gravel flat at its head. This cut, 1,800 feet in length, with a maximum depth of about 225 feet, follows the course of the old channel. The filling of this channel, up to the level of the bedrock surface at the head of the present canyon, consists chiefly of firmly cemented water-laid pebbly clays, horizontally bedded, with a few scattered bowlders in the lower portions near the rim and on bedrock along the sides and bottom of the channel. Wash gravel of variable thickness is also reported in portions of the channel. Overlying these pebbly clays is 60 feet or more of yellowish irregularly stratified sandy and gravelly beds. These high-level unconsolidated deposits, which extend for some distance up Crow Creek, have been trenched by the present stream to a considerable depth contemporaneously with the development of the rock canyon. Near the head of the present rock canyon the stream flat has an average width of 250 to 300 feet and lies about 100 feet below the top of the high-bench deposits, which here have an elevation of approximately 1,000 feet above sea level. The thickness of the stream-flat gravels is not known. A shaft 70 feet in depth is reported to have been sunk at the lower end of the flat without reaching bedrock. No record of the material passed through is available, but it appears probable that most of the section must be similar to that exposed in the cut and must have about the same gold content, and that the thickness of the stream gravels does not exceed a few feet. The completion of the big cut has demonstrated the low gold content of these high-bench fluvioglacial deposits. Exact figures are not available, but it appears that 1½ cents per cubic yard would be an exceedingly liberal estimate of the gold they contain. The higher gold content of the gravels of the stream flat is due to the concentration of the gold of the bench deposits by the

[1] Moffit, F. H., Gold fields of the Turnagain Arm region: Bull. U. S. Geol. Survey No. 277, 1906, pp. 41–43.

[2] Paige, Sidney, and Knopf, Adolph, Reconnaissance in the Matanuska and Talkeetna basins, with notes on the placers of the adjacent region: Bull. U. S. Geol. Survey No. 314, 1907, pp. 121–122.

present stream in the development of its present channel. Moffit states that the results of mining operations in 1904 in the flat above the canyon gave an average of 44 cents in gold per cubic yard of dirt moved. No further data are available.

The recent geologic history of this deposit is probably as follows: During the general retreat of the ice following the intense glaciation of the region the Crow and Glacier Creek glaciers separated. The Crow Creek Glacier retreated the more rapidly because of its smaller area of ice supply, but the Glacier Creek Glacier retreated sufficiently to allow the escape of the Crow Creek waters, which cut a gorge of considerable depth in the bedrock. A later advance of the Glacier Creek Glacier, accompanied probably by a slight advance of the Crow Creek Glacier, ponded the Crow Creek waters with a resultant deposition of their load and the filling of the gorge and of part of the valley with waterlaid sediments. With the final retreat of the glaciers to their present position Crow Creek cut a new channel through the fluvioglacial deposits, deviating somewhat from its former channel and exposing the latter where the channels cross.

Water for the present hydraulic plant is taken from Crow Creek by a ditch 5,700 feet in length, 6 feet wide at the top, 4 feet wide at the bottom, and 4 feet deep. A pipe line 3,000 feet in length, 24 inches in diameter at the intake and 15 inches at the giants, carries the water to three No. 7 Hendy giants, with 7 and 8 inch nozzles, operating under heads varying from 300 to 350 feet according to their position in the cut. The gold-saving apparatus consists of a bedrock sluice 600 feet in length, set in the bottom of the old channel, with boxes 5 feet wide by 4 feet deep placed on a grade of 9 inches to the box length. Twelve-inch cube hemlock block riffles are used in the boxes. Two box lengths from the lower end of the sluice two parallel 6-foot undercurrents have been installed. The tailings are dumped into the rock canyon of the present stream at the intersection of the two channels. Fifteen to twenty men were employed on the property during 1911.

GOLD PLACERS OF THE YENTNA DISTRICT.

By Stephen R. Capps.

EXPLORATION.

The Yentna district, as the name is commonly applied, embraces all the area that drains directly to Yentna River except the basin of Skwentna River, the largest tributary of the Yentna. The higher parts of the Alaska Range in the Yentna basin are so inaccessible that they are still unexplored, and the lower portion of the basin, which forms a part of the great Susitna Valley lowland, is a heavily timbered, brushy flat which offers little attraction for either the prospector or the geologist. The region covered by this report has therefore a roughly triangular shape, one side lying along the Yentna Valley, the second stretching along the Susitna lowland, and the third lying parallel to the Alaska Range and including its more accessible parts (Pl. VIII). A more complete report, including a discussion of the geology and the mineral resources of the region and a geologic map, is now in preparation.

Since 1905, when gold was first discovered in this region, prospecting and mining have been carried on continuously by which gold has been found to be widely distributed through the area, yet it has been obtained in paying quantities only in the so-called Cache Creek country, in the basin of Twin Creek, and at a few points in the valleys of Lake Creek and Kahiltna River. A new impetus to prospecting was given in the season of 1911 by the discovery of rich placer ground in the benches above Dollar Creek. The present known economic value of the region lies entirely in its placer gold, no valuable lodes having been discovered. Lignitic coal occurs at many places but is too poor in quality to attract much attention, for better and thicker coal beds occur at easily accessible points on Cook Inlet. The coal beds, however, have some value as a source of local fuel.

Before the work on which this report is based was done little was known of the geology of the region between Yentna and Susitna rivers. In 1898 Spurr[1] ascended the Yentna to the mouth of the

[1] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 31–264.

U. S. GEOLOGICAL SURVEY

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[1] Spurr,
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Skwentna, but in his journey along that stream was able to obtain little information in regard to the geology of the country to the north. During the same year Eldridge[1] made an exploratory trip up the Susitna and into the Tanana basin, and recorded many facts concerning the geology of the range in the northern part of the Susitna basin. In 1902 Brooks and Prindle[2] went up the Kichatna and obtained a geologic section of the Alaska Range along their route. In 1906 R. W. Porter made a topographic map of the Yentna district, and this, with some additions and corrections by the writer, was used as a base map for the present investigation. The conditions under which all of these explorations were carried on, however, made it impossible to extend the geologic work more than a short distance on either side of the route of travel, and as both the Yentna and Susitna rivers lie in broad, alluvium-filled basins, with few bedrock exposures along the streams, the geologic conditions in the upland area between them were unknown, except as they were indicated by a few facts gleaned from reports of prospectors and miners who had visited the region.

GEOGRAPHY.

TOPOGRAPHIC PROVINCES.

The Yentna district, bounded by Susitna and Yentna rivers and the crest of the Alaska Range, may be roughly divided into three provinces, each having distinctive topography. The first of these includes the lowlands of Yentna, Susitna, and Tokichitna rivers. This area extends westward from the base of the Talkeetna Mountains, on the east side of the Susitna, to the foothills of the Yentna district, a distance of nearly 50 miles, and has irregular projections which occupy the valleys of Yentna, Kahiltna, and Tokichitna rivers. It lies for the most part within 600 feet of sea level, and is characterized by broad, almost flat stretches along the main streams, and by slightly rolling interstream areas. The lowlands are nearly everywhere covered by a good growth of spruce or cottonwood timber, and between the trees willow, alder, and other brush plants grow profusely. The larger streams that cross the lowlands flow in well-defined valleys and most of them are swift, but many of the smaller streams are sluggish and meandering, and the interstream areas contain many small lakes.

The second topographic province includes the foothills belt which lies between the lowland and the rugged mountains to the northwest. In this belt are the Dutch, Peters, and Yenlo hills, and the hills at

[1] Eldridge, G. H., A reconnaissance in the Sushitna basin and adjacent territory, Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900.

[2] Brooks, A. H., and Prindle, L. M., The Mount McKinley region, Alaska: Prof. Paper U. S. Geol. Survey No. 70, 1911.

the head of Twin and Camp creeks. In general, all of these hills are smooth in outline and their summits reach elevations of 3,000 and 4,000 feet, although at the north end of the Dutch Hills somewhat rougher peaks rise to a height of 5,000 feet. Between the hill ranges and around their margins is a high upland plain, cut transversely by the Kahiltna Valley and sharply trenched by many of the streams which cross it but still retaining enough of its old surface to be recognizable. Between Yentna and Kahiltna rivers this plain lies at an elevation of between 800 and 1,600 feet, and in the basin of Cache Creek it rises to a height of about 2,000 feet. Very little of this high plain is heavily timbered. Scattered groves of spruce occur in favorable localities, but most of the vegetation consists of low bushes, grasses, and sphagnum mosses.

The third region, of a very different character from the others, comprises the rugged, alpine portion of the Alaska Range. The dividing line between it and the foothills belt extends from the lower end of the Tokichitna Glacier southwestward to Yentna River, a few miles above the forks of the stream. The mountains of the lower, southeast portion of the alpine belt have elevations of about 4,000 feet, but the height and ruggedness of the range increase abruptly to the northwest, culminating in Mount Foraker, 17,000 feet high, and Mount McKinley, 20,300 feet high, the loftiest peak of the continent. From the foothills to the crest of the range is a belt averaging about 25 miles in width and including an area of many thousand square miles of territory which is almost unexplored, and which, owing to the sharp, toothlike character of its ridges and to its glacier-filled valleys, is most difficult of access.

DRAINAGE.

The drainage throughout the Yentna region is tributary to Susitna River, most of it flowing to this stream by way of Yentna River, but a small area being drained by the Tokichitna, which joins the Chulitna. Within the Yentna district three great valley troughs transect both the mountain and the foothills belts at right angles to the trend of the range. The Tokichitna Valley, which is the shortest of these, is filled with a great glacier to within about 12 miles of the Susitna lowland. Below the glacier the river has the character of most glacial streams, being heavily charged with gravel and silt and spreading with a multitude of channels across its wide valley floor. Kahiltna River also heads in a great glacier, the upper portion of which lies in an unexplored region, but which probably receives the ice from the slopes of Mount Foraker. The glacier extends downward beyond the confines of the higher mountains and at its lower end is nearly 4 miles wide. Below the glacier the stream is turbid and spreads with many channels and sloughs across a broad flat which lies at an elevation of less than 600 feet above tide. This flat narrows noticeably about 15 miles below the glacial source of the stream, and for much of the remainder of its course to the Yentna the river flows as a single stream through a narrow canyon-like valley. Lake Creek, which lies between Kahiltna and Yentna rivers, heads in a lake in the higher mountains and flows for about 20 miles across the high upland plain in a valley cut but little below the level of the surrounding country. East of Yenlo Hills it has, like the Kahiltna, intrenched itself deeply and flows through a narrow valley having steep walls, which in places rise 300 feet above the stream. The valley broadens out and the banks become lower as the stream approaches its place of junction with the Yentna.

The third great transverse trough across the mountains and foothills is occupied by Yentna River. It heads far back in the range in glaciers which receive ice from the slopes of Mounts Russell and Dall. As this portion of the range is lower than that farther north, the glaciers are smaller, and the valley is free from ice much farther into the mountains than its neighbors to the north. Above the junction of the two main branches which form this river both streams have the characteristics of other glacial streams, with their many branching channels and wide expanses of bare gravel and sand bars. Below the junction the river maintains a much more definite channel, contains few islands, and is easily navigable by light-draft launches. The smaller creeks of the district are all tributary to one or the other of the above-mentioned streams.

ROUTES OF TRAVEL.

The only practicable route to the Yentna district is by way of Susitna and Yentna rivers. In the summer months the Alaskan Northern Railway may be used from Seward to the head of Turnagain Arm, a distance of 71 miles. From the terminus of the railroad, as well as from Seldovia and other points on Cook Inlet, launches carry both passengers and freight up Susitna River to Susitna station, which is the center of supplies for the Yentna country. Launches make occasional trips during the summer from Susitna station up the Yentna, which is navigable for light-draft boats almost to the forks of the river. The route most followed to the placer camps in the neighborhood of Cache Creek leaves the Yentna at McDougall, a small village at the mouth of Lake Creek. From McDougall a wagon road has been built which follows the east bank of Lake Creek upstream for about 15 miles and swings across to Kahiltna River. A bridge which was built across the Kahiltna in the winter of 1910–11 was washed out in the spring of 1911, so that it is necessary to swim horses at this point, travelers crossing in rowboats. Bayond the Kahiltna the trail follows the high ground along the west slope of the Peters Hills and crosses several miles of marshy ground which in midsummer is difficult to pass by horses. The Cache Creek valley is reached at the mouth of Spruce Creek and followed upward from this point.

As supplies can be transported overland much more cheaply by sled in winter than by any means in summer, almost all of the freighting is done in winter, either from Susitna station or from McDougall. From the former point the sled route follows Susitna and Yentna rivers to either the mouth of Kahiltna River or to McDougall, the route selected depending on the part of the country to be reached. Much of the freight for Peters Creek and its tributaries has been taken up Kahiltna River and Peters Creek. Practically all the freighting for Cache Creek is done by way of McDougall and the wagon road to the Kahiltna. From the trail crossing at Kahiltna River the sled route most used follows up the Kahiltna Valley for several miles and then swings up the slope to meet the summer trail a few miles south of Cache Creek.

Until 1907 this region was supplied in the summer by a pack train which used a trail from a point on Yentna River near the forks, and, following a course parallel with the base of the mountains, crossed the Kahiltna just below the glacier. It then lay along the northwest edge of the Cache Creek basin and terminated at Home Lake, in the Tokichitna Valley. This trail is now little used and, though portions of it can still be distinguished, it is for most of its length overgrown by brush and grass, so that one not familiar with its course would have difficulty in following it.

The diggings in the basin of Twin Creek are usually reached by way of the Yentna to McDougall. From McDougall supplies are sledded up the wagon road to a point more than halfway to the Kahiltna, where a winter trail branches to the west and follows up Lake and Twin creeks. In leaving the country in the fall the miners from Twin Creek usually build boats or rafts and float down the Yentna. From Cache Creek the trail and road are used to McDougall and launches taken from that point to Susitna station. From the headwaters of Peters Creek the trail to Tokichitna River is often followed and boats are built to descend this stream and the Chulitna to Susitna River.

VEGETATION.

One of the serious problems which confronts the miners in the various camps is the difficulty of obtaining timber suitable for sawing into lumber for sluice boxes and other mining uses, as most of the mines are located above timber line. Cache Creek valley and its branches had formerly some timber up to a point a mile or so above the mouth of Thunder Creek where a sawmill was built. Spruce trees 2 feet in diameter at the base were not uncommon. The heavy demand for logs for the sawmill has now caused the cutting away of all the best trees as far downstream as the mouth of Spruce Creek, so that a haul of at least 7 miles to the sawmill is necessary. A toll for sawing of half the logs brought in is charged the miners at this mill. Peters Creek is timbered below the lower canyon, and logs are brought from it to the diggings on upper Peters Creek and its affluents, both for lumber and for fuel. Some logs for these camps are procured also from the Tokichitna Valley. Lumber and fuel for the mines on Mills and Twin creeks are obtained from the lower reaches of these streams, a few miles below the camps.

Between June 1 and 10, grass sufficient to supply forage for horses appears at McDougall, but in the higher basins, such as that at the head of Cache Creek, the snow does not always disappear until early in July, and horse feed is not abundant until that time. From the beginning of July until the middle of September the grasses flourish with exceptional luxuriance, and good grazing may be found almost anywhere that horses can be taken.

GEOLOGY.

As the region here considered lies apart from areas which have already been studied, and as the hard rocks have failed to yield fossils, the age of the older formations represented is still uncertain. The areal distribution of the several formations is shown in Plate IX. The oldest rocks of the district consist of a series of slates and graywackes, which form the cores of all of the foothill ranges and are an important element of the Alaska Range, especially along its southeastern flank. The slates and graywackes are interbedded, in some places in about equal amounts, in other places with one or the other phase predominating. The slates range from fissile, thin cleaving rocks to more massive argillites, and the strong development of the lines of schistosity in many localities makes it difficult to distinguish the original bedding of the sediments. The graywacke beds are commonly hard and massive, and are with difficulty distinguishable from fine-grained dike rocks, for which they are often mistaken by the miners. This slate-graywacke series forms the hard bedrock of the placer camps in the Cache Creek basin.

Next younger in age than the slates are the diorites and granites and associated dikes of the high range. These cut the slates, and so are younger. The slates have undergone contact metamorphism near the large intrusive masses, and the abundant veins and stringers of quartz which are present for several miles from these bodies are probably the source from which the gold of the placer districts is derived.

Tertiary (Eocene) sediments of little-consolidated sands, shales, gravels, and some lignitic coal overlie the slates in the more favorably situated depressions between the foothill ranges and extend eastward from these hills, the beds forming the so-called "soft bedrock" of the miners. They disappear beneath the later deposits of the Susitna basin, but their structure along the slopes of the Yenlo and Peters hills and their presence in the deep canyons of Kahiltna River and Lake Creek indicate that they probably underlie much of the broad Susitna basin. Coal, which is probably from this formation, has been mined on the south bank of Yentna River, some 7 miles above its mouth. In the area near the head of Twin and Camp creeks, the coal-bearing series is overlain by a heavy deposit of stream-washed Tertiary gravel, much coarser than anything seen in the coal-bearing series itself. Exposures of this gravel are found also on the west side of Treasure Creek. The gravels are many hundred feet thick, and seem to be structurally conformable upon the coal-bearing beds. Elsewhere the coal-bearing series is overlain by the widespread blanket of glacial material which masks the older formations throughout a great part of the area outside of the high mountains. The glacial beds consist of morainic materials deposited directly by glacial ice and of gravels laid down by glacial streams. The morainic material commonly consists of tough blue clay in which gravels, bowlders, and angular pieces of rock are embedded, and in which the assortment of materials found in water-laid beds is completely lacking. Glacial striations are particularly abundant on the rocks in the glacial till of this region. The glacial gravels are most often seen as benches along the sides of the stream valleys. The glacial deposits shown on the map (Pl. IX) vary greatly in thickness, but over the area shown they are sufficiently thick to conceal the underlying formations. The latest deposits considered are the gravels of the present streams. These form narrow strips along most of the creeks of the area and in the valleys of the more important rivers cover large areas.

MINERAL RESOURCES.

GOLD PLACERS.

GENERAL FEATURES.

Placer gold is of widespread occurrence throughout the Yentna district. Fine colors of gold may be found almost anywhere along Yentna River, and some gold has been recovered along the bars of the lower Kahiltna and Lake Creek, many miles from the mountains from which it must originally have come. Gold in sufficient concentration to encourage continuous mining has, however, been discovered

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only in certain rather well-defined areas. The most important of these is the broad basin drained by Cache Creek and the headward tributaries of Peters Creek. The only other important producing camp is in the upper basin of Twin Creek. A study of the map will show that both of these areas lie between the troughs of the main river valleys. The factors which bear on the distribution of placer gold in paying quantities can not be adequately discussed for this region without first considering in some detail the former extent of the glaciers which reached so great a development along the Alaska Range, and such a study is beyond the scope of this paper. It will be undertaken later in the more complete report which is to follow. It may be said, however, that the present glaciers are only remnants of a vast ice sheet which once filled the Susitna basin and extended far down Cook Inlet. This great glacier was several thousand feet thick in the lower parts of the Yentna region, perhaps completely covering the Yenlo Hills, and leaving only the upper portions of the Peters and Dutch hills exposed, if indeed these two ranges were not also covered by the ice. At the time of the greatest glaciers an ice tongue moved southward through the broad valley of Cache Creek and a portion of this glacier pushed across the Peters Hills along the valley now occupied by Peters Creek, greatly eroding and deepening this valley, which may indeed owe its existence to erosion by glacial ice. Later, when the thickness of the vast glacial sheet had somewhat diminished, each of the many valleys of the foothill ranges was occupied by a vigorous valley glacier. The erosive action of these great slow-moving ice tongues was enormous, especially along the larger valleys, which head in the high mountains, and any placer gold that may have been concentrated in the valleys was scattered and mixed up with glacial deposits that are now spread over the lowlands. Only in places that were by their topographic positions protected from great ice erosion could the preglacial placers survive; and only in such places or in places where an unusual amount of postglacial erosion has permitted the reconcentration of the glacially scattered gold, or where erosion since the ice retreated has effected a new concentration, is gold now found in quantities sufficient to justify mining. So little is known of the more rugged portions of the Alaska Range that nothing can be said of the possibility that lodes which existed there might have supplied gold to the stream gravels. In the district around Cache Creek, where the geologic conditions are known, the heads of all the streams that carry placer gold are in valleys eroded in the slate-graywacke series. The rocks of this series contain many quartz veins and stringers, and although these have not yet been found to contain gold, it should be noted that only a small amount of prospecting for gold lodes has been done in them. Some pieces of quartz float containing free gold have been found in this region and the sluice boxes have yielded much gold to which quartz was attached, and even small pieces of quartz stringers with free gold and with fragments of the slate that formed the walls of the quartz vein. As almost all of the streams that cut the slates contain some gold, it appears highly probable that the placer gold has been derived from quartz veins in the slate-graywacke series.

In the basin of Twin Creek the conditions are different, for the gulches which have yielded the placer gold are cut into the gravels, sands, and slates of the coal-bearing series. It seems certain that the placer gold on these streams has been derived by reconcentration from the gravels of the upper part of the series. Whether or not those gravels originally received their gold from the slates is still a matter of conjecture.

Gold was first discovered in the Yentna district in 1905, and all the streams of the region on which mining is now being done have been worked steadily or intermittently for several years, no important new locations having been made. The most important development of the last year was the discovery of rich ground in an old preglacial channel on Dollar Creek, a discovery suggesting the possible existence of similar old channels in benches of near-by streams. During the summer of 1911 mining was done on Cache Creek and its tributaries, Dollar, Falls, Thunder, Rambler, Nugget, and Gold creeks; Peters Creek and its tributaries, Bird, Willow, and Poorman creeks; and Mills and Twin creeks and the small gulches which they drain.

CACHE CREEK BASIN.

FEATURES OF THE STREAMS.

Cache Creek is a rather large stream which joins Kahiltna River about 13 miles below Kahiltna Glacier. It and its larger tributaries head in Peters and Dutch hills, and its course lies through a broad, elevated trough, which runs between these ranges and is continuous from the Tokichitna to the Kahiltna, sloping gently toward the latter. Cache Creek drains the southwestern part of this trough. The many tributaries head in glaciated valleys in the hills; but on entering the broad interhill trough they pass from the slate-graywacke formation, or hard bedrock, out onto the loosely consolidated beds of the coal-bearing series which form the so-called soft bedrock. As Cache Creek in the upper part of its broad basin has an elevation of about 2,000 feet, and its junction with Kahiltna River is less than 600 feet above sea level, it falls 1,400 feet in 18 miles. It has therefore been able to intrench itself into the soft underlying formation and flows through a gorge whose walls in places rise 300 feet above the creek. Its tributaries also have made deep cuts where they cross the basin. The largest tributaries enter the stream from the northwest, and mining has been confined altogether to these streams and to the main creek.

CACHE CREEK.

CHARACTER AND EXPLOITATION OF THE DEPOSITS.

Cache Creek heads in a small glacial valley in the Dutch Hills, through which it flows for only 2 miles before it emerges into the broad and wide valley which it follows to Kahiltna River. In the hills its valley is cut in the slate-graywacke series, and the stream gravels lie upon hard bedrock. Near its head the stream has eroded its valley but little in postglacial times, but for a short distance back from the base of the hills it has cut a sharp canyon into the slates. This canyon ends abruptly at the contact between the slate series and the sands and shales of the coal-bearing formation, and from this point downstream the creek, though intrenched below the level of the broad plateau, has a wider valley floor. The valley walls, or benches, are about 50 feet high at the mouth of the canyon. At the mouth of Nugget Creek the stream bed is about 250 feet below the level of the surrounding deposits, and the depth increases to nearly 300 feet between Nugget and Spruce creeks. Below Spruce Creek the stream has a steep gradient through a bowlder-filled canyon, below which it reaches the Kahiltna Flats.

Gold was first discovered on Cache Creek in 1906, the year after the first discoveries in this region were made on the headwaters of Peters Creek. The first ground mined was at the canyon near the head of the stream on Discovery claim, which has been worked every year since. During the summer of 1911 two men were mining a short distance below the mouth of the canyon. The ground worked was that of the present stream flat and the gravels moved range from 4 to 7 feet in depth and lie upon slate bedrock. There are some large bowlders present, but most of them can be handled by one man. A short distance below the canyon the slate bedrock gives place to the coal-bearing series, which changes character within short distances, ranging from a fairly firm, gritty sandstone to soft clay shales. The pay streak is said to be rather well defined in the canyon and for a short distance below it, but spreads out in the wider valley below and is difficult to trace. The gold is rather unevenly distributed, for though most of it is found on bedrock the degree of its concentration depends somewhat on the character of the bedrock, the harder strata having retained it better than the softer. No records have been kept which would show the gold content of the gravels to the cubic yard or to the square yard of bedrock, but it is reported that the returns have averaged about $10 a day for each man employed. The sluice boxes, 14 inches wide, are set on a grade of 5 inches to the box length. The gravels are groundsluiced by the aid of canvas hose and water under pressure from the bench to the southwest to within a foot or so of bedrock and the rest of the gravel is shoveled in and bedrock cleaned by hand. The stream at "Discovery" claim can be depended upon to run a sluice head of water for the boxes used throughout the season and most of the time flows two sluice heads. The gold is coarse and bright and somewhat worn, though many pieces are rough and some cubes of crystalline gold have been found. Pieces worth $20 have been taken from this claim, and only about one-third of the gold recovered will pass through a 16-mesh screen.

The coarseness of the gold and the roughness of some of it indicate that it has traveled no great distance from its bedrock source and it must originally have come from the quartz veinlets of the slate-graywacke series in the upper part of the Cache Creek valley. The upper valley at one time contained a vigorous glacier and ice also came into it from the head of Bird Creek, across a low divide. This glacier eroded its basin and doubtless scattered and removed any preglacial gold which may have been concentrated in its upper portion. No ground carrying commercial values in gold has been found above the canyon of Cache Creek. Toward the mouth of the slate valley the ice scour was less severe, as the glacier joined a large, sluggish ice sheet in the broad basin between Dutch and Peters hills. Here the valley deepening was not pronounced and a part of the material picked up by the ice in the upper valley was dropped. It may be that the glacial deposits here covered up portions of the preglacial channel of Cache Creek without disturbing them. With the melting away of the glacier the stream cut through the glacial deposits and at and below the canyon intrenched itself into the slates and the softer beds to the eastward. In the rehandling of the glacial material any of the gold which it contained was concentrated in the stream bed, and if the valley was cut through any undisturbed portions of the old preglacial channel, this, too, would have contributed to the richness of the present placer deposits.

The possibility that remnants of the old channel still exist in the benches is suggested by several facts which have been learned during the years that mining has been carried on here. It is said that the pay streak terminates rather abruptly at its upstream end in the canyon, although some gold has been found farther upstream. In the spring of 1911 a cut was run into the high bench at the point where the pay streak failed. The bench consists of gravels lying on decayed rocks of the slate series and overlain by 15 to 20 feet of glacial till. In groundsluicing the upper portion of this cut some gold was recovered, but most of it lay on or in bedrock. The gold was coarse, the largest nugget being worth $9. It may be that at this place there is a portion of a preglacial stream channel which contained workable placer. At the time visited the development work on the bench was insufficient to show definitely the presence of such an old channel or to give any definite clue as to its length or direction.

In 1911 two men were mining on Cache Creek about a mile above the mouth of Nugget Creek. The ground worked was on the present stream flat and ranged in depth from 4 to 7 feet. The usual number of coarse bowlders were encountered, but most of them could be readily thrown from the pit. The gravels lie on "soft bedrock," composed of the clay, sand, and soft conglomerates of the coal-bearing series. At one place the creek is crossed by a bed of lignite, which held the gold and yielded good returns. The gold in the gravels is mostly found on bedrock, the richness of the ground depending to an important degree upon the character of the beds crossed. Where the bedrock is clay, little gold is found, but the sandy and gravelly beds have retained the gold much better. A grade of 5 inches to the box length is maintained, this being less than the fall of the creek. The sluice boxes in use are 20 inches wide, and the creek at this point supplies enough water for them throughout the summer. Water under pressure is obtained from Columbia Gulch, a small tributary of Cache Creek from the north, and is carried by ditch over the bench to a point opposite the pit, to which it is conducted through 6-inch canvas hose. A working head of about 75 feet is thus obtained and a 2½-inch nozzle is used in piping the gravel into the boxes. It is reported that the returns from the season's work on this ground were not large.

In the main valley of Cache Creek mining was done at a number of points between the mouths of Nugget and Spruce creeks from 1906 to 1908. In some places the ground worked was in the present stream flat; in others the gravels on benches along the valley sides were mined. In 1908 the Cache Creek Mining Co. was organized and purchased all of the main creek valley from a point 2½ miles below Spruce Creek to the mouth of Gold Creek, a distance of more than 12 miles, as well as a number of claims on the more important tributaries. The total holdings of the company embrace more than 3,000 acres, and extensive preparations have been made for developing the ground. A sawmill has been built on the main creek one-half mile above the mouth of Thunder Creek, which furnishes lumber for buildings, penstocks, flumes, and sluice boxes; and several thousand feet of hydraulic pipe, some as large as 34 inches in diameter, has been placed on the ground. During the season of 1910 and 1911 the energies of the company were in large part directed to procuring an adequate supply of water under pressure, so that their ground could be mined by hydraulic methods. A ditch, originally designed to carry 1,500 miner's inches of water, was surveyed to tap Nugget Creek on claim "No. 7 above," but was only partly completed. Its connection with Nugget Creek was never made, but during the period of the spring run-off it receives a considerable volume of water from the melting snows on the Dutch Hills and on the broad high bench which it traverses. A second ditch, to carry 2,300 miner's inches of water, was almost completed in 1910. This ditch was to draw its water from Cache Creek a short distance below the mouth of Nugget and carry it for nearly 2 miles to a penstock, from which it was to be taken through a 34-inch steel pipe to the point where needed. The working head at the penstock was 120 feet, and this would be increased to 180 feet at the sawmill. In building this ditch some slumping ground was encountered, and during the summer of 1911 the lower portion of the ditch was abandoned, and the water was carried from the completed portion to the so-called Pineo Bar through steel pipe.

In 1910 mining was carried on at two localities by this company. The upper one of these, on Pineo Bar, lies about halfway between the mouths of Nugget and Thunder creeks. The ground worked is a few feet above the present level of Cache Creek, and the gravels lie upon the sands, clays, and conglomerates of the coal-bearing series. In the bluffs on either side of Cache Creek the beds are seen to lie with only a slight inclination from the horizontal, but on the northwest side of the stream there has been extensive slumping, and the strata shown in the exposures of bedrock in the cut stand nearly vertical. The bench gravels here are certainly deposited upon a slumped portion of the valley wall. In 1911 work was continued at this place, but nothing was learned in regard to the gold recovered per cubic yard of gravel moved.

In 1910 a portion of the bed of Cache Creek was worked at a point near the mouth of Rambler Gulch. The creek was here flowing close to bedrock, and by diverting the stream from its channel during low water bedrock could be cleaned by removing only a thin layer of gravel. Gold was recovered here in considerable amounts, but its distribution was irregular, depending upon the character of the bedrock. Wherever the stream crossed a sandy or conglomeratic bed the gold had lodged, but the clayey beds were almost bare, the gold having passed on over them to find a more favorable resting place on the rougher bedrock. It is said that one working upstream could predict when a clayey bed was to be crossed by the exceptional richness of the sandy or gravelly portion of the bedrock just below. In 1911 a cut was run from the mouth of Rambler Creek up that stream for about 700 feet. A portion of the ground at the mouth of the creek was mined by pick and shovel, but that farther up was piped in by means of hydraulic giants. The depth of gravel was irregular, ranging from 18 inches to 10 or 12 feet, and the surface of the soft bedrock was uneven. At the stream mouth the gold was recovered from a bedrock of rather firm conglomerate, called cement rock by the miners, but farther upstream the beds of the coal-bearing series were encountered, the clayey shales predominating, with some sandy and gravelly beds and a little lignitic coal. These beds are tilted at various angles, and have evidently been affected by slumping. For the lower end of the cut water was supplied to the 3-inch nozzles from Rambler Creek, with a head of about 60 feet. Later in the season water was secured from the upper end of Lucky Gulch, with a head of 230 feet at Cache Creek. The dirt was piped into 24-inch boxes, set on a grade of 6 inches to the box length. At the upper end of the cut the values are reported to have decreased and work was discontinued, the plant being shifted to a bench on Cache Creek about 400 feet above the mouth of Rambler Creek. Here the surface of the gravels lay about 10 feet above the level of Cache Creek and the depth to bedrock averaged about 6 feet. Large bowlders were not common in this cut, and those encountered all lay upon bedrock. The value of the gold recovered is said to have averaged approximately $1.50 to the cubic yard of dirt moved.

GOLD CREEK.

Gold Creek is the uppermost tributary of Cache Creek from the north, and lies between the head of Cache Creek and Nugget Creek. It is a small stream, its total length being only 1¼ miles, its upper end heading in the slate hills and its lower portion flowing through a valley cut in the coal-bearing series. Gold was first discovered on it in 1909 near the point at which it passes from the slate onto the softer deposits. At this point the valley is narrow and V-shaped, the gravels to be mined rarely having a width of more than 20 feet. The depth to bedrock ranges from 2 to 6 feet, the gold being found on bedrock or in the crevices of the slates, which are here standing on edge. The gold is coarse and shotty, pieces up to $14 in value having been found. Its assay value is $17.81 per ounce, of which $0.06 is in silver. No mining was being done on this ground in 1911.

NUGGET CREEK.

Nugget Creek is the uppermost large tributary of Cache Creek, joining it a few miles below its head. Its source is in the Dutch Hills, through which it flows in a wide, straight, U-shaped valley, which shows strongly the erosive action of the great glacier that once occupied it. In the hills the basin of Nugget Creek is composed of the rocks of the slate-graywacke series, and the stream flows in a postglacial canyon which is shallow toward the valley head but which becomes narrower and deeper downstream. At the point where it leaves the slate hills the creek occupies a canyon cut 200 feet into the rocks, but at the base of the hills the slates give place to the softer rocks of the coal-bearing series, and through these the stream has widened its gorge, though the valley walls are high and steep throughout the remainder of its course to Cache Creek.

Gold was first discovered on Nugget Creek in 1905 and the ground first worked was in the lower portion of the rock canyon. Since that year mining has been carried on in the valley each summer. The claims lying immediately above the mouth of the canyon, known as Nos. 1, 2, and 3 below, have yielded the greatest part of the production and are now practically worked out, but a considerable area of ground which is known to contain paying quantities of gold remains unworked.

During the summer of 1911 mining was done on this creek by four parties. The largest camp, consisting of 10 men, was on No. 4 below, the ground worked lying a short distance below the mouth of the slate canyon. The stream gravels are from 6 to 8 feet thick, and lie upon the soft bedrock of the coal-bearing series. The gold is recovered principally from the gravel within a foot of bedrock and on the bedrock itself, which is of sandy or clayey material or loose conglomerate. The gold is very coarse, somewhat rusty, and moderately worn and smoothed. Nuggets worth $16 have been found below the canyon, and in the canyon one worth $60 was recovered. Simple mining methods are used, the upper portion of the gravels being groundsluiced off by means of water under pressure, delivered through canvas hose, with a head of 70 feet. The gravel immediately above bedrock and a part of the bedrock itself are shoveled by hand into 14-inch sluice boxes.

Above the present stream flat, at the mouth of the canyon, portions of the former valley floor of Nugget Creek appear as terraces or benches, seven of which can be distinguished. Workable placer has been found on a number of these benches, and one bench, 170 feet above the stream, was being mined at the time of visit. The gravel here, which was from 1 to 6 feet deep, lay on slate bedrock and is said to have yielded much gold. None of the benches, however, is large and the amount of paying ground on them is small.

Three men were engaged in mining at the junction of claims Nos. 1 and 2 above, at which place Nugget Creek lies in a slate canyon about 70 feet deep. The stream is crooked and its flat narrow, only small patches of gravel appearing between the creek bed and the base of the canyon walls. The ground worked ranged from 5 to 6 feet in depth and contained a good many bowlders, most of which, however, could be moved by hand. Hydraulic methods were employed for stripping away the upper portion of the gravels, and the water was obtained from a small tributary on the northeast side of the creek and conducted through a ditch over a thousand feet long to a point above the cut, where it was delivered through canvas hose with a head of 70 feet. Bedrock here consists of slates and graywackes, which stand at high angles and strike in the general direction of the course of the creek. The gold is coarse and somewhat worn, and is unevenly distributed over the bedrock. Where the bedrock is rough, much gold is found, but where it is smooth the gold recovered is not sufficient to pay for the handling of the ground.

On claim No. 3 above two men were mining on a bench which lies some 10 feet above the level of the stream. Pick-and-shovel methods were used for getting the lower part of the gravels into the sluice boxes, after the upper portion had been removed by groundsluicing. Sluice boxes 12 inches in width were set on a grade of 8 inches to the box length, and sufficient water was to be had during the entire season. Most of the gold recovered was found on bedrock, which is here slate or graywacke. The gold is coarse, nuggets ranging in value from $1 to $6 being common. It is planned to build a ditch in 1912 to bring water under 70 feet pressure to the cut, and to install 24-inch boxes, so that a larger quantity of ground may be handled.

Claim No. 4 above was purchased by a party of three men who commenced mining in the spring of 1911. A wing dam was constructed which diverted Nugget Creek for about 300 feet, and the bed of the creek was mined by shoveling the gravel into the sluice boxes. The ground ranges in depth from 2 to 9 feet, and most of the gold was found on or near bedrock, which is here composed of the uptilted beds of the slate-graywacke series. Much of the gold is coarse, somewhat rusty and worn, and although some fine gold was recovered the greater part occurred in pieces worth from 10 cents to $3.50. The result of the season's work on this claim are reported to have been fairly satisfactory, and it is the intention of the owners to obtain water under pressure by building a ditch, and to enlarge their sluice boxes next summer.

Two parties were mining during the summer of 1911 on the Jumping Jack claim, in the valley of Nugget Creek close to its junction with Cache Creek. Two men were working on the south side of the creek and one man on the north side. The gravels here range from 3 to 5 feet in depth, lie on soft bedrock, and are comparatively free from large bowlders. The bedrock surface is irregular, being cut by shallow grooves which diverge like the rays of a fan, showing the old channels which Nugget Creek once followed as it left its own valley to join Cache Creek. The gold is irregularly distributed over bedrock, the ground being "spotted," as the miners say. The gold is brighter and finer than that found in upper Nugget Creek. The season's work showed the gold tenor of the gravels in lower Nugget Creek to be too low to warrant working by pick-and-shovel methods.

LUCKY GULCH.

About 1½ miles below the mouth of Nugget Creek a small valley known as Lucky Gulch joins the Cache Creek valley from the northwest. This valley is sharply V-shaped and has a steep gradient. It heads on the broad bench in which Cache Creek has intrenched itself and is scarcely more than a mile long. Lucky Gulch lies exclusively within the area of the coal-bearing series, and throughout its length the stream flows over "soft bedrock," which is covered by only a shallow filling of stream gravels. At times mining has been done in this gulch in a small way, but its total production has not greatly exceeded $1,000. No work was being done at the time it was visited in 1911.

RAMBLER GULCH.

Rambler Gulch joins the Cache Creek Valley three-fourths mile below Lucky Gulch, from the same side, and, like it, is short and steep and lies altogether in the coal-bearing sediments. In its upper portion the ground was shallow and easily worked, and the creek bed was worked out in the early years of the camp, a few thousand dollars in gold being obtained. In 1911 mining was resumed on the lower portion of the creek, under conditions that have already been described (pp. 186–187).

THUNDER CREEK.

Thunder Creek heads in the slates and graywackes of the Dutch Hills near Nugget Creek. On leaving the hills it bends to the south, following the general direction of the Cache Creek valley, and joins Cache Creek 3½ miles below the mouth of Nugget Creek. In its course below the hills it is intrenched below the level of the surrounding plateau, its valley lying for the most part in the beds of the coal-bearing series. For a portion of its length, however, it has cut through the softer sediments into a ridge of underlying slates. The bedrock conditions, therefore, vary in different portions of the stream's course. During the summer of 1911 one man was mining on claim No. 3 below. The gravels, which are from 2 to 3 feet deep, were groundsluiced and the lower portion was shoveled into the boxes. Bedrock here consists of the soft materials of the coal-bearing series. Some lignite outcrops in the high bluffs of the stream. The gold is bright and fairly coarse, but the pay streak is irregular and the gold content varies greatly from place to place, so that the returns are uncertain. The lower mile of Thunder Creek has been staked as an association claim, and four men were mining on the upper half of it. The gravels average about 5 feet in depth and contain few bowlders which a man can not roll from the pit. The bedrock is of varying character, at places being of the soft coal-bearing beds, and at other places appearing to be a much-weathered and decayed phase of the slate series. Sluice boxes 22 inches in width, set on a grade of 6 inches to the box length, were in use, and a 1,200-foot ditch supplied water from Thunder Creek with a head of 35 feet at the cut. Canvas hose and a nozzle were used for piping off the upper portion of the gravels, and the ground near bedrock was shoveled in by hand. The gold is bright and rough, many pieces having quartz attached to them, and seems to have traveled no great distance from its source. It assays $17.80 to the ounce, and the ground worked ran from $2 to $2.50 per cubic yard. Toward the end of the season the work was retarded by a shortage of water.

FALLS CREEK.

Falls Creek is the next important tributary of Cache Creek south of Thunder Creek. It heads in the slates and graywackes of the Dutch Hills, flows in a course roughly parallel to that of Thunder Creek, and joins Cache Creek about three-fourths of a mile south of it. At the point where it passes from the slates onto the beds of the coal-bearing series it has formed a narrow canyon and a waterfall, which suggested its name. Gold was first mined on Falls Creek in 1905, in the canyon cut through the slates, and the stream afforded considerable production for a few years. In the narrower portion of the canyon the difficulties of diverting the creek prevented mining during the season, except for a short time in the spring, when the volume of the stream was small. At the time this creek was visited in 1911 two men were preparing to sluice ground on a high bench on the northeast wall of the valley, on claim No. 3 above. A ditch 2,000 feet long to supply water under pressure was almost completed, but aside from a few small prospect pits no mining had yet been done.

DOLLAR CREEK.

Dollar Creek, the lowest large tributary of Cache Creek from the west, joins Cache Creek 2 miles below the mouth of Falls Creek. The geologic and topographic conditions in its basin are much like those on Thunder and Falls creeks. Dollar Creek flows from the slate hills at its head out onto the Cache Creek plateau in a sharply incised valley, which gradually becomes deeper downstream, until at the mouth of the creek the valley bottom lies over 300 feet below the general level of the surrounding country. Even below the border of the Dutch Hills the slate bedrock is exposed by the stream cut for some distance out onto the plateau, showing that the old slate surface upon which the soft bedrock sediments were laid down was uneven. Since 1905 placer gold has been known to be present in this stream and a few thousand dollars have been recovered from the stream gravels in the slate canyon since that time. In previous years, however, the gravels have yielded only moderate returns for the expense and labor required to work them. During the spring of 1911 two men began mining on claim No. 2 above, but finding that the pay streak in the creek ended abruptly upstream they ran a cut into the high bench on the northeast side in the hope of finding the source of the gold. In working up the valley side the miners found that slates and graywackes extended to an elevation of about 70 feet above the creek. In the creek channel the beds of the slate series are hard and firm, but toward the top they are weathered and appear as fairly soft sandstones and shales. The beds of the coal-bearing series, which are only a few feet thick, appear above the slates. Some pieces of lignite were found in the cut. Above the soft bedrock lay a bed of stream-washed gravels, from which rich pans were obtained, as much as $2.50 being taken from a single pan. Above the stream gravels the exposure showed 20 feet of typical bowlder-studded glacial clay. At the time the place was visited too little work had been done to determine exactly the conditions at this place, but the facts gathered seem to show that the stream gravels were laid down in an old channel—perhaps a former channel of Dollar Creek—before the great glacial advance, as is shown by the overlying layer of glacial bowlder clay. It is also of interest to note that there was a good concentration of placer gold in preglacial times. The gravels in the old channel are of the same materials as are now found in the stream bed, the largest bowlders being 18 inches in diameter. The material is oxidized to a yellow color, and the pebbles are somewhat decomposed, the whole being cemented into a loose conglomerate which yields with difficulty to hydraulic methods of mining. The gold is coarse, rusty, and very angular. Some pieces, which seemed to be small nuggets, were found on close examination to consist of a large number of small grains cemented together by iron oxide. It is reported that the developments later in the summer showed that the gravels occupy a distinct channel, which diverges upstream from the present valley of Dollar Creek, although it was traced for only a short distance. It is also reported that two distinct pay streaks were found in the gravels, one a few feet above the other, and that the gold was associated with much broken, angular quartz, indicating the possibility that it came from a vein at no great distance. The season's output from this mine is said to have been highly satisfactory, and preparations were being made to install a hydraulic plant so that operations could be conducted on a larger scale.

PETERS CREEK BASIN.

PETERS CREEK.

Peters Creek occupies a valley intermediate between Kahiltna and Tokichitna rivers and in its upper portion is roughly parallel to these two streams. It heads in a broad, severely glaciated, U-shaped valley in the Dutch Hills, emerges from them to cross the Cache Creek Plateau at a right angle, crosses the Peters Hills through a deep, transverse trough, and enters the broad lowland of the Susitna Valley, the west edge of which it follows to its junction with Kahiltna River. Its total length is more than 35 miles. In its course through the higher parts of the Dutch Hills it flows in the bottom of the glacial trough in a channel which has been notched little or not at all into the slates and graywackes of these hills. In the more easily eroded coal-bearing beds of the Cache Creek plateau it has intrenched itself deeply in a canyon-like valley that extends headward into the slates for some distance above the mouth of Bird Creek, and a similar canyon extends for more than a mile up Bird Creek. As the Cache Creek plateau slopes downward toward Peters Hills, the stream valley becomes shallower and wider in that direction, but on entering the valley through these hills the creek again flows through a rock canyon. This second slate canyon terminates at the east border of the Peters Hills, the stream once more flowing between valley walls of the coal-bearing series, the banks gradually becoming lower downstream through the little known area of the Susitna lowland to the south and east.

Gold was discovered at a number of places on Peters Creek and its affluents in 1905, and mining has been done on that creek each summer since that time. In 1911 work was in progress at two places on the main stream. At the mouth of the canyon through Peters Hills, a short distance above the point at which the stream passes from the slates onto the soft bedrock, two men were mining on a bench about 30 feet above the stream level, where a few feet of gravel lies upon a slate bedrock. Water under a pressure of 70 feet, brought by ditch and canvas hose, was used for piping the gravels into the sluice boxes. The gravels contain rather abundant bowlders, and at the time the place was visited some of the ground was still frozen. The gold, which is for the most part concentrated on bedrock, is coarse, flat, worn, and somewhat rusty, and gives evidence of having traveled some distance from its source. The largest nugget found weighed 9 pennyweights, and the gold assayed about $17.75 to the ounce. The ground worked in 1910 was a short distance downstream from that worked in 1911, on a bench only a few feet above the stream. The bedrock at this place is a hard, rusty dike intruded into the slate. Prospect holes in the creek gravels below the canyon show placer gold on soft bedrock, but the gradient of the creek is too low and the ground too deep to permit mining by pick and shovel.

The bedrock source of the gold in lower Peters Creek is still open to question, but this gold, like that in the other parts of this district, was doubtless derived from the quartz stringers in the slates and graywackes. In lower Peters Creek some of the gold may have come directly from the rocks of Peters Hills through which the valley is cut, but as gold is found in the stream gravels above the Peters Hills and up to the head of the stream it seems probable that the present placers are in large part the product of reconcentration of gold that was scoured from the upper tributaries of the stream by glacial ice, scattered throughout the valley, and again reconcentrated by postglacial erosion.

About three-fourths mile below the mouth of Bird Creek, at the lower end of the upper rock canyon of Peters Creek, two men were mining near the contact of the slates with the soft bedrock. A dike of a crystalline intrusive rock crosses Peters Creek at this place. The creek gravels average about 6 feet in depth, and the gold is concentrated on or near bedrock. At the time the creek was visited in 1911 little ground had been mined, but the claims between the mouth of the canyon and Bird Creek are said to have produced a few thousand dollars altogether.

BIRD CREEK.

The valley of Bird Creek, a tributary of Peters Creek, lies altogether in the slates of Dutch Hills and is but little more than 2 miles long. Its head is a broad cirque, which was once occupied by a glacier that evidently joined the valley of upper Cache Creek. Bird Creek, however, turns northward from this broad valley, and in the last mile of its course flows through a narrow postglacial canyon. The canyon walls show excellent exposures of the slate and graywacke series, which at several places are cut by light-colored dikes. Gold is being mined at three places in the canyon. At the upper place, on the fourth claim above the mouth of the creek, the stream flows in a narrow gorge, which is 80 feet deep. The gravel benches are from 1 to 3 feet deep and are of small area, as in many places the stream fills the canyon bottom. Most of the gold mined has been recovered by diverting the stream with wing dams and cleaning the bedrock in the stream channel, much gold having penetrated a foot or two into the crevices of the slates. The gold is coarse and rough, and assays about $17.90 an ounce. One man was working on this ground in 1911. The gold is irregularly distributed, rich spots being succeeded upstream or down by barren ground, so that the returns are uncertain.

One man was mining on claim No. 3 above, and one on No. 2 above, under conditions much like those described for claim No. 4 above. The ground is 4 to 5 feet deep and is worked by groundsluicing and shoveling in. The slates are very irregularly bedded and great care must be exercised in cleaning bedrock, as the gold penetrates deeply into the cracks. At one place where a dike crosses the creek gold was found in crevices 5 feet below the stream bed. The gold is bright and coarse, and although many pieces are worn smooth much of it is rough and angular. The great drawbacks to mining are the irregular distribution of the gold and the large percentage of bowlders in the stream gravels.

The rock walls of the canyon of Bird Creek are in many places capped by a heavy layer of glacial clay from which some gold has been recovered, but not enough to encourage its further exploitation.

COTTONWOOD CREEK.

The only important tributary of Peters Creek from the north is Cottonwood Creek, which flows close to the west base of the Peters Hills and which itself has two western tributaries of economic importance.

Willow Creek.—The lower tributary of Cottonwood Creek is Willow Creek, which heads on the southeast flank of Dutch Hills and flows for about a mile through a slate valley, below which it is intrenched in the coal-bearing beds to its mouth. Gold was first found on Willow Creek in 1906, near the contact between the slates and the soft bedrock, and mining has been in progress on this stream each season since. In 1911 claim No. 1 below was being worked by five men. As the volume of the stream diminishes greatly toward the end of the summer it is the practice to groundsluice off as great an area in the period of early spring flood waters as can be mined during the remainder of the season and to clean up bedrock later, when the water is low. Water from a high ditch that gave 30 feet pressure at the cut was used in stripping off the upper gravels. The gravels mined are from 6 to 8 feet deep, and the gold is recovered from a soft, sandy bedrock. It is coarse, rusty, and somewhat worn, and assays $17.85 an ounce.

On Discovery claim 11 men, working in two shifts of 10 hours each, were mining by pick and shovel methods on ground a short distance below the mouth of the slate canyon. The ground was from 6 to 8 feet deep, and most of the gold was concentrated on soft, sandy, or gravelly bedrock. The work at the cut was hampered by the low grade at which the boxes had to be set, as it had been necessary to build a wall at the lower end of the claim and to pile tailings in order to keep from covering the ground on claim No. 1 below. The gold is bright, somewhat worn, and very coarse, nuggets having a value of $30 having been found and pieces weighing one-half ounce being common. The operations on this claim in both 1910 and 1911 were very successful, although a shortage of water in the fall of 1911 reduced the output below what it otherwise would have been.

A number of small tributary streams of Willow Creek, known as Rocky, Snow, Slate, and Falls gulches, all in the slates of the upper portion of the basin, have at times been mined in a small way. The total production of all four, from 1906 to 1911, inclusive, is estimated at between $7,000 and $8,000.

Poorman Creek.—Poorman Creek lies northeast of Willow Creek and is roughly parallel to it, joining Cottonwood Creek about 2 miles above the mouth of that stream. The gulches at its head have cut down into the rocks of the slate and graywacke series, but for most of its length it crosses the soft coal-bearing beds and is intrenched into them. Discovery claim lies across the contact between the slates and the soft bedrock. It was staked in 1906 and has been mined every year since that time. The greatest production was in 1907, when six men working for only a short season and with a very small supply of water, recovered 1,329 ounces of gold. The gravels mined that year lay on slate bedrock, and the ground was very shallow, so that it was quickly worked out. Since that year most of the work has been done on the lower portion of the claim, where the gravels are in places 11 feet deep and lie on soft bedrock. Some mining has been done on the benches above the present stream flat, and paying ground has been found on them. The creek gold is coarse and much of it is dark colored and rusty. Pieces valued at $33 have been found. The bench gold is brighter and not so coarse as that in the stream bed.

Claim No. 1 below and a fractional claim between No. 1 below and No. 2 below have been mined by the owner since 1906, but at the time the place was visited he and another man were working on the upper end of No. 2 below, by groundsluicing and shoveling in. The gravels are from 8 to 11 feet deep and lie on a loose conglomerate of the coal-bearing series. A bed of lignite, which crosses the creek on claim No. 1 below, has furnished some fuel for the camp. The gravels are nowhere exceptionally rich, but the gold is said to be evenly distributed in them across the whole width of the flat, a distance of 150 feet in places, and might be profitably recovered if some more economical method of mining could be employed. The gold, most of which occurs in the lower 3 feet of gravels, is coarse, rusty, and worn smooth. The largest nugget found had a value of $28. The small flow of Poorman Creek has always hindered mining during the later half of the season.

TOKICHITNA BASIN.

A tributary of the Tokichitna, known as Long or Dog Creek, heads in the broad plateau near the head of Cottonwood Creek. In 1908 three men mined successfully on this stream, the gold being found on slate bedrock. In 1910 an attempt was made to continue mining here, but the depth of gravels increased abruptly in the stream bed, and a deep excavation made by groundsluicing with an automatic dam failed to reach bedrock. The production in 1911 was therefore light.

LAKE CREEK BASIN

LAKE CREEK.

Lake Creek is a large stream, 40 miles long, which heads in a lake in the high mountains between Yentna and Kahiltna rivers and flows over a high plateau in the upper half of its course. Throughout the lower half of its course it is intrenched in glacial materials and beds of the coal-bearing series, flowing in a canyon which in places has a depth of 300 feet. In the headward portions of its basin gold has been found in many places, but in sufficient quantities to mine only in the basin of Mills Creek. In the lower intrenched portion of the valley some gold was recovered from the stream bars several years ago, but no permanent camps were established. It is reported that in 1911 one man was mining gravels on a bench 50 feet above the stream, about 12 miles from its junction with Yentna River. All the gold taken from lower Lake Creek is fine and has evidently traveled far from its source. Much of it was probably taken up by the glacial ice from the higher mountains and deposited in the glacial clays and was reconcentrated by the stream.

MILLS CREEK BASIN.

Mills Creek is a tributary of Camp Creek from the west. Camp Creek, which empties into Lake Creek, drains a portion of the foothills and of the high plateau between that stream and Yentna River. In the upper portion of Mills Creek basin only the soft beds of the coal-bearing series and their associated gravels are exposed, the rocks of the slate and graywacke series which are seen in the basins of the streams of the Cache Creek region not appearing at the surface. Gold in paying quantities has been found only in the gulches of the hills that surround the two main forks of the stream. These hills were formerly covered and smoothed by the great glacier which mantled the region, but since its retreat the streams have cut considerable valleys in the easily eroded materials of which the hills are composed.

Gold was first discovered in this basin in 1906 in Wagner Gulch, a small tributary of Mills Creek, near its head. The gulch is steep and narrow and contains only a small stream. The ground to be mined averaged only 20 to 30 feet wide in the valley bottom and was from 3 to 10 feet deep. The gold was found on a somewhat consolidated bed of gravels in the stream bed or on the sands and clays of the coal-bearing series. It is bright in color and is flat and much worn, showing evidence that it has been transported some distance from its bedrock source. This gulch is about mined out, as the pay streak terminated rather abruptly upstream. No work was done on it in 1911.

In Chicago Gulch, another tributary of upper Mills Creek, the conditions for mining are much like those on Wagner Gulch, except that the valley is smaller and steeper. The fall of the creek is about 1 foot in 6, and the stream gravels average about 20 feet in width from one valley wall to the other. Bowlders are numerous, but few are too large for one man to handle. The flow of the stream becomes small during the later part of the summer and sluice boxes 12, 10, or 8 inches wide are used, according to the supply of water. The gold is coarse, but is flat and flaky, and few large nuggets have been found. The pay streak in this gulch, like that on Wagner Creek, played out abruptly upstream. One man was mining on Chicago Gulch in 1911.

Little work has been done in the main valley of Mills Creek, as prospectors there have always had difficulty in reaching bedrock. The dryness of the season of 1911 put an end to mining on the smaller gulches at an earlier date than usual, and a number of men thus found opportunity to sink a bedrock drain in the main creek valley a short distance above the mouth of Chicago Gulch. Bedrock was reached at a depth of 12 feet, and it was reported that sufficient gold to warrant mining was found.

Twin Creek forms one of the headward forks of Mills Creek and, like it, lies in a basin composed solely of the gravels, sands, and clays of the coal-bearing series. Gold has been mined on three small tributaries known as Big Boulder, Little Boulder, and Johns creeks. They are small, steep-sided gulches cut into the soft bedrock, with steep gradients and narrow valley floors. The conditions in these gulches are like those in Wagner and Chicago gulches, already described. The stream gravels have been mined for the last six years by various people and the production, though never large, has been fairly steady.

The bedrock in the basins of Mills and Twin creeks is quite different from that in the heads of the streams in the Cache Creek region, and the same explanation of the origin and distribution of the placer gold can not be applied to both areas. In the Cache Creek district all the producing creeks head in the slates and graywackes of the foothills ranges or flow through materials which have come from these hills, and the gold was certainly derived from the slates. The basins of Mills and Twin creeks lie altogether in the sands and shales of the coal-bearing series and the associated gravels, and the present valleys of the streams have been eroded in postglacial time. It seems certain, therefore, that the placer gold of the creeks was scattered through the deposits in which the streams are eroding and has been concentrated by them to form workable placer. Sufficient prospecting of the materials of which the hills are composed has not been done to determine their gold content, but the manner in which the pay streaks terminate rather abruptly upstream in the several gulches suggests that most of the gold is derived from certain well-defined strata in the hills and is found in the creeks only below the point at which these strata are crossed by the streams. The gold is flat and worn, having been rehandled by the streams. Its original source may have been the slates in the mountains to the northwest, but of this there is no definite evidence.

PROSPECTS.

In addition to the producing creeks already described, prospecting has been done on many streams in the Yentna district, some of which give considerable promise and may soon support a mining population. Kichatna River and its tributary, the Nakochna, which lie southwest of Yentna River, above the Skwentna, have been prospected by a number of men, and have yielded some fine gold. It is reported that these streams afford extensive areas of gold-bearing gravels suitable for dredging. Independence Creek, a small tributary of the Yentna below its forks, contains some gold and has been prospected for several seasons.

The streams between Mills Creek and Kahiltna River, including Camp, Sunflower, and Lake Creek basins, have been prospected, and though gold is present in all of them, no paying ground has so far been found. Unsatisfactory prospects have also been found on the streams between Dutch Hills and the main mountain range.

On the east side of Peters Hills, on the headward tributaries of Martin Creek, coarse gold has been found, although this drainage basin has received little attention from prospectors. The geologic conditions are somewhat similar to those on the producing tributaries of Cache Creek, and from this it would appear that this neglected area is at least worthy of more thorough prospecting.

The recovery of considerable fine gold from the bars of Lake Creek and Kahiltna River and reports that encouraging amounts of gold in the wide flats on the lower courses of these streams give hope that at some future time these streams may support a dredging industry.

SUMMARY OF PLACER MINING.

Placer gold has been mined in the Cache Creek district since 1905 and in the basin of Mills Creek since 1906. Though the region has at no time been the scene of great activity or of large production, its output has been steady and the interest in it has steadily grown greater. The population has increased from a few men in the early years to more than 100 men in 1911, most of whom were actively engaged in mining or in development work. In the Cache Creek district the gold assays from $17.70 to $18.10 per ounce, and in the Mills Creek camps it averages about $17.65 an ounce. The total output up to the present time is estimated at $383,000, of which about $63,000 was produced in 1911. These figures should be encouraging if the lack of transportation and the freight charge of 10 to 15 cents a pound for all supplies and equipment brought to the mines are considered. Should a railroad penetrate the Susitna Valley and reduce the time and expense of landing supplies at the camps, much ground which is not now worked could be mined at a profit and the gold output of the region would be greatly increased.

COAL.

The accompanying map (Pl. IX) shows the areas over which the beds of the coal-bearing series of rocks outcrop at the surface, but it by no means indicates all the area underlain by this series, which in many places is covered by glacial materials and stream gravels. It should not be understood that all the area so mapped contains workable coal beds, for in most places the exposures are imperfect, and only a portion of the series can be seen. At many localities in the Yentna district, however, there are outcrops of lignitic coal of varying thickness. All the coal examined was of low grade and was light and woody in texture, with a black to brownish color, and would be classed as medium to low grade lignite. No coal has been mined commercially and no extensive openings have been made which show it in an unweathered state. The best natural exposures of coal are on Cottonwood Creek, a small stream near the Mills Creek mining camps; on Short Creek, a small tributary of Cache Creek; and on Peters Creek below the lower canyon. At these localities coal beds ranging in thickness from 3 to 12 feet are exposed. Coal taken from them has been used for fuel by miners in places where timber is scarce, but has no other present commercial value.

GOLD PLACERS BETWEEN WOODCHOPPER AND FOURTH OF JULY CREEKS, UPPER YUKON RIVER.

By L. M. Prindle and J. B. Mertie, Jr.

GENERAL CONDITIONS.

An area roughly blocked out by the basin of Fourth of July Creek on the east, Woodchopper Creek valley on the west, Yukon River on the north, and an ill-defined line paralleling the Yukon on the south has long been known to contain auriferous gravels. The region thus blocked out, which is here to be described, comprises more than a thousand square miles.

The town of Eagle, on the Yukon 30 miles above the eastern boundary of the region, and Circle, on the Yukon 30 miles below its western boundary, are the nearest settlements. There are steamboat landings and a few buildings at Nation, on the Yukon near the mouth of Fourth of July Creek, and also at the mouth of Woodchopper Creek. Besides these there are some scattered small mining camps back from Yukon River. The northern part of this region is readily accessible from the Yukon, but in the parts that are remote from that river the means of communication are still very primitive. Trails and winter sled roads lead up most of the principal creeks.

Some mining was probably done in this region as early as 1898, but the developments here to be noted have been made chiefly during the last six or seven years. The incomplete data at hand indicate that the value of the total gold production of the region to date is less than $150,000, the greater part of which has come from Mineral Gulch, a tributary of Woodchopper, and from Fourth of July Creek. Some gold has been taken from Coal Creek and a little from tributaries of Washington Creek. In 1911 placer mining was being done on Woodchopper, Coal, and Fourth of July creeks and employed about 30 men. The long-continued drought, which resulted in low water in the streams depended on for sluicing, seriously interfered with mining, and consequently the gold output was very low.

SURVEYS AND INVESTIGATIONS.

The accompanying sketch map (Pl. X) includes data obtained by Geological Survey parties at different times. Most of the drainage shown has been taken from the map of the Circle quadrangle, which is based on accurate topographic surveys made in 1903, 1904, 1905, and 1908. The basin of Fourth of July Creek and vicinity, however, has not been covered by instrumental surveys, and its drainage as indicated on the map is based on foot traverses and is therefore only approximately correct.

Among the previous geologic workers in this field whose results are here utilized are Collier,[1] who investigated the Tertiary coal measures of Washington Creek; Brooks and Kindle,[2] who studied the Yukon section; and Brooks,[3] who has reported on the placers of Woodchopper and Washington creeks. The senior writer[4] in 1903 traversed the southern part of the area here to be described, and in 1911, assisted by Mr. Mertie, made brief visits to parts of the basins of Woodchopper, Coal, and Fourth of July creeks.

The region considered is bounded on the north by the Yukon Valley, which here has a winding course, resembling incised meanders. In this region the valley is from half a mile to a mile wide, but a few miles below the mouth of Woodchopper Creek it widens out to merge into the Yukon Flats. It is bounded by steep walls which rise to an upland about 800 to 1,200 feet above the water. Into this upland the streams, such as Woodchopper and Fourth of July creeks and their tributaries, have incised sharply-cut narrow valleys, and the interstream areas, which are remarkably even-topped, rise southward from the river. Along an irregular line from 10 to 25 miles south of the Yukon the flat-topped ridges give way to an upland of much stronger relief, made up of an intricate system of high ridges and spurs and some prominent peaks, of which Mount Sorenson (5,620 feet) and Twin Mountain (5,660 feet) are the highest. This part of the region has a minutely ramifying drainage system, the streams traversing open valleys whose slopes are much more gentle than those of the valleys nearer the Yukon.

All the area is drained to the Yukon by parallel streams which maintain northerly courses. Charley River, the largest of these, traverses the central part of the field, but most of its drainage basin lies outside the region here considered.

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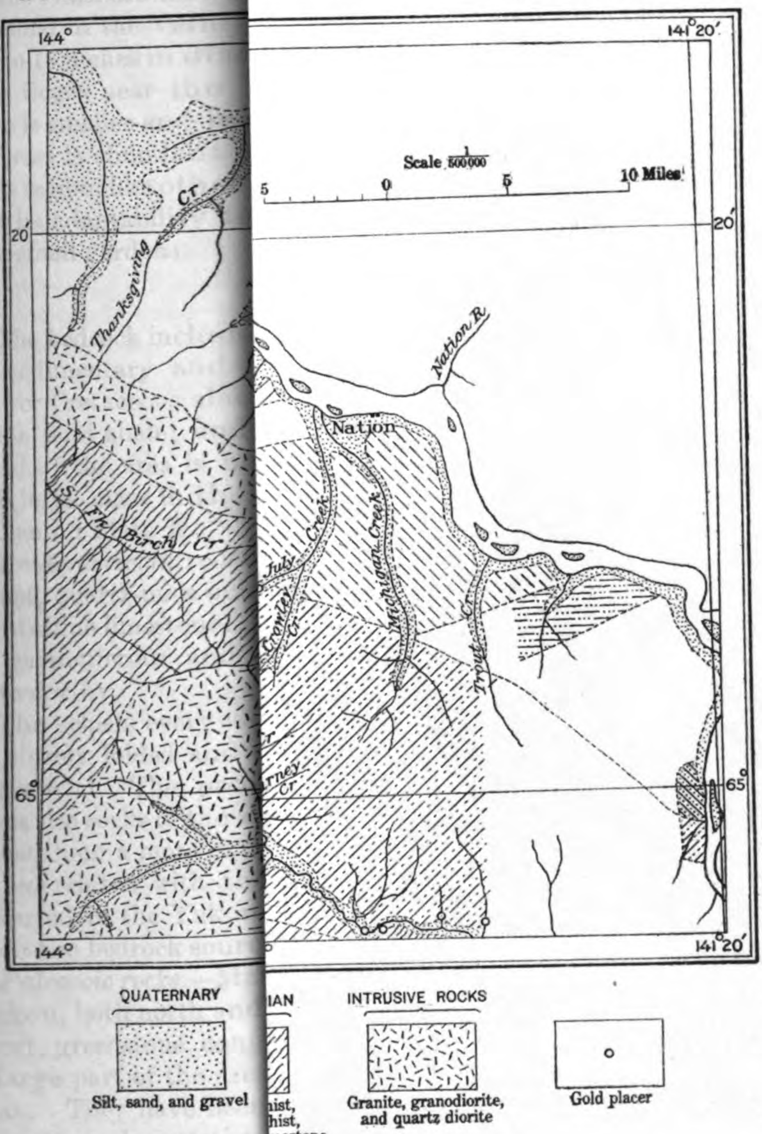
[1] Collier, Arthur J., The coal resources of the Yukon, Alaska: Bull. U. S. Geol. Survey No. 218, 1903, pp. 28-29.

[2] Brooks, A. H., and Kindle, E. M., Paleozoic and associated rocks of the upper Yukon, Alaska: Bull. Geol. Soc. America, vol. 19, 1908, pp. 255-314.

[3] Brooks, Alfred H., The Circle precinct: Bull. U. S. Geol. Survey No. 314, 1907, pp. 198-204.

[4] Prindle, L. M., Description of the Circle quadrangle: Bull. U. S. Geol. Survey No. 295, 1906.


144°
141°20′
Scale 1/500000
5
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Thanksgiving Cr
Nation R.
Nation
S. Fk Birch Cr
July Creek
Crowley Cr
Michigan Creek
Trout Cr
Cr
rney Cr
65°
144°
141°20′
QUATERNARY
IAN
INTRUSIVE ROCKS
Silt, sand, and gravel
hist,
hist,
mestone
Granite, granodiorite, and quartz diorite
Gold placer

Y CREEKS.

VEGETATION.

A large part of the region stands above timber line, which is here at an altitude of about 2,500 feet. The valleys in the highland area to the south are but scantily timbered with spruce. The best timber is found in the valley bottoms, near the Yukon, where spruce trees up to 18 inches in diameter yield the timber needed for use in mining. The ridges near the Yukon are also forest-covered, but the spruce here is smaller and is serviceable chiefly for fuel.

Grass is abundant in the open valleys and also above timber line. This region, like other parts of the Yukon basin, will grow some crops, but its adaptability to agriculture has thus far been tested only by a few small gardens.

GEOLOGY.

The bedrock includes schists, regarded as pre-Ordovician; a variety of sedimentary and volcanic Devonian and Carboniferous rocks; Lower Cretaceous slate and sandstone; Tertiary conglomerate, sandstone, and shale; and Quaternary silt, sand, and gravel. Nearly a third of the area is made up of intrusive granitic rocks, which form one large mass in the southwest. The distribution of these rocks is shown on Plate X.

Pre-Ordovician rocks.—The pre-Ordovician rocks include quartzite schist, quartz-mica schist, hornblende schist, carbonaceous schist, and crystalline limestone. The occurrence in the western part of the area of garnetiferous and staurolitic varieties of quartz-mica schist is noteworthy.

The schists everywhere show complex structure. They have been so closely folded and overturned that many of the folds are nearly horizontal. The predominant characteristic, differentiating them from the rocks of the succeeding group, is their content of mica, which gives them a more or less glistening appearance. These rocks are to be correlated with the Birch Creek schist, which is so widely distributed in the Yukon-Tanana region. There is evidence that they were the bedrock source of some of the gold now found in the placers.

Paleozoic rocks.—Many kinds of Paleozoic rocks lie adjacent to the Yukon, both north and south of the river. These include shale, slate, chert, greenstone, conglomerate, and limestone. These rocks occupy a large part of the area shown on the map. Their structure is complex. They have been closely folded, but do not exhibit the metamorphism characteristic of the pre-Ordovician rocks. Some of them are definitely known to be of Devonian and Carboniferous age (the latter including Nation River and Calico Bluff formations), and it is probable that they include also Silurian rocks. The most prominent members of this group are greenstones, which form rough, irregular ridges close to the Yukon, and massive limestones, also found in the vicinity of the Yukon, conspicuous both by their light color and by the precipitous slopes of the spurs in which they occur.

The areas occupied by the unaltered Paleozoic sediments have not, as a rule, been regarded as favorable localities to search for placer gold. On the other hand, some of the associated greenstones are known to be mineralized, and the sediments themselves may be mineralized where intruded by igneous rocks.

Mesozoic rocks.—The Lower Cretaceous rocks are closely folded slate, sandstone, and quartzite. Some of the slates in the lower part of the valley of Washington Creek contain quartz veins, which, according to Brooks, are most probably the source of some of the placer gold found on tributaries of Washington Creek.[1] The following statement is quoted from his report:

> This occurrence, though probably of small commercial import, has a far-reaching significance, as it indicates that there has been an intrusion of mineralized veins since these younger rocks were deposited. The writer is, however, of the opinion that this mineralization is not general enough to encourage the search for placers where these Cretaceous slates form the country rock.

Tertiary rocks.—The rocks of Tertiary age are predominantly conglomerate, but include less extensive beds of slate, sandstone, and interbedded lignitic coal. The conglomerate is the most conspicuous member of this division. It is composed principally of red, green, and black chert, quartzite, and vein quartz, though it contains some pebbles of schist or granite. The largest pebbles are about 5 inches in diameter. The beds of conglomerate are massive, and their total thickness probably exceeds 1,000 feet. Folding has been close, and in places along Seventymile River the beds are vertical. In other places the beds are nearly horizontal. The conglomerate weathers easily to gravel resembling stream gravels, and the surface of the high ridge between Seventymile River and Fourth of July Creek is composed of gravel derived from the underlying conglomerate. In this area the width of the conglomerate north and south is about 10 miles. The occurrence of the conglomerate also on Washington, Coal, and Woodchopper creeks suggests that it forms a continuous belt from Seventymile River to Woodchopper Creek and beyond toward Circle.

The economic importance of this conglomerate has been emphasized by Brooks,[1] who writes:

> There appears to be a fairly well defined belt of conglomerate running parallel to the Yukon from Seventymile Creek to Birch Creek, near the big bend. Both in the Seventymile basin and on Woodchopper Creek placers have been found which must have derived their gold from this rock. Therefore the conglomerate must, in part at least, be auriferous.

[1] Brooks, Alfred H., Bull. U. S. Geol. Survey No. 314, 1907, p. 199.

This conglomerate was probably laid down in Tertiary time, after the mineralization of the older rocks, and its gold content is comparable to that of the present placers. Such auriferous conglomerates have long been known in the Yukon region, having first been noted by Spurr, who termed them "fossil placers." There is no evidence that the conglomerate itself carries sufficient value to pay for milling, though this is not impossible. The fact that the associated placers are only of moderate richness argues against any considerable values being found in the parent rock.

Much of the conglomerate is only loosely consolidated and weathers so readily that it is easily mistaken for high-bench gravel. As a result prospectors sometimes assume that it marks an old river channel and expect to find very rich leads. Though it is not impossible that the conglomerate represents the deposit of an old watercourse, it by no means follows that such a deposit would be any richer than the placers of the present stream. The term "old channel" has a very alluring sound to those who are familiar with the occurrence of gold in California. Even if this conglomerate should locally be found rich in gold, only such parts of it as are decomposed could be mined by placer methods. Therefore the gold in it, except where it has served to enrich present streams, has now no commercial significance.

Quaternary deposits.—The unconsolidated materials include silt, sand, and gravel, separable into Pleistocene and Recent, according as they have been deposited on high benches, up to about 200 feet above the Yukon, or on the low benches and bottoms of the present valleys. The high-bench deposits are found mostly in the vicinity of the Yukon. The deposits of the present streams have been derived largely from the conglomerate and are described in detail under the heading "Gold placers" (pp 206-210).

Granitic rocks.—The large area of intrusive rocks shown on the map, in the southwestern part of the region, is only a part of a much larger mass. The predominant types are biotite granite, granodiorite, and quartz diorite. Some of these have cut Paleozoic rocks and have been the source of bowlders in conglomerates that are regarded provisionally as Cretaceous. It is probable that they were not intruded contemporaneously, but that some are pre-Cretaceous and some post-Cretaceous. Twin Mountain is one of the prominent points formed by these rocks. They occur near the heads of both Woodchopper and Coal creeks and have contributed material to the alluvial deposits of these streams. Garnets and staurolite, which are very abundant in the schists near the head of Woodchopper Creek, are doubtless due in part to their contact action.

A close genetic relation between the igneous intrusives and the auriferous mineralization in the Yukon-Tanana region has been established,[1] and the presence and distribution of the igneous rocks may therefore have important bearing on mineral resources.

[1] Prindle, L. M., Occurrence of gold in the Yukon-Tanana region: Bull. U. S. Geol. Survey No. 345, 1908. pp. 179-186.

GOLD PLACERS.

SOURCES OF THE GOLD.

So far as known no workable gold-bearing veins have been found in the region considered in this paper, so that the placers are the only mineral resource which need here be discussed. The placer gold has been derived in part from the Tertiary conglomerate, in part from the old schists, and in part from the Paleozoic sediments and greenstones. A little alluvial gold has also been found, which had its bedrock source in mineralized portions of the Mesozoic slates. This region therefore contains placer gold which has been derived from the four different bedrock sources of gold in the Yukon-Tanana region. The occurrences of placer gold on the different creeks will be described, so far as the data at hand will permit.

PRODUCTIVE CREEKS.

FOURTH OF JULY CREEK.

Fourth of July Creek rises about 12 miles from the Yukon, and flows northeastward throughout the greater part of its course. Crowley Creek, its largest tributary, enters it from the east about 6 miles below its head. About 4 miles farther downstream the creek leaves its valley, crosses the flat of the Yukon in a northwesterly course, and enters a slough of the Yukon. Michigan Creek, a neighboring stream on the east, which leaves its valley at about the same distance from the Yukon as Fourth of July Creek, is reported to enter the same slough only about a quarter of a mile farther upstream.

The main part of the valley of Fourth of July Creek is cut to a depth of about 2,000 feet below the level of the ridges. The stream flat throughout most of the valley is from 200 to 400 feet wide. The stream above the mouth of Crowley Creek flows close to the steep slope of the ridge limiting the valley on the east. A gentle benchlike slope on the west, about 1,000 feet wide, merges with the base of the ridge, limiting the valley on the west. The portion of the valley below Crowley Creek is mostly narrower, the upper valley being limited by steep slopes on both sides till the valley of the Yukon is approached, where the valley floor widens and merges with that of the Yukon. At this point there is a benchlike slope on the east a half mile or more in width. The grade of the creek is about 100 feet to the mile. The drainage area is comparatively small and the precipitation for this general area is low, the maximum averaging hardly more than 10 inches a year, so that the quantity of water is generally insufficient for use in mining. The timber resources are limited to a comparatively light growth of small spruce and a small amount of birch and poplar. Some larger spruce timber grows in the valley of the Yukon.

The bedrock of Fourth of July Valley from the mouth to Crowley Creek is predominantly limestone, which at the point where the creek enters the Yukon Valley forms picturesquely weathered cliffs that tower above the stream on its western side. Upper Carboniferous fossils are abundant in similar limestone near the mouth of Michigan Creek, and the limestones at both these localities are regarded as of the same age and are correlated with upper Carboniferous limestones on the north side of the Yukon above Nation River, described by Brooks and Kindle.[1] The limestones occur as massive beds, which at some localities have been so folded as to be in a vertical position, and at others, where cut by the Yukon, form conspicuous open folds.

The bedrock from Crowley Creek to the head of Fourth of July Creek and around all the headwaters, so far as observed, is conglomerate, which is continuous with the conglomerate of Seventymile River, whose age has been determined as Tertiary. Along the Seventymile these rocks have in places been closely folded and here and there the beds are nearly vertical. Their structure on the ridges is for the most part obscured by the gravel into which they have weathered. It has been rather definitely determined that the gold of the placers has been derived from this conglomerate, the only portion of the Fourth of July Valley and its tributaries where gold has been mined being those areas where the conglomerate is the bedrock and where the streams have had no access to any other bedrock.

Most of the work on the main creek has been confined to about six claims. The depth to bedrock averages about 9 feet and the thickness of gravel that is being mined is 5 to 6 feet. Most of the gravel is comparatively fine, the largest pebbles being about 6 inches in diameter, but it includes a few bowlders of quartzite and hard Paleozoic conglomerate, 3 feet or more in diameter. All pebbles and bowlders observed were well worn, and there is but little doubt that all have been derived from the Kenai conglomerate.

Most of the gold lies close to bedrock, the greatest part of it being found in the lowest foot of gravel. The width over which it is found had not been determined. Most of it is in flat and rather thick flakes, the largest one-fourth inch in diameter. It is reported to range in assay value from $18.89 to $18.91 per ounce, and is recovered in amounts reported to range from $8 to $75 per box length of 12 by 12 square feet, the average being about $25.

The most noteworthy feature of mining during 1911 was the introduction of mechanical means for working the gravels on a larger scale. An 86-horsepower steam scraper was put in operation during the first week in September, and those in charge of it expected to use it extensively during the summer of 1912. This scraper was trans-

[1] Brooks, A. H., and Kindle, E. M., Paleozoic and associated rocks of the Upper Yukon, Alaska: Bull. Geol. Soc. America, vol. 19, 1908, pp. 295-297.

ported during the summer under its own power from the Yukon a distance of about 10 miles over the brushy valley at an average speed of about half a mile a day. Holes were dug at regular intervals in the frozen ground. A large hook was used as a deadman, and the scraper was pulled forward on its foundation of logs by means of the cables attached to the drum.

Open-cut work was being done in 1911 on Ruby Creek, which enters Fourth of July Creek about 3 miles above the point where the scraper was in use. The bedrock of this valley, so far as observed, is only the conglomerate. The depth to bedrock where mining was in progress is 12 to 15 feet. The gravel is made up of material derived from the conglomerate. The gold is found in about 20 inches of gravel next to bedrock. Values are reported from $50 to $75 to the box length of 12 by 12 square feet. Operations had been at a standstill throughout most of the season on account of lack of water.

WASHINGTON CREEK.

Washington Creek was not visited, and therefore the following account is quoted from Brooks's report[1] based on his examination in 1906:

Washington Creek flows through a northward-trending valley whose floor is half a mile to a mile in width. The bedrock for the lower 3-miles of the creek is black slate or shale of Cretaceous age.[2] Farther upstream the creek cuts a greenstone and chert formation, probably of Devonian age, and 10 miles from the Yukon it crosses another belt of Cretaceous age which forms the bedrock in Nugget Gulch, a small southerly tributary. These rocks are succeeded to the south by a broad belt made up of a Tertiary conglomerate, sandstone, and shale series, which contains some lignitic coal seams. This belt of coal-bearing rocks has a width of at least 10 miles. Still higher up the valley older rocks are said to occur again.

Placer gold has been found at two localities in the Washington Creek basin—(1) in Nugget Gulch, about 9 miles from the Yukon, and (2) on Surprise and Eagle Creeks, about 10 miles above. The placers on Nugget Creek consist of very much localized accumulations of coarse gold on bedrock. Values are so irregularly distributed that it is questionable whether the placers can be mined at a profit. The gold appears to have its source in the Cretaceous slates, and it is worthy of consideration at least whether the mineralization of the bedrock is not sufficiently localized to pay the cost of extraction. The upper locality was not visited by the writer, but from the best accounts the gold here appears to be derived from a conglomerate. The value of the total production of Washington Creek does not exceed a few thousand dollars.

COAL CREEK.

Coal Creek is about 20 miles long. The placer deposits of the lower part of its basin probably derive their gold, as do those of the adjacent parts of Woodchopper Creek, from the Tertiary conglomerates. These placers were not visited.

[1] Bull. U. S. Geol. Survey No. 314, 1907, pp. 200-201.

[2] Collier, A. J., Coal resources of the Yukon: Bull. U. S. Geol. Survey No. 218, 1903, pp. 28-32.

The most noteworthy discovery in the Coal Creek Valley has been made at a point about 15 miles from the mouth of Coal Creek, several miles south of the belt of conglomerate. The rocks in this portion of the valley are chert, shale, greenstone, and limestone, regarded as Paleozoic, forming a belt several miles wide. Still farther south are schists, regarded as pre-Ordovician, and intrusive granite.

The auriferous gravel found is near the southern extension of the Paleozoic rocks at a point about 1 mile below a narrow portion of the valley, referred to by the miners as the canyon. Gold was discovered in the spring of 1910. The depth to bedrock where ground was being prepared for working is only about 7 feet and the productive gravels are reported to be over 100 feet wide. Some of the gold is coarse, pieces worth $12 to $14 having been found. Only work preparatory to mining in 1912 had been done at the locality. The season had been very dry and scant opportunity had been given to work sufficient ground to determine the gold content of the gravels. Many garnets are mixed with the gold at this locality, and the gravels contain also fragments of garnetiferous schist like that forming much of the bedrock near the headwaters of Coal Creek. These facts suggest that the placer gold has been derived in part, at least, from the schists.

WOODCHOPPER CREEK.[1]

Woodchopper Creek, which is about 12 miles long, enters the Yukon from the west, about 30 miles above Circle. Its flood plain is about half a mile in width, and the alluvium is probably 8 to 15 feet deep. Five miles from the Yukon, Mineral Creek, the scene of some placer mining, joins Woodchopper Creek from the south. The floor of the Mineral Creek valley is 100 to 150 [feet] wide, and the slopes are broken by benches. Woodchopper Creek has a gradient of about 100 feet to the mile. Remnants of benches are to be seen along the creek, the highest of these being marked by the ridge on the northwest side, which is flat and slopes toward the Yukon.

In the lower mile of Woodchopper Creek only massive greenstones were observed. Above these is a belt of black slate and limestones about a mile wide that continues nearly to the mouth of Mineral Creek, where it is succeeded by friable conglomerates in a belt said to be several miles wide. Chert and quartz pebbles dominate in the conglomerate, which is only imperfectly consolidated and outcrops in few places. This fact often leads to its being mistaken for bench gravel by the prospector.

So far as known the gold-bearing alluvium is confined to those creeks that cut the conglomerate, which therefore appears to be the source of the gold. Mineral Creek and its tributary, Alice Gulch, are the only streams which have thus far been found to be productive. Prospects are reported from Grouse and Iron creeks.

At the mouth of Mineral Creek the alluvial floor of the valley is about 75 yards wide, but narrows upstream. A mile upstream, at the mouth of Alice Gulch, it broadens out again into a basin about 75 yards wide. On the south wall of Mineral Gulch three well-defined benches were observed having altitudes of about 20, 150, and 250 feet above the creek.

Muck is encountered on some claims to a depth of 30 feet; the gravels underneath vary in thickness from 2 to 5 feet and are made up chiefly of well-rounded quartz and chert pebbles. The pay streak lies in parallel channels 12 to 14 feet wide, as many

[1] Matter in smaller type quoted from Brooks, Bull. U. S. Geol. Survey No. 314, pp. 203-204.

as three of these channels having been found in a width of 80 feet. The pay streak under present systems of mining is from 1½ to 4 feet in thickness. A varying amount of bedrock is taken up, depending on its looseness. Apparently gold occurs in bedrock beyond the depth to which it can be profitably extracted. The bedrock appears to be chiefly conglomerate, but in some places a plastic clay which may be a weathered shale interbedded with the conglomerate has been encountered. Prospectors report that the values are found in the conglomerate but appear to be absent in the clay. The conglomerate bedrock is invariably iron stained, where found under the placers. Gold has been found in the lower benches of the creek, but the higher benches have not been prospected.

The gold in the creek bed is usually bright colored, but that of the benches is dark. Most of the gold is coarse, the largest nugget having a value of $30. The value of the gold as reported by the miners is $19.09 to $19.30 per ounce, which would make it the highest of all found in the Yukon Province. Values of 5 to 50 cents to the pan on bedrock are reported, but there are no data available for the average tenor of the pay streak.

Besides the areas on Mineral and Alice creeks, where mining was in progress in 1906 and also in 1911, the area of possibly productive gravel had been enlarged by the discovery of gravels in the Woodchopper Valley about 1 mile above the mouth of Mineral Creek and 8 miles from the Yukon.

West of the stream in this part of the valley there is a flat, a half mile or more wide, on which, several hundred feet from the creek, gold has been discovered. The bedrock is conglomerate; the depth to bedrock is about 22 feet, and the thickness of gravel is about 11 feet. In the lower part of the gravels there are a great many granite bowlders, the largest 2 feet or more in diameter. The gold is reported to occur in the lower 6 feet of gravel, next to bedrock. The productive ground is reported to have a width of about 70 feet and to carry as high as $1 to the square foot of bedrock surface. Sufficient work has not been done, however, to determine whether there is a persistent body of productive ground. If this deposit should prove to be economically workable its accessibility to the Yukon will be an important factor in its exploitation.

Auriferous gravels are distributed over a considerable area along Woodchopper Creek, but no very rich placers have been found, nor have any very extensive deposits of low-grade gravels been developed.

The relative accessibility of the placers to the Yukon is favorable to cheap mining, but the small amount of water available for sluicing is a drawback. With one exception all the operations have been of a primitive type, the steam shovel on Fourth of July Creek being the only machinery employed except a few steam hoists.

PLACER MINING IN THE FORTYMILE, EAGLE, AND SEVENTYMILE RIVER DISTRICTS.

By E. A. Porter..

GENERAL CONDITIONS.

The estimated value of the combined gold production of the Fortymile and Seventymile river districts for 1911 was $212,000; the estimated value of the output for 1910 was $200,000. The result of the work done during the open season of 1911 was disappointing to most of the small operators in these districts, as the creeks were at an extreme minimum stage for practically the entire season, and it was impossible to strip or tear down any large areas of overburden in order to get at the gold on bedrock. The winter operations were somewhat more successful, however, but even the winter yardage was considerably less, for fewer miners were at work on the creeks than in preceding years. On the other hand, the dredges and other large enterprises were very successful, and the result of their work tended to overcome the general depression prevailing among the smaller operators.

The increase of the gold output for 1911 over that for 1910 must be attributed to the success of the two dredges on the headwaters of Fortymile River. They were the only dredges in operation in the district during 1911, but their success was so marked that no doubt others will be installed, especially on Seventymile River. It was fortunate that these dredges were so successful, for they gave employment to many men who otherwise would have had to leave the district for more promising fields. The drought and the abandonment of Fort Egbert, at Eagle, threw many men out of employment, forcing them to seek work in other parts of the district or elsewhere.

On Dome Creek extensive ditch building for hydraulic mining was undertaken to develop the higher placer grounds along the creek. During the season of 1911 a small ditch was in operation and an extension was planned which would enable it to deliver practically the entire flow of Dome Creek. Further plans call for a 5-mile ditch with a capacity of 20 second-feet. All these improvements were undertaken by the Auburn Gold Mining Co.

Other ditches for hydraulic work were either built or contemplated on Denison Fork, Franklin Creek (below its mouth), and Twin Creek, in the Fortymile River district, and on Alder, Pleasant, Sonickson, and Crooked creeks, in the Seventymile district, but owing to the dryness of the season they could not exert much influence on production along these creeks.

No new discoveries were made in this region, but in December it was reported that a rich strike had been made near the head of Sixtymile River, which is close to the headwaters of South Fork of Fortymile River. The extreme headwaters of the Sixtymile are in Alaska, but the greater part of the river is in Canada. It is not known at this time whether the reported strike is in Canada or Alaska. The gold is said to average one dollar to the square foot of bedrock, and the rock lies about 20 feet deep. The valley in which the discovery was made is about 20 miles long and 2,000 feet wide.

During the season of 1911 a new power plant was put in operation by the Treadgold interests near Dawson, Yukon Territory. It utilized water power from Klondike River and was thus able to supply cheap power to both the Treadgold projects and the Guggenheim interests. As a result the power supplied by the Coal Creek Co. lost its market, and the expensive plant on Coal Creek was forced to close down. Having large capital invested, the Coal Creek Co. was forced to seek a new field and naturally turned to the Fortymile district as the one nearest at hand. Near the close of the season of 1911 representatives were sent to various parts of the district to find new ground to open up, but the results of their investigations have not yet been announced. It is only reasonable to expect, however, that the Coal Creek Co. will transfer their power to the Fortymile district if they can get proper inducements.

The difficulty of transportation in the Fortymile and Seventymile regions is burdensome to both permanent residents and transient visitors. Several years ago a road was constructed from Eagle to the head of Discovery Fork—about 16 miles—but this has been so much neglected that it has become almost impassable. There is also little indication of the road once constructed between the head of Discovery Fork and Fortymile River. An old road from Steele Creek to Jack Wade Creek is in use, but during the open season the first few miles of this road are so boggy as to be impassable. Well-worn or even well-defined trails are rare, and the few miles of good trail have been located and built by mail carriers and other individuals. A private road has been built from Eagle to Seventymile River by the miners of the district, who by hard labor and with few appliances maintain it in winter, so that it is fairly serviceable for small loads. In summer this road is so wet and spongy as to be almost impassable. Private trails have been blazed, but most of them are hardly recognizable. A road from Eagle northward to Fortymile River and southward to Seventymile River seems to be greatly desired by the people of the district. Such a highway, if properly built and maintained by the Government, would be amply justified, for good roads would do more than any other thing to reestablish confidence in the district. The topography and geology of this region is similar to that of the Klondike district and other parts of Yukon Territory, so that the problem of locating and constructing good roads should not be difficult.

FORTYMILE DISTRICT.

A report on water-supply investigations in the Fortymile and Seventymile districts (pp. 219–235) furnishes information that bears on this report. The water was exceptionally low during the season of 1911, when the minimum stream flow for the district was probably reached. With a low water supply the production of the placer mines must fall below the average, and had it not been for the successful work of two dredges the total production of Fortymile district during the season would have been very small. In fact, the climatic conditions and the abandonment of many claims have kept the output of the small operators at a minimum ever since the discovery of gold in the district.

Considerable lode prospecting was attempted during the season, but no important lode was found. The ground is covered with a heavy growth of moss, which seriously handicaps the work of the quartz or lode prospector.

NOTES ON LODE PROSPECTS.

A little work has been done on a copper deposit situated near the headwaters of Kechumstuk Creek. This property was not visited and nothing was learned of the character of the deposit. So far as known not much development has been accomplished.

In the basin of Mosquito Fork small quartz veins cut the greenstones and greenstone schists, which form the country rock. These are iron stained and some carry gold. None have been developed, except on what is known as the Tweeden property, near the mouth of Gold Creek, where a cliff of greenstone, which has been fractured, contains some quartz veins and stringers along lines of cleavage. These veins or stringers are iron stained and carry free gold, which is probably derived from the decomposition of iron sulphides. The ore exposed is small in amount, but the owner reports that it carries a large content of gold. The development work accomplished when the place was visited consisted of a 4 by 8 foot tunnel, 40 feet long, entering at the base of the cliff, and a crude arrastre propelled by a water wheel placed in Gold Creek. Operations were discontinued early in June, as the owner was unable to collect the gold, which is very fine.

PLACER WORKINGS.

Eagle Creek.—Five men spent the season in various kinds of work on Eagle Creek and were able to take out some winter ground for sluicing during the spring run-off. On account of low water the summer was practically lost, so far as productive mining was concerned, but much dead work was done in preparation for the winter work. The winter of 1911–12 promises to be exceptionally prosperous, as the prospecting indicated that the gravels carry much gold.

Chicken Creek and branches.—It is estimated that 26 men were at work on Chicken Creek and its branches during the season of 1910–11 and all were working up to June 12. After that date very little was accomplished, as the water supply fell to the minimum and remained low for the rest of the season. On one or two of the small creeks the operators were unable to finish sluicing their winter dumps. It has been estimated that, on account of the dry season, the production of Chicken Creek fell 65 per cent below what it would have been with a good water supply. Toward the end of the season there was talk of options for dredging being taken on the entire creek, and it is known that advances were made to several of the miners. A meeting was held at Chicken Creek in August, at which a neighboring power company proposed to pump water from Mosquito Fork to the head of Myers Fork and thereby supplement the present supply. It is understood that the proposed undertaking was not considered feasible on account of the great cost of raising the water to the higher elevation.

The placer grounds of Chicken Creek contain much gold, although the gravel is rather deep, and if an adequate supply of water can be procured without too great expense, they should yield good returns. Various plans contemplate obtaining water either by storage, by pumping, or by diverting water at Kechumstuk into a canal running to Chicken Creek. The plan last named seems the most practicable, but it would involve heavy expense and should be preceded by extensive prospecting to determine whether the quantity of gold obtainable is sufficient to warrant the expenditure.

Denison Fork.—Adjoining the right bank of Denison Fork near its mouth are some bench lands that carry gold in placers. In the summer of 1911 Mr. J. V. Anderson constructed several hundred feet of ditch to a small branch, and during the spring run-off expects to get enough water to work down these benches and recover the gold. This plan seems feasible, even though it is on a small scale and can be carried on for only part of the season.

Napoleon Creek.—Owing to the poor water supply but little work was done on Napoleon Creek in the summer of 1911. Practically the whole output for the year was obtained from the winter dumps, which were sluiced during the early summer.

Franklin Creek.—Franklin Creek was practically dry throughout the season. Mining was done for only a few days.

Walker Fork.—The main source of production on Walker Fork came from the upper Mulvane dredge, which had a very successful season, although for about three weeks in August there was barely enough water to float the dredge. It was kept afloat by making the low dams as tight as possible, and no other difficulties were met with in operating it. The dredge consists of a 25 by 60 foot scow drawing 3 feet of water and carrying 36 open-connected buckets, which have a capacity of 2½ cubic feet each. It is capable of digging to a depth of about 30 feet, but on Walker Fork the average depth to bedrock was about 12 feet. The ground ahead of the dredge has been stripped for the last two seasons, and there was very little frost to interfere with the operation of the buckets. It is planned to work the dredge up to the mouth of Poker Creek in 1912 and there dismantle it and move it downstream about 3 miles. Here the dredge will be rebuilt, and it should have ground for three seasons' work. The ground at this place has been stripped and prospected by a drill every 50 feet across the creek bed. The plans for moving the dredge indicate that the prospecting afforded encouraging results.

On Poker, Davis, and Cherry creeks work was done by about six men, who were handicapped all summer by the low water. Below Cherry Creek no work was going on, as the dredge formerly located here had been moved to South Fork of Fortymile River.

Wade Creek.—There was almost no production from Wade Creek on account of the inadequate water supply. The winter work was more successful, and this occupied about 28 men. Several operators left Wade Creek at the end of the season, not intending to return. Its production is not likely to be again as great as it has been in the past, unless some more rich ground is found or cheaper methods are used to work the low-grade placers now known.

Canyon and Squaw creeks.—On Squaw Creek also the season of 1911 was a failure on account of lack of water. Much dead work was accomplished, however, and several prospect holes were sunk. If the season of 1912 has an average water supply there should be renewed activity on the creek.

The season of 1911 was an average one on Canyon Creek. Below Squaw Gulch an outfit was at work with a steam plow and scraper and accomplished much assessment work. Most of the placers on Canyon Creek are reported to be of low grade, but it is hoped that they can be successfully worked by dredge. One man did some work near the head of Canyon Creek, but was unable to take out much gold on account of continued low water.

South Fork of Fortymile River.—The principal producer on the South Fork was the Mulvane dredge, which began operations about the 20th of June at a point known as Pump Bar, about 3 miles below Franklin. This dredge consists of a 30 by 70 foot scow with a draft of 3 feet and carries 28 open-connected buckets with a capacity of 3 cubic feet each and a 35-foot ladder. The depth of the workable gravels averaged about 11 feet. In 1909 a dredge was installed at practically the same point, but proved to be a failure. The new dredge, however, gave encouraging results from the start, and the season's work appears to have been very satisfactory to the company. High water occurred several times during the summer, but caused no delay, as the superintendent was prepared for it.

The gold seems to be deposited not across the entire bed of the stream but mainly along the sides or on the inside edges of the curves. The dredge passed over several spots where the ground above low-water level had been worked some years ago by men who used rockers, and who had evidently done their work well, for in the clean-up on the dredge little gold was recovered at these places. This result emphasizes the fact that much preliminary prospecting should be done before a dredge is installed. At the end of the season the company obtained options on the river claims up to the mouth of Franklin Creek, and it will probably take at least two years to dredge these claims.

The success of this work shows that many of the placers of the district can be worked by dredge and has restored confidence among the miners of the district, many of whom, because of repeated failures, had become discouraged. Almost every failure, however, is traceable to lack of proper equipment or to poor judgment in the installation of the plant.

Dome Creek.—As already stated (p. 211), the Auburn Mining Co. has undertaken to develop the placer benches along this stream. A 5,000-foot ditch has been constructed to divert the waters of Powers Pup to a high bench farther down Dome Creek. Further plans call for an extension of this ditch to a point 4 miles above Powers Pup, where the waters from Dome Creek will be available for an increased supply for the ditch. This ditch will have a capacity of 20 second-feet (1,000 inches), with a grade of 1 foot in a thousand. The water will be used in washing down the deep gravels along the high benches near and below the Eagle summer trail. During June, 1911, the company employed nine men in building ditches and other work, and it proposes to construct an additional ditch in 1912.

Other creeks.—A 9,000-foot ditch has been completed, which diverts the waters of Twin Creek into a small reservoir 150 feet above a high bench extending along Fortymile River. The miners were unable to operate this plant because of the scant water supply. The bench is said to carry considerable gold in places, but scarcity of water prevented the stripping of much ground to bedrock.

On Flat Creek and Fortyfive Pup little work was accomplished on account of low water, and in the North Fork area of the Fortymile practically nothing was done.

The two dredges near the mouth of Fortymile River—the smaller being in Alaska and the other on the Canadian side—were sunk at the spring break-up. A few men attempted to obtain a little gold from the Fortymile bars by rocking, and another man built several hundred feet of ditch below Franklin Creek to wash down bench gravels.

EAGLE DISTRICT.

In the Eagle district, as in the adjoining districts, mining operations were handicapped by lack of water, and operations probably reached the lowest stage known in many years. On American Creek four men worked for a part of the season, but the production was very small. The only excitement on the creek was caused by the finding of a $135 nugget on "No. 8 above."

On Discovery Fork the production was limited by the small water supply, although some very rich ground was practically stripped. On Wolf Creek considerable dead work was done in constructing a first-class automatic dam. The builders left for the Ruby strike in July, but intended to return and prospect the ground thoroughly during 1912.

SEVENTYMILE DISTRICT.

The total production from the Seventymile district for 1911 fell to a minimum, the decrease being due in large measure to a lack of water. Because of the continued drought the miners found it impossible to remove the overburden from the bedrock. Eighteen men were working in the district nearly all summer but were unable to accomplish very much except on Crooked Creek, where the operators were satisfied with the results of the season, though they were handicapped by lack of water. Flume Creek was abandoned except for assessment work. On Alder Creek three men were at work for the whole or a part of the season. The operations on this creek are in a preliminary stage, and consequently little gold was taken out, but the results appear to have been encouraging.

Barney Creek.—Nothing was attempted on Barney Creek until the later part of the season, and during that period the creek was so low that it was barely possible to get a sluice head. By utilizing the water supplied by light rains an operator was able to strip a small area to bedrock.

On the bench land between Barney and Pleasant creeks four men attempted to wash down a part of the bench by hydraulic pressure. Several thousand feet of ditch was built, but owing to lack of water nothing was accomplished.

Washington Creek.—One man by hard work was able to take out a little gold at the mouth of Washington Creek and on the neighboring benches, but his operations were small.

Sonickson Creek.—The ditch recently constructed leading from Sonickson Creek to the bench lands near the falls on Seventymile River was much used during the season of 1911. The canal proved to be very successful, giving a head of 150 feet at the falls. The pressure was used in washing the overburden into the main river and leaving the bedrock exposed to be shoveled in later.

Crooked Creek.—Three men were at work on Crooked Creek for the entire season and operations were more successful here than elsewhere in the Seventymile district. A considerable area of bedrock was cleaned up on a group of claims, but for several periods during the summer operations were suspended on account of low water. However, the season on Crooked Creek was fairly satisfactory and much dead work was accomplished for the future.

Other creeks.—On Fox Creek three men were at work for two months and stripped about 300 feet of ground with the aid of an automatic dam, but the results of the season were very unsatisfactory, as much time was lost on account of the low stage of the creek.

On Curtis Creek or bar one man attempted to strip a small area of ground, but was unable to accomplish much with the small amount of water available. On Hudson Collie, a pup of Rock Creek, several shafts were sunk to bedrock during the winter season, but the results were not encouraging.

A little "sniping" was done on the Seventymile River bars near the falls and considerable gold was taken out during the short time available.

WATER SUPPLY OF THE FORTYMILE, SEVENTYMILE, AND EAGLE DISTRICTS.

By E. A. Porter.

INTRODUCTION.

The object of the water-supply investigations in the Alaska placer districts, begun in Seward Peninsula in 1906 and extended to the Fairbanks district in 1907, is to obtain information that will be of value to the mining industry. The work consists of stream gaging not only in well-developed districts like the Fairbanks but also in districts like the Fortymile, where but little use has yet been made of water.

In 1910[1] studies of water supply were begun in the Fortymile and Seventymile regions, by C. E. Ellsworth. In May, 1911, the work in these regions was taken up by the writer and continued through the season, and its results are given briefly in this preliminary report. The season of 1911 was exceptionally dry, but some very interesting and valuable data were obtained in regard to what is considered to be a comparatively low run-off of the several streams.

The writer desires to express thanks to the many mine operators who not only have cordially cooperated in the work, but who have extended every courtesy to different members of the Survey working in this field. Among those who deserve special mention are J. V. Anderson, J. P. Carroll, Mr. Coffin, Mrs. E. C. Curtis, Earl Davis, August Fritch, Arthur Froelick, F. J. Herbster, J. A. Kemp, Jack McLin, Charles Martin, L. G. Michaels, Jay A. Mattison, Frank Montgomery, James Murphy, Mr. Patterson, T. E. Phillips, John B. Powers, John Roberts, E. A. Robertson, Joseph Shatshok, Henry Siemer, Ole Tweeden, and Alex. Turnbull.

GEOGRAPHIC SKETCH.

The country included in the Fortymile and Seventymile River drainage areas is a typical example of a thoroughly dissected upland. It is a westerly continuation of the famous Klondike region and forms part of the Yukon Plateau. Long ago it was elevated and was

[1] Ellsworth, C. E., and Parker, G. L., Water supply of the Yukon-Tanana region, 1910: Bull. U. S. Geol. Survey No. 480, 1910, pp. 173-215.

deeply trenched by a number of small streams; in comparatively recent times it has been again elevated, the uplift resulting in a further deepening of the valleys by 500 to 700 feet. Parts of the old valley bottoms, still covered with heavy accumulations of gravel, are found at many points, where they form terraces along the river valleys. From a distance the region has a hilly or mountainous aspect, but in reality it consists of a series of long branching ridges, the summits of which have been carved by unequal denudation into irregular hills and hollows. Most of the ridges radiate from domes, of which there are many in this region. Elevations range from about 800 feet above sea level at Eagle, to 6,000 feet or more at other points, the highest area being the Glacier Mountains, not far west of Eagle. On this rugged well-defined ridge snow lies late and comes early, and in protected spots remains throughout some years; masses of ice also accumulate in sheltered canyons and afford a steady supply of water to Mission Creek and to tributaries of the North Forks of Fortymile and Seventymile rivers.

CLIMATE AND VEGETATION.

Much general ignorance prevails in regard to the climate of Alaska and especially of the Fortymile and Seventymile regions, to which many ascribe a year of continuous ice and snow. It is true that the cold is intense at times, but not for long periods. The snowfall in the interior of Alaska is very light compared with that in other parts of Alaska and that in the northern United States. The winter days are short but both days and nights are generally clear, and the sharp air is invigorating. The summers are very pleasant, and there is practically no darkness from May 25 to August 10. Data regarding precipitation in the Fortymile region are included in the tables appearing elsewhere in this volume (pp. 248–250).

At Eagle, Steele Creek, and other points many vegetables are grown that compare favorably in size and quality with any of the imported products.

The timber supply of the region is moderate, but affords the various miners and companies plenty of logs and lumber. The most valuable timber consists of birch and spruce, which grow in many valleys. Cottonwood grows rapidly in many places, and the majority of the ridges are overgrown with a thick, tough brush. The entire area is covered with a heavy growth of moss.

WATER POWER.

The following tables summarize briefly the records made of the flow of streams in the Fortymile and Seventymile River districts that offer a possibility of water-power development.

In comparing the columns showing days of deficient discharge for different years on any stream, allowance should be made for difference in length of periods, also for the part of the season covered by the records. Ordinarily the longer the period the greater will be the number of days of deficient discharge for any given number of horsepower, and the less favorable will be the comparison with some other year in which the records extend over a shorter time. Moreover the days of deficient discharge will be a greater percentage of the total number of days if the observations include only the low-water months.

The tables also give the horsepower (80 per cent efficiency) per foot of fall that may be developed at different rates of discharge and show the number of days on which the discharge and the corresponding horsepower were respectively less than the amounts given in the columns for "discharge" and "horsepower."

Estimated discharge and horsepower table for Fortymile and Seventymile rivers for 1911.

Discharge in second-feet.	Horsepower (80 per cent efficiency) per foot fall.	Days of deficient discharge.		Discharge in second-feet.	Horsepower (80 per cent efficiency) per foot fall.	Days of deficient discharge.	
		Fortymile River at Steele Creek, May 16 to Sept. 20, 1911.	Seventymile River at "the falls," June 20 to Sept. 25, 1911.			Fortymile River at Steele Creek, May 16 to Sept. 20, 1911.	Seventymile River at "the falls," June 20 to Sept. 25, 1911.
165	15	....	18	770	70	29	88
176	16	....	30	880	80	34	92
187	17	....	33	990	90	43	95
198	18	....	42	1,100	100	45	96
209	19	....	42	1,650	150	66	98
220	20	0	43	2,200	200	79	98
275	25	1	43	2,750	250	84	98
330	30	3	64	3,300	300	88	98
385	35	4	71	3,850	350	88	98
440	40	9	74	4,400	400	93	98
495	45	10	75	4,950	450	99	98
550	50	15	83	5,500	500	103	98
720	60	28	87				

FORTYMILE DISTRICT.

LOCATION OF AREA.

The Fortymile district is included in the area drained by Fortymile River. The district has been topographically surveyed and is covered by three maps,[1] two published separately and one in process of compilation.

[1] Fortymile quadrangle, No. 640: Maps can be obtained from the Director, U. S. Geological Survey, Washington, D. C., at 5 cents per copy.

Circle quadrangle, No. 641: Contained in Bulletin 295, which can be obtained from the Director, U. S. Geological Survey; also in print as a separate publication, price 10 cents.

Area south of Circle and Fortymile quadrangles: In process of compilation.

The following list gives the locations at which gaging stations were maintained or discharge measurements were made in 1911 in the Fortymile district:

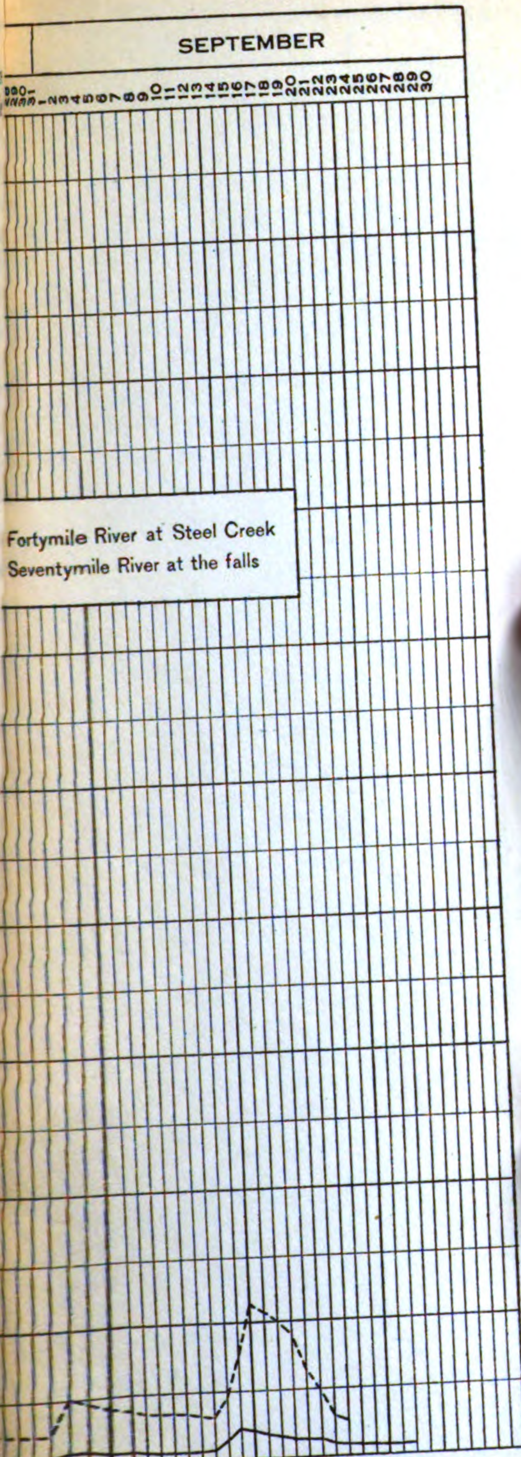
- Fortymile River drainage basin:
  - Fortymile River at Steele Creek.
  - King Solomon Creek at Liberty.
  - Liberty Fork at mouth.
  - Dome Creek at trail crossing.
  - Dick Vale Creek at trail crossing.
  - Twin Creek at head of ditch.
  - Steele Creek at mouth.
  - Canyon Creek below Squaw Gulch:
  - Squaw Gulch at claim "No. 1 above."
  - South Fork of Fortymile River drainage basin:
    - South Fork of Fortymile River above Franklin Creek.
    - Denison Fork at mouth.
    - Mosquito Fork above Chicken Creek.
    - Gold Creek at mouth.
    - Mosquito Fork below Kechumstuk Creek.
    - Kechumstuk Creek at mouth.
    - Walker Fork at mouth.
    - Walker Fork above Cherry Creek.
    - Wade Creek at claim "No. 10 above."
    - Buckskin Creek above Fortyfive Pup.
    - Fortyfive Pup at claim No. 13.
  - North Fork of Fortymile River drainage basin:
    - North Fork of Fortymile River above Middle Fork.
    - Champion Creek below Arkansas Creek.
    - Champion Creek above Bear Creek.
    - Bear Creek at mouth.
    - Bullion Creek at mouth.
    - Hutchinson Creek below Confederate Creek.
    - Hutchinson Creek below Montana Creek.
    - Montana Creek at claim No. 7.

FORTYMILE RIVER DRAINAGE BASIN.

FORTYMILE RIVER.

Fortymile River, which is formed by the union of its North and South forks, flows eastward for about 40 miles and joins the Yukon. The total drainage area of Fortymile River is approximately 6,350 square miles, about 4 per cent of which lies in Canadian territory. Parts of the uppermost headwaters of Walker Fork, a tributary of South Fork, lie in Yukon Territory, Canada, and the main river crosses the Canadian boundary about 23 miles above its mouth. The mouth of Fortymile River is midway between Dawson and Eagle, 45 miles from either.

Near the international boundary the river flows through a narrow rock canyon, from which it emerges into an open valley and thence takes a more moderate grade to its union with the Yukon. A promi-



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g.	Sept.
580	1,020
475	920
425	830
400	750
400	700
	700
	700
	690
	670
080	
950	
800	
120	....
020	....
875	....
710	....
510	....
580	....
525	....
500	....
400	....
400	....
400	....
32	1,090
41	.185
16	.14

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nent feature of the lower Fortymile is a well-defined bench that marks the elevation of an earlier valley floor. At Steele Creek this bench is about 500 feet above the water level. The plane of the present valley floor and that of the older one converge downstream and unite near the mouth of Kechumstuk Creek at an elevation of about 2,000 feet above sea level.

Below the junction of the forks of the Fortymile the river is joined by O'Brien, Flat, Twin, Nugget, and Uncle Sam creeks from the north and Steele, Canyon, Davis, and Moose creeks from the south. All these streams have heavy gradients and most of them are marked by high bench lands at their mouths.

Daily discharge, in second-feet, of Fortymile River at Steele Creek for 1911.[a]

[Drainage area, 5,890 square miles.]

Day.	May.	June.	July.	Aug.	Sept.
1	....	17,600	1,220	580	1,020
2	....	11,100	1,220	475	920
3	....	11,700	970	425	830
4	....	11,100	2,400	400	750
5	....	10,200	3,180	400	700
6	....	13,400	6,550	400	700
7	....	10,200	5,700	400	700
8	....	7,550	4,080	325	690
9	....	6,000	3,030	275	670
10	....	5,100	2,080	250	640
11	....	4,590	1,650	375	920
12	....	3,630	1,420	790	1,550
13	....	4,760	1,120	1,370	2,275
14	....	3,560	875	875	2,140
15	....	3,630	1,550	920	2,020
16	6,100	5,100	5,300	1,420	1,800
17	7,680	4,590	4,680	2,540	1,320
18	13,200	4,680	2,280	2,080	970
19	40,000	4,000	1,950	1,950	640
20	38,000	3,100	1,650	1,800	550
21	18,000	2,470	1,120	1,420	....
22	10,000	3,260	1,420	1,020	....
23	6,000	1,800	1,650	875	....
24	5,600	1,650	1,550	710	....
25	7,550	1,600	970	610	....
26	12,000	1,420	920	580	....
27	11,600	1,270	920	525	....
28	8,550	1,270	1,470	500	....
29	8,550	1,470	1,550	500	....
30	8,800	1,220	970	500	....
31	17,600	....	710	500	....
Mean	13,700	5,470	2,130	832	1,090
Mean per square mile	2.33	.930	.361	.141	.185
Run-off (depth in inches on drainage area)	1.38	1.0	.42	.16	.14

[a] The rating curve is well defined below 16,000 second-feet.

A hydrograph showing the discharge of Fortymile River at Steele Creek in 1911 is given on Plate XI.

Daily discharge, in second-feet, of Steele and Twin creeks for 1911.

Day.	Steele Creek at mouth.[a] [Drainage area, 125 square miles.]					Twin Creek at head of canal.[b] [Drainage area, 4.4 square miles.]			
	May.	June.	July.	Aug.	Sept.	May.	June.	July.	Aug.
1		15.6	0.4	1.3	3.3		6.2	3.1	0.5
2		8.6	.3	1.0	2.5		4.7	4.7	.5
3		4.0	.5	.9	2.5		4.2	6.2	.5
4		4.4	1.0	2.2	1.8		4.2	10.8	.5
5		14.0	12.5	1.8	1.8		6.2	12.6	.5
6		15.6	14.0	1.3	1.8		14.4	12.6	.5
7		11.0	9.5	.9	1.8		6.2	10.8	.5
8		7.0	5.0	.6	1.8		10.8	10.8	.5
9		7.0	2.8	.5	1.8		10.8	10.8	.5
10		7.0	1.3	.5	1.8		6.2	9.0	.5
11		8.0	1.0	6.0	2.5		6.2	7.5	.5
12		6.4	.8	6.0	15.5		6.2	4.7	.5
13		4.0	.5	2.8	28.0		4.7	4.2	.5
14		4.0	.4	3.3	20.0		3.6	3.6	.5
15		2.5	2.2	6.0	12.5		3.6	2.5	.5
16		3.3	1.3	7.0	7.0		4.7	.8	1.6
17		2.8	1.0	7.8	3.3		4.7	.8	3.3
18		2.8	1.0	5.0	1.0		4.2	.8	2.7
19		2.5	.9	5.0	1.0		2.5	12.6	1.4
20		.6	.5	3.7	.9		2.5	9.0	.8
21		.5	.5	2.5			2.5	6.2	.8
22		.5	.5	2.2			2.5	6.2	1.0
23	15.6	.5	.5	1.0		5.5	1.6	4.7	1.0
24	14.6	.5	18.5	1.0		5.5	1.2	4.7	1.0
25	19.4	.5	9.5	1.0		6.8	1.2	9.0	1.0
26	15.6	.5	8.6	1.0		6.8	.8	6.2	1.0
27	11.0	.4	9.5	1.0		6.8	.8	6.2	1.0
28	6.4	.4	9.5	1.0		6.8	.5	4.7	1.0
29	6.0	.4	5.6	1.0		5.5	1.2	4.2	1.0
30	45.0	.4	3.3	1.0		14.4	2.0	3.0	1.0
31	26.0		2.5	1.8		14.4		1.0	1.0
Mean	18.0	4.5	4.0	2.5	5.6	8.0	4.4	6.3	1.1
Mean per square mile	1.44	.360	.320	.200	.448	1.82	1.00	1.43	.25
Run-off (depth in inches on drainage area)	.48	.40	.37	.23	.33	.61	1.12	1.65	.29

[a] The discharge is well defined below 20 second-feet.
[b] The discharge curve is based on two measurements and is only approximate.

Daily discharge, in second-feet, of Liberty Fork and King Solomon creeks for 1911.

Day.	Liberty Fork Creek at mouth.[a] [Drainage area, 45 square miles.]					King Solomon Creek at Liberty Fork.[b] [Drainage area, 552 square miles.]				
	June.	July.	Aug.	Sept.	Oct.	June.	July.	Aug.	Sept.	Oct.
1							12.0	12.0	31.0	
2			8.5		26.5		10.5	9.6	22.0	
3							18.5			
4							18.5			
5							102			
6							133			
7		50.5					59.5			
8			7.2	9.2	12.5		38.8	3.0	10.5	
9				9.2			37.5	3.0		
10	40.5					278	36.0	9.0	15.0	
11			15.5		11.2	386	33.5		15.0	9.0
12		20.0					22.0			
13							19.0			
14							16.0			
15							12.0			
16							9.0			
17		9.3	20.0	20.0		84.0	6.5	9.0	36.0	
18						78.7	5.0	36.0	22.0	
19							4.0			
20							3.0	15.0		
21		8.5	7.2	15.5		55.0	4.5	15.0	22.0	1.5
22							6.0			
23							12.0			
24							26.5			
25							32.0			
26			10.0				38.8			
27		15.5		26.5		18.5	73.5	12.0	31.0	
28		17.8				15.0	72.8	12.0	31.0	
29							38.8			
30			15.5				25.6			
31							17.8			
Mean							17.8			
Mean per square mile							.553			

[a] The rating curve is well defined below 40 second-feet.
[b] The rating curve is well defined below 120 second-feet.

Daily discharge, in second-feet, of Canyon and Squaw creeks for 1911.

Day.	Canyon Creek 2 miles below Squaw Creek.[a] [Drainage area, 58.4 square miles.]			Squaw Creek at claim "No. 1 above."[b] [Drainage area, 24.4 square miles.]			
	July.	Aug.	Sept.	June.	July.	Aug.	Sept.
1		7.2	8.7		1.9	0.7	3.1
2		6.9	8.7		1.9	.6	3.1
3		7.2	7.9		3.1	.6	3.1
4		7.9	7.9		3.1	.6	2.5
5		7.2	7.9		6.7	.5	2.5
6		7.2	7.6		4.7	.5	2.5
7		6.9	7.6		4.7	.5	2.5
8		6.9	7.6	85.0	3.1	.3	
9		6.9		76.0	1.9	.3	
10		7.9		67.7	1.9	.6	
11		13.5		67.7	1.2	1.2	
12		9.8		59.0	.7	1.2	
13		9.4		44.1	.7	1.2	
14		9.4		31.7	.7	3.1	
15		10.3		25.7	1.9	3.7	

[a] The discharges are well defined below 8 second-feet.
[b] The discharges are well defined for all stages.

Daily discharge, in second-feet, of Canyon and Squaw creeks for 1911—Continued.

Day.	Canyon Creek 2 miles below Squaw Creek. [Drainage area, 58.4 square miles.]			Squaw Creek at claim "No. 1 above. [Drainage area, 24.4 square miles.]			
	July.	Aug.	Sept.	June.	July.	Aug.	Sept.
16		11.0		20.8	1.2	4.7	
17		10.3		20.8	1.2	4.7	
18		10.3		20.8	.7	6.7	
19		9.4		16.5	.7	4.7	
20		8.7		14.4	.7	3.7	
21		8.7		12.2	.7	3.1	
22		7.9		12.2	.7	3.1	
23	3.9	7.9		9.2	.5	2.5	
24	6.6	7.9		6.7	.5	1.9	
25	7.2	7.6		6.7	.5	1.9	
26	7.2	7.6		6.7	.6	1.9	
27	7.9	7.6		5.6	.6	1.9	
28	9.4	7.6		5.6	2.5	1.2	
29	7.9	7.6		4.7	2.5	1.2	
30	7.2	7.9		3.1	1.2	1.2	
31	7.2	8.7			.7	2.5	
Mean	7.2	8.4	8.0	27.0	17.0	2.0	2.8
Mean per square mile	.123	.144	.135	1.11	.697	.082	.114
Run-off (depth in inches on drainage area)	.04	.17	.04	.95	.80	.09	.03

Miscellaneous measurements in Fortymile River drainage basin in 1911.

Date.	Stream and locality.	Drainage area.	Discharge.	Discharge per square mile.
		Sq. mile.	*Sec.-ft.*	*Sec.-ft.*
June 9	Dome Creek, at summer trail	24.9	20.30	0.82
July 7	....do	24.9	5.91	.24
8	Dick Vale Creek at forks	13.1	2.75	.21
27	Dome Creek at summer trail	24.9	4.54	.18
Sept. 4	....do	24.9	2.83	.11
6	....do	24.9	2.50	.10

SOUTH FORK OF FORTYMILE RIVER.

South Fork of Fortymile River is formed by the union of Denison and Mosquito forks about 25 miles above its mouth. From the forks the river flows due east for about 4 miles to a point below the mouth of Atwater Creek, where the stream makes an abrupt turn to the left and flows north to its union with the North Fork.

The principal tributaries to the South Fork from the west are Butte, Buckskin, and Franklin creeks; those from the east and south are Uhler and Napoleon creeks, Walker Fork, and Atwater Creek. The largest of these is Walker Fork, which has its source in Canadian territory. This stream is important because the placers on several of its tributaries, including Wade, Twelvemile, Davis, and Poker creeks, have been large producers of gold. Liberty Fork and Cherry Creek are the most important streams flowing into Walker Fork from the south.

Mosquito Fork, which with Denison Fork forms South Fork of Fortymile River, heads at an elevation between 3,000 and 4,000 feet in the ridge paralleling Tanana River at a distance of about 20 miles. The first tributary to Mosquito Fork above its mouth is Chicken Creek, which although it has a very small drainage area, is important on account of its great production of placer gold. Eagle Creek, also the scene of some mining, affords only a scanty water supply. Gold Creek is an important branch of Mosquito Fork, which it joins about 12 miles below Kechumstuk Creek, the largest tributary of the fork. Near the mouth of Kechumstuk Creek, at an elevation of about 2,000 feet, an abrupt decrease in the gradient of the fork is noticeable, and its valley above this point widens out into low, grassy meadows divided by many sloughs. These meadows narrow again about 8 miles above Kechumstuk Creek at a point where a spur from the south approaches the fork. This spur marks the lower end of the flat swampy area known as Mosquito Flats, which constitutes a large part of the upper drainage area of Mosquito Fork. The flats extend along the stream for about 20 miles and at some places are 12 to 14 miles wide. They are a tangle of swamps and lakes and sloughs and during wet seasons are said to be practically covered with water.

Denison Fork, the other main tributary of the South Fork, rises not far from Tanana River. The flat basin at its head is not so pronounced as that of Mosquito Fork, but the valleys are broad and swampy and have very gentle slopes. Its drainage area of 1,540 square miles is about equally divided between two forks which unite to form the main stream about 12 miles above its mouth.

Daily discharge, in second-feet, of South Fork and Denison Fork for 1911.

Day.	South Fork of Fortymile River at Franklin.[a] [Drainage area, 3,180 square miles.]					Denison Fork Creek at mouth.[b] [Drainage area, 1,540 square miles.]				
	May.	June.	July.	Aug.	Sept.	June.	July.	Aug.	Sept.	Oct.
1		3,240	340	340	200					314
2		2,560	340	340	200					
3		2,300	340	340	200					
4		2,170	340	265	200					
5		2,210	340	265	200					273
6		2,340	340	265	200					226
7		1,950	1,040	265	200					
8		1,910	1,250	200	200					
9		940	705	200	200					
10		575	795	200	200					
11		575	750	200	232					
12		575	750	302	340					
13		575	705	340	415					
14		575	660	415	495					
15		495	3,210	415	495					
16		495	4,140	415	495					
17		495	3,700	415	415					
18		495	2,210	495	415					
19	7,000	495	1,420	495	340					
20	6,000	415	705	495	340		700			

[a] The rating curve is well defined below 5,000 second-feet.
[b] The discharges are probably accurate within 10 per cent.

Daily discharge, in second-feet, of South Fork and Denison Fork for 1911—Continued.

Day.	South Fork of Fortymile River at Franklin. [Drainage area, 3,180 square miles.]					Denison Fork Creek at mouth. [Drainage area, 1,540 square miles.				
	May.	June.	July.	Aug.	Sept.	June.	July.	Aug.	Sept.	Oct.
21	5,000	415	660	495			520			
22	4,000	415	575	415			426			
23	3,000	415	495	378			374	138		
24	3,000	415	455	415			321			
25	2,690	340	415	340			289			
26	3,100	340	415	340			280			
27	2,690	340	378	302			273			
28	2,170	340	378	265			257		289	
29	1,780	340	340	265			242		305	
30	2,300	340	340	265			242		321	
31	4,100		340	265			240			
Mean	3,600	970	932	336	299					
Mean, per square mile	1.13	.305	.293	.106	.094					
Run-off (depth in inches on drainage area)	.55	.34	.34	.12	.07					

Daily discharge, in second-feet, of Gold, Mosquito Fork, and Kechumstuk creeks for 1911.

Day.	Gold Creek at mouth.[a] [Drainage area, 115 square miles.]				Mosquito Fork Creek at Kechumstuk.[b] [Drainage area, 824 square miles.]			Kechumstuk Creek at Kechumstuk.[b] [Drainage area, 189 square miles.]		
	May.	June.	July.	Aug.	Aug.	Sept.	Oct.	Aug.	Sept.	Oct.
1		328				71	455		15	257
2		216				70	440		15	250
3		195				70	413		13	129
4		160				70	393		13	131
5		216				70	382		15	129
6		216				69	285		14	124
7		140				69	168		14	111
8		110				69	70		14	131
9						72	62		13	25
10						72	66		14	35
11						138	74		15	33
12						542	66		224	31
13						816	58		530	22
14						896	61		535	23
15						888	61		476	22
16						888			472	16
17						880			444	
18			17.0			868			420	
19						868			412	
20						864		31	404	
21					182	860		26	396	
22					160	848		23	388	
23					136	840		21	380	
24				10.2	133	824		19	360	
25					122	816		18	352	
26					81	800		18	349	
27					75	536		16	331	
28	80.0				72	515		16	331	
29	61.5				72	512		15	320	
30	435.0				72	497		15	295	
31	510.0				71			15		
Mean					107	513	203	194	252	92
Mean, per square mile					.130	.624	.246	.103	1.33	.487
Run-off (depth in inches on drainage area)					.05	.70	.14	.04	1.48	.28

a The discharges for this station are well defined below 50 second-feet.
b The rating table is well defined for all stages.

Daily discharge, in second-feet, of Walker Fork, and Wade and Napoleon creeks for 1911.

Day.	Walker Fork above Cherry Creek.[a] [Drainage area, 15.8 miles.]			Wade Creek at claim "No. 10 above."[a] [Drainage area, 23.1 square miles.]					Napoleon Creek at mouth. [Drainage area, 13.3 square miles.]			
	June.	July.	Aug.	June.	July.	Aug.	Sept.	Oct.	June.	July.	Aug.	Sept.
1	......	13 9	5.2	......	2.3	2.3	5.2	12.1	......	1.0	1.0	0.7
2	......	13.9	4.3	......	2.3	2.3	5.2	15.7	......	1.0	1.0	.7
3	......	16.3	3.3	19.8	2.3	2.3	5.2	12.1	......	1.0	.8	.8
4	......	25.0	6.5	29.6	2.3	3.5	5.2	9.5	......	1.0	.8	.8
5	45.8	16.3	5.2	79.4	5.2	3.5	3.5	9.5	4.2	1.0	.8	.8
6	69.0	12.0	3.8	39.2	12.1	2.3	3.5	5.2	15.5	1.0	.8	.8
7	57.4	8.3	3.8	29.6	5.2	2.3	2.3	7.1	11.0	1.0	.8	.8
8	60.0	10.0	3.8	19.8	3.5	1.3	2.3	5.2	8.5	.85	.8	.8
9	65.0	5.2	3.8	15.7	2.9	1.3	2.3	3.5	3.3	.85	.8	1.0
10	70.0	6.5	4.3	19.8	3.5	.6	3.5	3.5	2.3	.80	3.0	1.0
11	70.0	8.3	78.6	15.7	5.2	5.2	3.5	3.5	1.0	.80	10.0	3.0
12	65.0	3.8	40.0	15.7	4.2	5.2	19.8	2.3	1.0	.80	3.2	10 0
13	75.0	3.8	25.0	15.7	3.5	5.2	24.3	2.3	1.0	.80	1.3	7.5
14	70.0	8.3	23.7	12.1	2.9	7.1	15.7	2.3	1.0	3.00	.8	7.5
15	60.0	8.3	25.0	12.1	3.5	5.2	15.7	2.3	1.0	12.20	1.3	3.2
16	50.0	5.2	40.0	9.5	7.1	7.1	15.7	2.3	1.0	1.30	3.2	2.0
17	20.0	3.8	34 2	9.5	5.2	7.1	9.5	3.5	1.0	1.30	3.2	2.0
18	20.0	2.5	25 0	9.5	3.5	5.2	3.5	3.5	1.0	1.30	3.2	2.2
19	20.0	2.5	18.8	7.1	2.3	5.2	3.5	......	1.0	1.00	2.0	2.1
20	16.3	1.3	13.9	7.1	2.3	3.5	3.5	......	1.0	.80	1.0	1.8
21	16.3	2.5	13.1	5.2	2.3	3.5	5.2	......	1.0	.60	1.0	1.0
22	16.3	2.5	9.3	6.1	2.3	2.3	5.2	......	1.0	.60	1.0	2.1
23	18.8	1.8	8.3	5.2	2.3	2.3	5.2	......	1.0	.60	1.0	2.0
24	13.9	2.5	8.3	3.5	5.2	2.3	7.1	......	1.0	.60	.8	2.5
25	13.9	1.3	6.5	2.3	3.5	2.3	7.1	......	1.0	.60	.6	3.0
26	16.3	4.3	6.5	.6	5.2	2.3	9.5	......	1.0	.80	.5	3.2
27	16.3	12.0	6.5	2.3	7.1	3.5	44.6	......	1.0	.90	.4	7.5
28	16.3	13.1	10.0	3.5	3.5	2.3	15.7	......	1.0	1.00	.4	3.2
29	10.0	10.0	12.0	2.3	3.5	2.3	15.7	......	1.0	1.30	.5	2.3
30	12.0	9.3	12.0	2.3	2.3	5.2	12.1	......	1.0	1.30	.5	1.3
31	......	8.7	14.0	......	2.3	5.2	......	......	......	1.00	.5	......
Mean	37.8	7.8	15.3	14.3	3.9	3.6	9.3	5.8	2.49	1.36	1.49	2.59
Mean, per square mile	2.39	.494	.968	.619	.169	.156	.403	.251	.187	.102	.113	.194
Run-off (depth in inches on drainage area)	2.31	.570	1.12	.64	.19	.18	.45	.17	.18	.12	.13	.22

[a] The discharges for this station are well defined below 35 second-feet.
[b] Records should be accurate within 10 per cent.

Daily discharge, in second-feet, of Forty-five Pup and Buckskin creeks for 1911.

Day	Forty-five Pup at claim No. 13.[a] [Drainage area 9.1 square miles.]						Buckskin Creek above Forty-five Pup.[a] [Drainage area, 33 square miles.]				
	May.	June.	July.	Aug.	Sept.	Oct.	May.	June.	July.	Aug.	Sept.
1	......	18.6	1.8	1.8	2.5	7.4	......	......	......	......	......
2	......	13.2	1.8	1.8	2.5	......	......	42.2	......	......	......
3	......	13.2	1.8	1.3	1.8	......	......	......	......	......	......
4	......	13.2	1.8	3.5	1.8	......	......	......	5.9	4.7	......
5	......	24.2	1.8	3.5	1.8	......	......	......	5.9	3.4	......
6	......	18.6	1.3	2.5	1.8	......	......	......	......	......	......
7	......	13.2	1.3	1.8	1.3	......	......	......	......	......	......
8	......	7.4	.7	1.8	.7	......	......	......	......	......	......
9	......	5 5	.7	1.3	.7	......	......	......	......	......	......
10	......	5.5	.7	1.3	1.8	......	......	......	......	......	......
11	......	3.5	1.8	3.5	5.5	......	......	......	22.6	......	......
12	......	5.5	1.3	3.5	15.9	......	......	......	5.9	......	......
13	......	7.4	1.3	2.5	13.2	......	......	11.8	5.9	......	......
14	......	13.2	1.8	2.5	6.6	......	......	11.8	......	......	......
15	......	18.6	3.5	4.4	5.5	......	61.1	......	16.7	......	......

[a] The discharges are well defined below 20 second-feet.

Daily discharge, in second-feet, of Forty-five Pup and Buckskin creeks for 1911—Contd.

Day.	Forty-five Pup at claim No. 13.[a] [Drainage area, 9.1 square miles.]						Buckskin Creek above Forty-five Pup.[a] [Drainage area, 23 square miles.]				
	May.	June.	July.	Aug.	S pt.	Oct.	May.	June.	July.	Aug.	Sept.
16		13.2	1.8	4.4	4.4						
17		30.5	1.3	3.5	3.5						
18		18.6	.7	3 5	3.5						
19		7.4	.7	2.5	3.5						
20		5.5	.7	3.5	3.5						
21		5.5	.7	1.8	2.5					4.7	
22		3.5	.7	1.3	3.5						
23		3.5	.7	1.3	3.5				.9	.9	
24		3.5	.7	1.3	3.5				.9	.9	
25		3.5	.7	.7	4.4			5.9			
26		3.5	1.3	.7	4.4						
27		1.8	5.5	.7	5.5						
28		1.8	5.5	.7	5.5						
29		1.8	4.4	.7	5.5						9.9
30	53.4	1.8	3.5	.7	6.6						
31	36.6		2.5	2.5							
Mean.		9.54	1.8	2.2	4.2						
Mean per square mile		1.04	.198	.242	.461						
Run-off (depth in inches on drainage area)		1.16	.22	.27	.51						

Miscellaneous measurements in South Fork of Fortymile River drainage basin for 1911.

Date.	Stream and locality.	Drainage area.	Discharge.	Discharge per square mile.
		Sq. miles.	*Sec.-ft.*	*Sec.-ft.*
July 17	Mosquito Fork at mouth	1,120	313.7	0.28
20	do	1,120	193.4	.17
Aug. 23	do	1,120	198.0	.18
27	Walker Fork at mouth	414	20.8	.05

NORTH FORK OF FORTYMILE RIVER.

North Fork of Fortymile River is a swift and large stream whose volume fluctuates with the precipitation in its basin. The main tributaries of the North Fork rise in an area of irregular ridges ranging in elevation from 3,000 to 6,000 feet above sea level. The North Fork is joined by the Middle Fork, which is a trifle larger than the North Fork. The headwaters of the Middle Fork rise in a country similar to that of Mosquito and Denison forks, and therefore it probably has a more uniform flow than the North Fork. Besides these two streams Comet and Champion creeks are also worthy of mention. The volume of the North Fork is increased by Slate, Bullion, and Hutchinson creeks, entering the main stream from the west. All these streams have heavy grades and their seasonal flow is relatively constant. During the season of 1911 the basin of the North Fork was practically deserted, and it was impossible to obtain records on the run-off of the streams, except in the Hutchinson Creek basin.

About 10 miles below the union of the North and Middle forks the river formerly followed a large meander locally known as the "Kink." Although the distance around it was 2¾ miles, the two channels at the neck of the meander were separated by a sharp rock ridge only about 100 feet high and about the same distance in width at the water level. Several years ago a channel was blasted through the rock ridge to divert the water and thus drain the meander for mining. A fall of 17 feet was thus concentrated in a horizontal distance of only a little over 100 feet and is capable of developing considerable water power.

Daily discharge, in second-feet, of Montana and Hutchinson creeks for 1911.

Day.	Montana Creek [a] at claim No. 7 above. [Drainage area, 5.9 square miles.]			Hutchinson Creek [a] below Montana Creek. [Drainage area, 29.0 square miles.]			Hutchinson Creek [a] below Confederate Creek. [Drainage area, 22.0 square miles.]		
	July.	Aug.	Sept.	July.	Aug.	Sept.	July.	Aug.	Sept
1		1.2	20.5			125.0			
2		1.2	16.0						
3		1.2	8.8			100.0			
4		1.2	4.4						
5		1.2	4.2						8.6
6		1.2	3.9						7.3
7		1.2	3.7						9.1
8		1.2	3.5						9.7
9		1.2	3.5						10.3
10		1.2	6.5			136.0			11.1
11		3.2	12.6		78.0	160.0			35.0
12		2.9	10.7						31.3
13		2.9	8.8	6.8			4.3		28.9
14	1.7	3.0	7.9			35.6	7.3		27.2
15	2.5	3.9	10.0		15.2				12.4
16	1.2	4.4	10.0						11.1
17	1.2	4.4	10.0						
18	1.2	3.2	10.0						
19	1.2	2.9	10.0						
20	1.2	2.7	12.0					5.3	
21	3.2	2.2	12.0						
22	3.5	2.7	12.0					7.3	
23	1.5	3.0	12.0						
24	1.7	1.7	12.0	41.0				6.3	
25	1.2	1.5	14.1		12.0	136.0			25.6
26	1.7	6.3			64.4				
27	2.2	7.9							
28	1.7	4.8							
29	1.2	3.5		15.2			5.3		
30	1.2	4.2			41.0				
31	1.2	16.0			110.0			6.3	
Mean	1.6	.32	9.6						
Mean per square mile	.271	.543	1.63						
Run-off (depth in inches on drainage area)	.19	.63	1.52						

[a] The records are reliable for all stages of stream.

Miscellaneous measurements in North Fork of Fortymile River drainage basin for 1911.

Date.	Stream and locality.	Drainage area.	Discharge.	Discharge per square mile.
July 5:		*Sq. mile.*	*Sec-ft.*	*Sec.-ft.*
3 p. m.	Quartz Creek at telegraph line		6.94	
4 p. m.	do		48.00	
Aug. 16	Champion Creek at Arkansas Cabin	43.4	33.63	0.78
17	Champion Creek just below Bear Creek	173.0	87.48	.50
17	Bear Creek at mouth	48.0	28.55	.60
18	North Fork of Fortymile River above Middle Fork	724.0	1,063.00	1.47
18	Bullion Creek at mouth	34.3	8.97	.26

SEVENTYMILE DISTRICT.

LOCATION OF AREA.

The Seventymile district comprises the area drained by Seventymile River and all its tributaries. This area adjoins the Eagle district on the north and borders the lands drained by tributaries of North Fork of Fortymile River. The district lies within the Eagle precinct, and Eagle is the supply point for all the mines. The area has been topographically surveyed and is shown on the Geological Surveys maps of the Fortymile and Circle quadrangles.

The gaging stations, or points of measurements, for 1911 follow:

- Seventymile River drainage basin:
  - Seventymile River above Granite Fork.
  - Seventymile River at the falls.
  - Flume Creek one-fourth mile above mouth.
  - Alder Creek at claim "No. 7 above."
  - Deep Creek at mouth.
  - Nugget Creek at mouth.
  - Granite Creek at mouth.
  - Barney Creek at ditch intake.
  - Barney Creek ditch below forks.
  - Barney Creek at mouth.
  - Sonickson Creek at ditch intake.
  - Sonickson Creek ditch at head.
  - Sonickson Creek ditch at mouth.
  - Washington Creek at mouth.
  - Broken Neck Creek at mouth.
  - Mogul Creek at mouth.
  - Crooked Creek below Eldorado Creek.
  - Curtis Bar Creek at mouth.
  - Fox Creek at Rolf's claim.
  - Bryant Creek 2 miles above mouth.
  - Rock Creek at bridge.

SEVENTYMILE RIVER DRAINAGE BASIN.

Seventymile River drains an area of about 700 square miles, practically three-fourths of its basin lying on the south side of the river. The headwaters of the main river lie in the high rugged divide separating the basins of Seventymile and Charley rivers. Seventymile River drains the eastern slope of this divide and flows eastward for about 60 miles to a point 4 miles from its mouth, where it makes a right-angle turn and flows northward, joining the Yukon about 20 miles below Eagle.

The principal southern tributaries of Seventymile River, beginning the enumeration at its headwaters, are Diamond Fork, Flume, Alder, Deep, Nugget, Granite, Green, Sonickson, Mogul, and Bryant creeks. Of these streams, Granite and Mogul creeks furnish a steady supply of water to the main river. Both creeks have a heavy fall, but no workable placers have yet been found on them. The heavy timber on Mogul Creek now supplies some large saw logs to the district. The tributaries of the Seventymile from the north are small, short streams, usually falling to a minimum as soon as the snow leaves the ridges. They are Barney, Washington, Broken Neck, Crooked, and Fox creeks—all containing workable placers.

Seventymile River is in the main a swift, treacherous stream, which falls from its head to the flats near its mouth at a rapid rate. Like Fortymile River it has been eroding its bed rapidly. Bench lands are conspicuous along the valley slopes at altitudes ranging from 50 to 150 feet above the river. At the point known as the "falls" there is a vertical drop of about 25 feet, capable of developing considerable power.

Daily discharge, in second-feet, of Seventymile River at the falls for 1911.[a]

[Drainage area, 465 square miles.]

Day.	June.	July.	Aug.	Sept.	Day.	June.	July.	Aug.	Sept.
1		354	190	220	21	1,050	150	346	170
2		304	166	214	22	874	450	304	170
3		340	150	190	23	890	310	274	170
4		500	146	170	24	874	180	235	170
5		390	134	166	25	740	265	196	170
6		1,550	120	154	26	775	265	174	
7		906	110	146	27	610	450	180	
8		525	110	134	28	510	442	196	
9		340	134	130	29	442	370	190	
10		250	150	146	30	410	254	170	
11		196	430	310	31		226	190	
12		170	378	442	Mean	737	344	306	219
13		154	280	402	Mean per square mile	1.58	.739	.659	.471
14		280	280	340	Run-off (depth in inches on drainage area)	.64	.85	.76	.43
15		280	580	316					
16		180	1,130	286					
17		170	670	256					
18		150	775	235					
19		134	622	190					
20	930	130	475	180					

[a] The rating table is well defined below 500 second-feet.

A hydrograph showing the discharge of Seventymile River at the falls in 1911 is given on Plate XI (opposite p. 222).

Daily discharge, in second-feet, of Alder Creek at claim "No. 7 above"[a] for 1911.

[Drainage area, 11.8 square miles.]

Day.	May.	June.	July.	Aug.	Sept.	Oct.
1	......	23.5	6.9	6.1	8.3	5.9
2	......	29.0	7.1	5.7	12.1	5.5
3	......	43.5	7.1	6.1	7.7	5.5
4	......	46.4	8.3	5.9	5.5	5.5
5	......	45.0	52.0	5.5	7.7	5.5
6	8.3	38.0	11.7	5.5	5.3	5.1
7	12.1	29.0	9.2	5.5	5.1	5.1
8	12.9	23.5	8.3	5.1	4.7	4.3
9	11.1	21.0	7.3	5.5	5.1	......
10	10.0	15.2	6.1	6.7	5.9	......
11	9.2	14.1	8.3	7.7	7.7	......
12	7.7	18.5	8.3	6.5	8.6	......
13	8.3	20.0	7.7	7.1	8.3	......
14	11.1	20.0	12.1	14.1	7.7	......
15	11.1	23.5	12.1	12.1	7.1	......
16	10.0	23.5	5.9	12.9	7.1	......
17	10.4	21.0	8.3	14.1	7.1	......
18	16.0	18.5	7.7	9.6	6.7	......
19	22.0	23.5	8.3	10.0	7.3	......
20	20.0	15.2	5.5	9.2	7.1	......
21	12.9	12.1	9.2	8.3	6.7	......
22	10.0	10.4	7.3	7.1	5.9	......
23	9.7	12.1	6.3	6.7	6.7	......
24	8.3	10.4	6.9	8.3	6.9	......
25	15.2	10.0	5.9	8.3	6.3	......
26	33.2	9.7	8.1	12.1	6.5	......
27	20.8	8.6	10.4	5.5	6.3	......
28	17.0	8.3	11.7	5.5	6.5	......
29	12.9	8.1	10.0	7.7	6.3	......
30	35.0	7.3	7.7	5.5	5.9	......
31	52.0	......	6.9	8.3	......	......
Mean	15.7	20.3	9.6	7.9	6.9	5.3
Mean per square mile	1.33	1.72	.814	.669	.584	.449
Run-off (depth in inches on drainage area)	1.28	1.92	.94	.77	.65	.14

[a] The discharges are well defined for all stages.

Daily discharge, in second-feet, of Sonickson, Crooked, and Fox creeks for 1911.

Day.	Sonickson Creek above ditch intake.[a] [Drainage area, 12.6 square miles.]			Crooked Creek below Eldorado Creek.[a] [Drainage area, 17.2 square miles.]				Fox Creek 3 miles above mouth.[a] [Drainage area, 8.3 square miles.]			
	July.	Aug.	Sept.	June.	July.	Aug.	Sept.	May.	June.	July.	Aug.
1	4.0	7.1	......	......	1.5	2.0	3.5	......	......	2.5	3.4
2	4.4	......	......	......	1.5	1.5	3.5	......	......	2.5	3.1
3	4.2	......	......	......	9.5	1.5	3.5	......	......	2.5	3.1
4	7.5	4.4	......	......	3.5	1.5	2.5	......	......	2.5	2.8
5	......	......	......	......	2.5	1.2	2.5	......	......	2.5	2.8
6	......	......	......	......	2.5	1.2	2.5	......	......	2.5	2.5
7	......	3.8	......	......	2.5	1.2	2.0	......	......	2.5	2.5
8	18.2	......	6.4	......	2.0	1.2	2.0	......	......	2.8	2.5
9	......	......	......	......	2.0	1.2	2.0	......	......	2.5	2.5
10	......	......	......	......	2.0	2.0	2.0	......	......	2.5	3.3
11	3.8	13.9	......	......	1.2	8.0	4.5	......	......	2.5	5.1
12	......	......	18.2	10.3	1.2	4.5	1.5	......	......	2.3	4.1
13	......	......	......	55.0	1.2	3.5	21.5	......	......	2.1	3.7
14	10.7	......	......	21.5	1.2	3.5	13.0	......	......	2.1	3.7
15	......	19.0	......	15.0	1.2	38.0	9.5	......	......	2.1	7.3
16	......	17.3	......	11.3	1.2	21.5	6.5	......	......	1.8	6.9
17	4.4	......	......	9.5	1.2	26.5	5.5	......	......	1.8	6.9
18	3.8	......	9.2	8.0	1.2	19.2	5.5	......	6.6	1.8	7.3
19	2.7	......	......	8.0	1.2	17.0	5.5	......	4.8	1.8	6.0
20	......	......	......	6.5	1.0	15.0	6.5	......	4.1	1.8	5.4
21	3.8	......	......	5.5	11.3	6.5	......	......	3.7	7.3	5.3
22	8.1	......	......	4.5	5.5	5.5	......	......	3.7	6.6	4.3
23	5.7	......	......	3.5	2.0	4.5	......	......	3.1	4.8	3.9
24	7.8	......	......	2.5	2.0	3.5	......	......	3.1	3.7	3.7
25	19.9	......	......	2.5	2.5	2.5	......	......	3.1	3.7	3.4
26	20.8	7.8	......	92.5	9.5	2.5	......	......	3.1	5.1	3.4
27	17.3	7.8	......	2.0	9.5	2.5	......	......	3.1	5.4	3.4
28	......	......	......	1.5	4.5	2.5	......	......	3.1	4.8	3.4
29	......	......	......	1.5	3.5	2.5	......	......	2.5	4.1	3.4
30	......	......	......	1.5	2.5	2.5	......	......	2.5	4.1	3.4
31	......	......	......	......	2.0	3.5	......	......	......	3.7	3.7
Mean	......	......	......	9.1	3.1	6.8	5.3	......	3.6	3.3	4.1
Mean per square mile	......	......	......	.587	.180	.40	.308	......	.433	.398	.494
Run-off (depth in inches on drainage area)	......	......	......	.41	.21	.46	.23	......	.17	.46	.57

[a] The discharge curve is well defined for all stages.

Miscellaneous measurements in Seventymile River drainage basin for 1911.

Date.	Stream and locality.	Drainage area, square miles.	Discharge in second-feet.	Discharge in second-feet per square mile.
June 19	Mogul Creek at mouth	64.4	120.3	1.87
21	Nugget Creek at mouth	2.7	.9	.33
25	.....do	2.7	.4	.15
25	Deep Creek at mouth	4.8	.8	.17
25	Granite Fork at mouth	138.0	194.7	1.41
26	Barney Creek at mouth	....	.8	....
26	Washington Creek at mouth	14.6	2.2	.15
26	Broken Neck Creek at mouth	2.9	1.3	.45
27	Curtis Bar Creek at mouth	1.7	1.3	.76
27	Rock Creek at bridge	7.3	.6	.08
30	.....do	7.3	.4	.06
July 1	Mogul Creek at mouth	64.4	69.9	1.08
2	Bryant Creek at trail	21.4	57.5	2.69
5	Rock Creek at bridge	7.3	.9	.12
5	Curtis Bar Creek at mouth	1.7	.95	.56
6	Broken Neck Creek at mouth	2.9	.60	.21
7	Granite Fork at mouth	138.0	40.2	.30
7	Seventymile River above Granite Fork	207.0	53.2	.25
8	Barney Canal below forks	....	.8	....
9	Barney Creek or Right Fork	....	.45	....
11	Mogul Creek at mouth	64.4	120.3	1.87
11	Washington Creek at mouth	14.6	3.53	.24
11	Broken Neck Creek at mouth	2.9	1.10	.40
13	Curtis Bar Creek at mouth	1.7	1.80	1.06
13	Bryant Creek at trail	21.4	50.40	2.35
13	Rock Creek at bridge	7.3	1.20	.16

EAGLE DISTRICT.

LOCATION OF AREA.

The name Eagle district as used in this report denotes the area adjacent to the town of Eagle. The streams included in this area are Mission Creek, with its tributaries, and Yukon River at Eagle. The entire district has been topographically mapped, and considerable mining has been done within it.

Below is given a list showing the locations at which gaging stations were maintained in 1911 in the Eagle district:

Mission Creek drainage basin:
- Mission Creek above Oregon Creek.
- Mission Creek above Excelsior Creek.
- Mission Creek below Excelsior Creek.
- Mission Creek above American Creek.
- Excelsior Creek at mouth.
- Wolf Creek at Swanson dam.
- American Creek at claim "No. 8 above."
- American Creek at United States pumping plant.
- Discovery Fork of American Creek below Star Gulch.

MISSION CREEK DRAINAGE BASIN.

The Mission Creek basin lies between the Fortymile and Seventymile basins and contains approximately 170 square miles. Mission Creek enters the Yukon at the town of Eagle and is about 30 miles long. The water of the creek comes mainly from the eastern slope of the Glacier Mountains, and American Creek is also an important tributary. Mission Creek has a precipitous fall throughout its length, and at some flood periods the stream is very hard to cross. In the last 9 miles of its course the creek follows the base of the high ridge that extends westward from the Yukon at Eagle.

American Creek, which rises in the high ridges bounding the extreme northern part of the area of Fortymile River, is the largest tributary of Mission Creek and enters that stream from the south about a mile above its mouth. It flows northeastward and is about 10 miles in length. Discovery Fork is the main branch of American Creek and joins it about 8 miles above the mouth. American Creek and its branches flow through narrow V-shaped canyons. The stream has a high grade and is rapidly eroding its floor. The placers of American Creek and Discovery Fork have yielded considerable gold, chiefly to small operators. Wolf Creek is a small but swift stream entering Mission Creek from the south about 4 miles above its mouth.

Daily discharge, in second-feet, of Mission and Wolf creeks for 1911.

Day.	Mission Creek above Oregon Creek.[a] [Drainage area, 20 square miles.]				Wolf Creek above Swanson dam.[b] [Drainage area, 19.5 square miles.]			
	June.	July.	Aug.	Sept.	June.	July.	Aug.	Sept.
1		18.0	12.0	12.0		7.5	5.0	
2		18.0	11.5	14.0		5.0	5.0	
3		17.0	11.0	16.0		7.5	3.5	
4		17.0	10.0	18.0		7.5		
5		27.5	10.0	20.5		5.0		
6		20.5	9.0	20.5		5.0		
7		17.0	9.0	20.5		5.0		
8		14.0	9.0	22.0		5.0		
9		12.0	9.0	24.0		5.0		
10		11.5	9.0	22.0		3.5		
11		11.5	20.5	20.5		3.5		
12		11.5	17.0	19.0		3.5		22.5
13		11.5	14.0	18.0		3.5		
14		11.5	20.5	18.0		3.5		
15		11.0	20.5	17.0		3.5		
16		11.0	20.5			3.5		
17	81.0	10.0	24.0			2.0		
18	52.5	10.0	22.0			2.0		
19	52.5	10.0	20.0			2.0		
20	44.0	9.0	18.0			2.0		
21	36.0	15.0	17.0			4.3		
22	30.0	20.5	15.5			8.8		
23	24.0	17.0	14.0			6.2		
24	22.0	14.0	14.0			4.2		
25	20.5	17.0	9.0			13.0		
26	22.0	20.5	9.0			44.7		
27	24.0	17.0	10.0			26.0		
28	24.0	17.0	10.0			19.0		
29	20.5	15.5	11.0			11.5		
30	18.0	14.0	11.0			7.5		
31		13.0	12.0		7.5	7.5		
Mean	33.6	14.8	13.8	18.8		7.7	4.5	
Mean per square mile	1.68	.740	.690	9.40		.395	.231	
Run-off (depth in inches on drainage area)	.87	.85	.80	.52		.46	.03	

[a] The discharges for this station are only approximate.
[b] The rating curve is well defined for all stages.

Daily discharge, in second-feet, of American Creek and branches for 1911.

Day.	Discovery Fork of American Creek below Star Gulch.[a] [Drainage area, 14.8 square miles.]					American Creek at claim "No. 8 above."[a] [Drainage area, 24.1 square miles.]				American Creek at United States pumping plant.[a] [Drainage area, 67.3 square miles.]	
	June.	July.	Aug.	Sept.	Oct.	June.	July.	Aug.	Sept.	June.	July.
1		3.9	7.2	6.6	5.8		11.5	6.5			30
2		3.9	7.2	5.8	4.3		10.8	5.5	18.7		20
3		3.8	7.2	5.4	4.6		8.5	5.0			26
4		3.7	7.2	5.0	4.3		6.5	4.5			23
5		5.2	7.2	5.0	4.3		12.0	4.0			30
6		4.3	7.2	5.0	4.3		21.4	3.5			38
7		3.9	7.2	5.0	3.9		16.1	3.0	10.8		38
8		3.9	3.9	5.0	3.9		13.0	3.0			23
9		3.8	3.8	5.0	3.9		13.0	2.6			26
10		3.7	4.1	5.0	3.9		10.8	6.0			20
11		3.9	5.8	7.1	4.3		10.8	10.8			23
12		3.8	5.2	12.0	4.3		8.6	10.8			18
13		3.7	5.2	9.5	4.6		8.0	10.8		185	23
14	18.0	3.8	5.2	8.3	5.0		7.0	10.8		160	26
15	17.1	3.7	6.0	7.0	5.0	61.7	6.5	10.8		138	18
16	14.8	3.7	6.0	6.2	4.6	57.3	5.0	10.5		138	18
17	13.1	3.7	8.3	5.8	4.6	57.3	4.0	68.3		119	18
18	13.1	3.7	7.3	5.8	4.3	49.3	3.0	33.4		119	23
19	9.8	3.7	6.4	5.8	4.3	41.3	2.6	25.0		100	18
20	9.8	3.7	5.8	5.0	4.3	36.0	2.6	16.1		57	23
21	8.8	3.9	5.4	5.0	3.9	32.0	4.0	10.0		46	18
22	7.7	5.0	5.2	5.0	3.7	27.0	4.0	8.0		38	30
23	5.4	4.3	5.2	5.0		25.0	10.0	7.0		38	26
24	5.0	6.5	5.0	5.4		23.0	20.0	7.0		30	23
25	4.8	9.3	4.8	5.4		21.4	33.4	7.0		30	38
26	5.6	13.0	4.8	5.4		18.7	49.0	6.5		23	70
27	4.3	10.1	5.4	5.4		16.1	27.0			26	70
28	5.0	7.7	5.4	5.8		21.4	21.4			26	70
29	4.6	5.8	5.4	5.8		18.7	16.0			30	46
30	4.3	5.2	5.0	5.8		16.0	10.0			26	26
31		4.6	7.7				8.6				20
Mean	8.9	4.9	5.9	6.0	4.4	32.6	12.4	11.4		74	30
Mean per square mile	.602	.331	.398	.406	.207	1.35	.515	.473		1.10	.446
Run-off (depth in inches on drainage area)	.38	.38	.46	.45	.24	.80	.59	.46		.73	.51

[a] Records are believed to be reliable within 6 per cent.

Miscellaneous measurements in Mission Creek drainage basin for 1911.

Date.	Stream and locality.	Drainage area.	Discharge.	Discharge per square mile.
		Sq. miles.	*Sec.-ft.*	*Sec.-ft.*
June 27	Mission Creek above Excelsior	93.1	89.76	0.96
27	Excelsior Creek at mouth	31.1	20.05	.64
27	Wolf Creek at crossing	28.4	7.50	.26
July 2	Mission Creek below Excelsior	93.1	66.20	.71
31	Mission Creek above American Creek	168.0	107.20	.64
Aug. 13	Mission Creek below Excelsior	124.0	100.0	.80

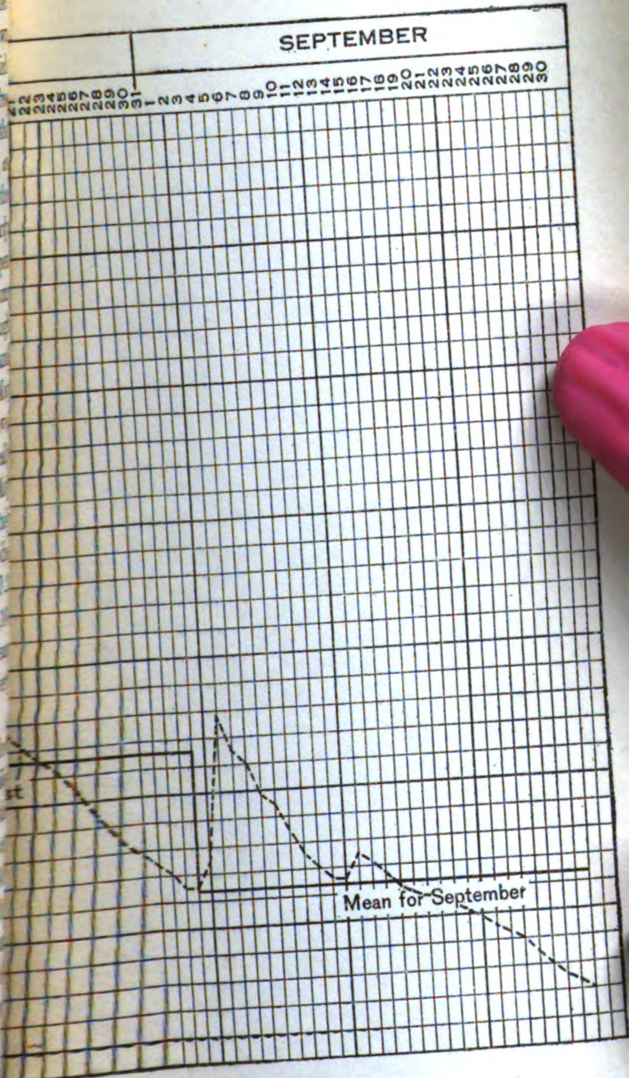
YUKON RIVER AT EAGLE.

A daily record of the flow of the Yukon at Eagle has been kept for the open season of 1911. It extends from May 9 to October 1 and is probably the most reliable as well as the longest record yet obtained on this river. The Yukon has two distinct seasons, which are known as the "open" and the "closed" season. In the former, which extends from about May 20 to October 20, the river is open, or free from ice. By the "closed" season is meant that period when the river is filled with floating ice or covered with a solid sheet of ice, as it is from about October 20 to May 20. During the closed season the watershed of the river becomes frozen, and in March and the early part of April the flow of the Yukon is obtained mainly from open springs and from lakes. As a result the river reaches its minimum stage during this period. By the end of April the sun is high enough to thaw the drainage area, and the water from melting snow and ice causes the river to rise very rapidly. About the 10th of May the river usually reaches a stage so high that the ice begins to move, and after a run of ice extending over ten days the river is practically clear. The maximum stage of the river occurs at the end of May and has no doubt at times reached a discharge of approximately 330,000 second-feet at Eagle. In 1911 the crest, or maximum discharge, occurred May 22 and was 249,000 second-feet. On April 24 the river was measured at Eagle and gave a discharge of 10,100 second-feet, which is believed to be about the minimum for the year, and it is reasonable to assume that this result will represent very closely the minimum at Eagle from year to year.

Mr. William Ogilvie, a Canadian engineer, has estimated the flow of the Yukon at the international boundary, which is about 12 miles south of Eagle, upstream. In December, 1895, he estimated the winter flow as about 96,000 second-feet, the mean summer flow as 135,000 second-feet, and the flow at flood stages as 180,000 to 225,000 second-feet. These data serve for a comparison with the results obtained at Eagle during 1911. In the table herewith the mean summer flow is shown to be not far from 135,000 second feet, but Mr. Ogilvie's figures for the winter flow are shown to be too large, and his estimates of flood stages too small.

Other measurements of flow have been made on the Yukon, but these can not serve to indicate the flow at Eagle. At the mouth of the Yukon the average flow, as estimated by the Coast and Geodetic Survey, is about 436,000 second-feet, and below the Lewis and Pelly the average flow is given by Canadian engineers as 67,000 second-feet.

A hydrograph of the daily flow of the Yukon at Eagle from May 9 to October 1, 1911, is given on Plate XII, and the following table shows the mean monthly discharge and run-off per square mile:



Sept.
107,500
112,000
139,000
133,000
130,600
[illegible]
100,300
99,400
97,700
96,900
95,300
93,000
90,000
88,000
87,000
[illegible]

Daily discharge, in second-feet, of Yukon River at Eagle for 1911.[a]

[Drainage area, 122,000 square miles.[b]]

Day.	Apr.	May.	June.	July.	Aug.	Sept.
1			201,400	186,000	143,800	107,500
2			187,500	184,500	142,600	112,000
3			180,000	174,400	139,000	139,000
4			171,600	173,000	142,600	133,000
5			164,600	171,600	145,000	130,600
6			166,000	170,200	152,000	124,000
7			164,600	173,000	152,000	122,000
8			159,000	174,400	145,000	117,000
9		121,000	171,600	175,800	143,800	113,000
10		123,000	170,200	178,600	137,800	111,100
11		121,000	167,400	196,600	135,400	107,500
12		118,000	166,000	190,500	133,000	107,500
13		116,000	161,800	178,600	134,200	112,000
14		114,000	173,000	173,000	134,200	111,100
15		116,000	164,600	159,000	133,000	108,400
16		117,000	161,800	161,800	131,800	106,600
17		116,000	166,000	184,500	131,800	104,800
18		133,000	173,000	203,000	135,400	103,000
19		175,800	187,500	187,500	142,600	103,000
20		225,400	190,500	175,800	140,200	101,200
21		238,200	193,500	167,400	139,000	100,300
22		249,400	195,000	159,000	135,400	99,400
23		243,000	189,000	156,600	133,000	97,700
24	10,100	220,600	184,500	156,600	131,800	96,900
25		206,200	178,600	152,000	127,000	95,300
26		173,000	166,000	159,000	122,000	93,000
27		171,600	173,000	153,400	117,000	90,000
28		166,000	184,500	152,000	114,000	88,000
29		166,000	187,500	152,000	112,000	87,000
30		167,400	187,500	150,600	111,100	86,000
31		180,000		156,200	107,500	
Mean		164,300	176,200	170,600	133,700	106,900
Mean per square mile		1.35	1.44	1.40	1.10	.876
Run-off (depth in inches on drainage area)		1.15	1.61	1.61	1.27	.98

[a] The rating curve for this station is well defined for all stages. All hydraulic data in May, 1911, were secured by ice floats.
[b] Approximate and subject to revision.

PLACER MINING IN THE FAIRBANKS AND CIRCLE DISTRICTS.

By C. E. Ellsworth.

FAIRBANKS DISTRICT.

GENERAL CONDITIONS.

Slow but steady progress is being made in the Fairbanks district toward placer mining by more improved methods and on a larger scale. The only important improvement made in 1911 consisted of the installation of a dredge on Fairbanks Creek, the first to be operated in the district. Plans are reported to be under way for installing more dredges in the near future in places where conditions favor their employment.

The value of the gold production of the Fairbanks district in 1911 is estimated to be approximately $4,500,000; the value in 1910 was $6,100,000. The decrease is due mainly to the fact that most of the bonanzas of the camp have been worked out, and the major part of the mining during the last year was therefore confined to relatively low-grade deposits. A stampede to Ruby Creek caused a shortage of men in June and July, when some of the larger operators closed down their plants. The usual lack of water prevailed, producing conditions that were probably worse than in 1910. It is estimated that the number of men engaged in mining varied from about 800 during the dull period in the winter to a maximum of nearly 2,000 at the height of the summer season, and the number of claims being worked varied from 75 to 125. The winter mining operations are believed to have produced about $1,000,000 worth of gold.

PRODUCTIVE CREEKS.

GOLDSTREAM BASIN.

Goldstream Creek was probably the largest producer in the Fairbanks district during the winter of 1910–11 and the summer of 1911. Although many of the large producing mines of earlier years have been worked out, the tracing of the pay streaks has continued with marked success, particularly along the left limit bench claims above and below Fox Creek. Several new workable deposits have been found, some of which are of relatively high grade. It is estimated that 12 claims employing 85 men were worked in the winter of 1911, and during the height of the summer season there were probably 300 men engaged in mining on 20 claims.

On Engineer Creek during the winter 11 claims furnished work for 160 men, and in the summer 10 claims employed a maximum of 360 men. Most of the operations were large, several mines at times during the summer employing as many as 100 men.

Pedro Creek, on which, in 1901, gold was first discovered in the Fairbanks district, had a prosperous year. In the winter very little beyond prospecting was done, but in the summer 10 or 12 plants of various capacities furnished employment for about 200 men. Several steam scrapers were operated successfully on the creek. Considerable ground on Pedro Creek is owned by a dredging company, and it is expected that by the end of the season of 1912 a machine will be in operation.

From 50 to 60 men were engaged in mining on Gilmore Creek most of the year. Open-cut methods were chiefly employed in the summer, but the winter operations were, of course, entirely underground. The mines on First Chance Creek, which have been small producers for several years, did better in 1911. During the winter 14 men were engaged in drift mining on First Chance, and 4 men worked at open-cut mining during the summer.

Good prospects were found on Allen Creek, a small tributary of Goldstream.

CHATANIKA RIVER BASIN.

Cleary Creek showed a marked decrease in operations in 1911, particularly along the middle and upper parts of the stream, which have produced much gold in the past. Farther down, in the vicinity of Chatanika, several large outfits, employing from 20 to 50 men, were working continuously during the summer. In the winter the work was confined mainly to blocking out ground in preparation for the open season, when water would be available for washing the gravel as fast as hoisted. The Cleary Creek pay streak has been traced well out into the Chatanika Flats, and although the ground is deep and expensive to work, the flats promise to show considerable activity for several years. From 25 to 30 outfits were mining along Cleary Creek and the Chatanika Flats throughout the year, employing from 100 to 125 men in the winter and from 300 to 350 men in the summer.

Encouraging results have been obtained on Wolf Creek, where from 10 to 15 men were engaged in mining most of the year. Some mining was done on Chatham Creek also.

The production of Dome Creek for the last year probably exceeded that of 1910. Several small outfits were working between "No. 13 above" and "No. 7 below," but the increase in production was due to the rich gravel found on the Niggerhead Association claim, near the mouth of the creek. The pay streak is said to be several hundred feet wide and to average about 3 feet in depth. Most of the prospecting was done with a churn drill.

Very little mining was done on upper Vault Creek, the principal producing claims on this stream being the Alabama, Oregon, Sierra, and Isabel associations, which are situated in the Chatanika Flats, near the mouth of the creek. The operators believe that the Vault pay streak joins that of Dome Creek on the Alabama Association claim. An average of about 75 men were engaged in mining on the creek during the year.

On Treasure Creek 4 outfits employing 25 to 30 men were working in the winter, and during the summer 10 men were mining on 3 claims.

On Little Eldorado Creek the gold is very irregularly distributed, and considerable loss was suffered last year before that fact became known. In 1911, however, the operators were more successful; more placers will probably be found as prospecting continues. From 8 to 10 claims were worked during the year, employing in all from 75 to 175 men.

The hydraulic plant on Homestake Creek was put into operation as early in the season as climatic conditions would permit and the work was carried on with fair success during the period when the melting of ice and snow furnished a sufficient supply of water. The rainfall, however, was very light and the plant remained idle for a considerable part of the season.

FISH CREEK BASIN.

Fairbanks Creek continues to be one of the important producers of the district, and its production for 1911 will probably exceed that of 1910. From 10 to 15 outfits were working between "No. 10 above" and "No. 11 below," and about 150 men were employed On "No. 2 below" a new discovery seems to have been made. The gold is so different in appearance from any that has been found before on the creek that the operators believed they have found an entirely new pay streak. Latest reports indicate that the pay streak is over 200 feet wide. The gold is very coarse, and some of the ground is said to contain as much as $2 to $3 to the pan.

On "No. 8 above" a dredge was installed in the summer by the Alaska Exploration Co. The dredge had been operated on Stewart River, in Yukon Territory. In July it was taken by river to Chena, where it was dismantled into parts that could be handled and was shipped by train to Gilmore, thence it was hauled on wagons over the divide to its present location, where it was reconstructed and put in operation September 11. It is of the Risdon make and has 3½ cubic foot close-connected buckets and a 40-foot ladder. The scow measures 32 by 90 feet and draws 3½ feet of water. The gross weight of the machine is 300 tons. The cost of moving, dismantling, and reconstructing was reported to have been $30,000. The motive power is steam, wood being used for fuel. Considerable delay was caused by the breaking of links in the bucket chain, and late in October the dredge was closed down for the season. New links will be shipped over the trail, so that operations may be resumed early in the spring.

Considerable mining was done on Fish Creek, but the ground is said to be of lower grade than last year's results had led many of the operators to expect. During the summer 6 steam plants with self-dumping hoists were in operation and about 50 men were employed. Between 75 and 100 men wintered along the creek, but the work done was mostly prospecting.

On Last Chance Creek 4 or 5 men were mining by open-cut methods on one claim during the summer.

A pay streak is said to have been located on Pearl Creek, which is the tributary to Fish Creek from the right opposite "No. 7 below."

CRIPPLE CREEK BASIN.

Mining operations on Ester Creek continued to decline during the past year, and many of the richer claims are now worked out. Several new discoveries have been made, however, and the outlook for next season's mining seems fairly good. Commercial placers have been found on the second and third tiers left limit bench claims, and the known area of occurrence continues to increase as prospecting proceeds.

Eva Creek, which is a small tributary of Ester Creek from the left limit, opposite "No. 5 below," has been prospected extensively, and rich gravel is reported to have been found.

On the right limit of Ready Bullion one plant was working by open-cut methods; all other work was by drifting.

Some mining was done on St. Patrick Creek, but nothing was done on Cripple Creek proper. It is estimated that about 35 men were mining in the basin during the winter and about 500 in the summer.

BEAVER CREEK BASIN.

No more discoveries were made in the Beaver Creek region, although about 25 men were prospecting in the basin during the winter. Discovery claim, on Ophir Creek, is said to contain workable placers, and mining will probably be done there during the winter of 1911–12. Some very coarse gold has been found on the right limit bench claim of Nome Creek opposite the mouth of Ophir Creek, and one man continued prospecting by open-cut methods through the summer, when there was sufficient water. Only 4 or 5 men remained in the basin after the opening of the summer season.

CHENA RIVER BASIN.

Two or three outfits were mining on Smallwood Creek. The depth to bedrock is about 125 feet, and the pay streak ranges from 20 to 120 feet in width. The reported values are about $1 per square foot of bedrock, and the gold is rather coarse. On "No. 4 below" a nugget valued at $50 was found. About 10 men were engaged in mining during the summer.

It is reported that a company has been organized for dredging and hydraulicking on Middle Fork of Big Chena River in the vicinity of Palmer and Shamrock creeks, and that work would begin there in the fall of 1911. Another outfit was prospecting with a churn drill along the headwaters of the Big Chena.

SALCHAKET-TENDERFOOT REGION.

Mining continued in the Salchaket and Tenderfoot regions on about the same scale as in preceding years. Details of the operations are lacking, as the writer was not able to visit this field.

CIRCLE PRECINCT.

GENERAL CONDITIONS.

The value of the gold production of the Circle precinct in 1911 is estimated at approximately $350,000, which exceeds that of any year since 1898. The increase was due entirely to the improved methods employed. Five hydraulic plants were in operation during the whole or a part of the summer, and, although the water supply was insufficient during the greater part of the season, hydraulic methods, where intelligently applied, have proved to be superior to the hand methods that they have in part supplanted.

PRODUCTIVE CREEKS.

MASTODON CREEK.

Mastodon Creek was, as usual, the largest producer of the district. It is estimated that during the winter there were 7 producing claims employing 14 men and during the following summer from 8 to 10 outfits employing from 50 to 60 men. Three hydraulic plants were installed in the course of the year. The largest one, situated near the mouth of the creek, was put in operation in May. The water supply was derived from both Mastodon and Independence creeks and was carried in 18 to 26 inch riveted steel pipes. On the Mastodon Creek branch 9,000 feet of pipe was used, and a working head of 245 feet was obtained. From Independence Creek the water was carried 4,000 feet by pipe, and a head of 95 feet was available. A hydraulic elevator with a 10-inch throat was installed to elevate the gravels in the creek bottom. The two upper plants, one on claim "No. 14 above" and one on claim "No. 23 above," were smaller and were used mainly to strip the ground and prepare it for other methods of recovering the gold. At the plant on "No. 14 above," a Ruble elevator was reported to have been used with considerable success.

MAMMOTH CREEK.

The hydraulic plant on claim "No. 7 below" on Mammoth Creek was operated until about the middle of July, when it was moved to a location just above the mouth of Miller Creek where work was resumed later. About 10 men were employed in operating the plant, and it is understood that when the water supply was sufficient the results were satisfactory. The Porcupine branch of the Bonanza Creek ditch was completed in July, and throughout the summer several men were employed in repairing and enlarging the main ditch.

EAGLE CREEK.

Notwithstanding the severe shortage of water on Eagle Creek, the hydraulic plant moved a large body of gravel and demonstrated conclusively what could be accomplished by this means even under the most adverse conditions. Two shifts of 4 men each were ordinarily employed.

Some mining was done with pick and shovel on Mastodon Fork of Eagle Creek.

DEADWOOD AND SWITCH CREEKS.

No new developments were made on Deadwood Creek, and the production was probably about the same as in 1910. About 30 men were engaged in mining during both winter and summer. Considerable prospecting with a churn drill was done below where the creek emerges from the foothills, to determine the feasibility of dredging in that vicinity, but none of the results are known.

On Switch Creek 2 or 3 outfits employing from 1 to 3 men each were mining from time to time during the year.

OTHER CREEKS.

On Independence Creek 2 outfits employing 6 men were mining in the summer. No winter work was done on the creek. Mining was also done on Half Dollar and Greenhorn creeks. About 10 men were working by various methods along the bars of Birch Creek, and the prevailing low water was particularly favorable to them.

WATER SUPPLY OF THE FAIRBANKS, SALCHAKET, AND CIRCLE DISTRICTS.

By C. E. Ellsworth.

INTRODUCTION.

Since 1907 water-supply investigations have been carried on in the Yukon-Tanana region by the United States Geological Survey, and each year the essential results have been published in the general progress report for Alaska in as brief form as the proper use of such data would permit.

The following report is a continuation of those already published, and only such matter is quoted or in part republished as is considered necessary to make this report in itself of working value to engineers and mine operators.

The thanks of the writer are due to many residents of the country for their kindly cooperation. He also wishes to acknowledge special indebtedness to the following gage observers: Messrs. George L. Dalby, Jack Hendricks, William Hugel, Alfred Johnson, Frank Miller, Dan Nickelson, John Olsen, J. R. Parkin, Charles H. Rogers, Louis Schmidt, H. A. Stade, Mrs. F. Warren, and Messrs. Robert Warren and James Woods.

DATA AND METHODS.

The methods of carrying on the work and collecting the data were essentially the same as those used for similar work elsewhere in the United States, but were adapted to the special conditions found in Alaska.

In the consideration of industrial or mining enterprises which use the water of streams it is necessary to know the total amount of water flowing in the stream, the daily distribution of the flow, and the conditions affecting the flow. Several terms are used—such as second-foot, miner's inch, and gallons per minute—to describe the quantity of water flowing in a stream, the one selected depending on the use to be made of the data.

"Second-foot" is in most general use for all classes of work, and from it the quantity expressed in other terms may be obtained. It is an abbreviation of cubic foot per second, and may be defined as the quantity of water flowing per second in a stream 1 foot wide and 1 foot deep at the rate of 1 foot per second. It should be noted that it is a *rate* of flow, and to obtain the actual quantity of water it is necessary to multiply it by the time.

"Second-feet per square mile" is the average number of cubic feet of water flowing per second from each square mile of area drained, on the assumption that the run-off is distributed uniformly, as regards both time and area.

"Run-off, depth in inches on drainage area," is the depth to which the drainage area would be covered if all the water flowing from it in a given period were conserved and uniformly distributed on the surface. It is used for comparing run-off with rainfall, which is expressed in depth in inches.

The "miner's inch," the unit used in connection with placer mining, also expresses a rate of flow and is applied to water flowing through an orifice of a given size with a given head. The head and size of the orifice differ in different localities, thus making it a most indefinite and unsatisfactory unit. Owing to the confusion arising from its use, it has been defined by law in several States. The California miner's inch is in most common use in the United States and was defined by an act approved March 23, 1901, as follows: "The standard miner's inch of water shall be equivalent or equal to 1½ cubic feet of water per minute, measured through any aperture or orifice." This miner's inch corresponds to the so-called "6-inch pressure" and is one-fortieth of a second-foot.

The determination of the quantity of water flowing past a certain section of a stream at a given time is termed a "discharge measurement." The quantity is the product of two factors—the mean velocity and the area of the cross section. The mean velocity is a function of surface slope, wetted perimeter, roughness of bed, and the channel conditions at, above, and below the gaging station. The area depends on the contour of the bed and the fluctuations of the surface. The two principal ways of measuring the velocity of a stream are by floats and current meters.

All measurements by the engineers of the Survey were made with the current meter except those on Yukon River at Eagle (see pp. 30–31), but as float measurements can readily be made by the prospector the method is described below.

The floats in common use are the surface, subsurface, and tube or rod floats. A corked bottle with a flag in the top and weighted at the bottom makes one of the most satisfactory surface floats, as it is affected but little by wind. In flood measurements good results can be obtained by observing the velocity of floating cakes of ice or débris. In all surface-float measurements the observed velocity must be multiplied by 0.85 to 0.90 to reduce it to the mean velocity. The subsurface and tube or rod floats are intended to give directly the mean velocity in the vertical. Tubes give excellent results when the channel conditions are good, as in canals.

In measuring velocity by a float, observation is made of the time taken by the float to pass over the "run"—a selected stretch of river or creek from 50 to 200 feet long. In each discharge measurement a large number of velocity determinations are made at different points across the stream, and from these observations the mean velocity for the whole section is determined.

The area used in float measurements is the mean of the areas at the two ends of the run and at several intermediate sections.

PRECIPITATION.

Such records as are available for 1911 indicate that the precipitation throughout the Yukon-Tanana region did not vary far from the normal. In many localities its distribution was very unfavorable for mining. Most streams reached a lower stage than had before been recorded, although the average for the summer was about normal. On some streams the month in which the minimum flow occurred shows a mean run-off in excess of the average.

Most of the stations at which the most reliable and longest records have been kept are located at a considerably lower elevation than the mines. The Chicken Creek, Discovery Fork, and Crooked Creek stations probably represent very closely the average meteorologic conditions that prevail in the mining districts, and when several years' records shall have been obtained the data collected at the lower stations will be of greater value for comparison.

The following table gives the monthly precipitation at all points in the Yukon-Tanana region where records have been kept subsequent to 1903. Such scattered records as were kept previous to 1903 have been compiled by Abbe.[1]

Monthly precipitation, in inches, at stations in Yukon-Tanana region, 1903–1911.

[Rainfall or melted snow is given in the first line; snowfall in the second line.]

Station.	Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Central	1906	0.56	0.06	0.05	0.47	0.86	4.91	4.82	1.85	0.52	0.70	0.80	0.35	15.95
		6.1	1.0	1.4	4.7	2.0					7.0	8.0	4.0	34.2
Do	1907	1.04	.42	2.57	.93	.57	2.21	1.40						
		10.0	4.0	4.0	8.0	1.5								
Circle	1906												.75	
													9.5	
Do	1907	1.02	.57	.28	.15	.29		1.36	2.79	1.73			.63	
		8.5	7.8	3.25									8.2	
Do	1908	1.23	.25	.76	1.45	.29	.20	.87	1.08	2.21	.40	.75	1.11	10.60
		9.2	2.5	6.8	8.0						3.0	8.5	11.2	51.2
Do	1909	.44	.47	.17	.75	.60	2.24	3.25	1.02					
		4.5	5.2	1.0	3.0									
Charity Creek	1903				.11	.27	1.33	2.80	2.33	2.28	.20			
											3.0			

[1] Abbe, Cleveland, jr., Prof. Paper U. S. Geol. Survey No. 45, 1906, pp. 189–200.

Monthly precipitation, in inches, at stations in Yukon-Tanana region, 1903–1911—Con.

Station.	Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Chicken Creek[a]	1911						0 45	1.08	0.68	1.02	0.50	0.09	0.09	
Cleary	1907						.84	2.55	2.88	3.82				
Crooked Creek[b]	1911							2.52	2.18	1.30				
Discovery Fork[c]	1911						1.24	2.36	2.33	1.15				
Eagle Creek	1908								2.99					
Fairbanks	1904											1.10	2.00	
Do	1905	0.92	0.50	0.05	0.20				2.63	.86		1.20	.60	
		9.1	5.0	.5	2.0							12.0	5.1	
Do	1906	1.75	.37	.33	.10	0 36	1.05	2.82	1.50	.25	.30	.65	1.15	10.63
		17.5	3.7	3.3	1.0						.6	6.5	11.5	44.1
Do	1907	3.30	.86	2.42	.03	.35	1.47	1.51	1.81	3.58	2.44	.35	.59	18.71
		33.0	8.6	24.2	.3						2[illegible].4	3.5	5.9	99.9
Do	1908	.42	.21	1.10	.11	.52	.96	.73	.71	1.57	.47	.51	.65	7.96
		4.2	2.1	11.0	.8								8.1	26.2
Do	1909	.90	.08	.05	.66	.38	1.64	1.90	1.73	.39	.80	.52	.80	9.85
Do	1910	.70	.14	.02	.36	.39	2.16	.46	1.09	1.91	.66	.50	.76	9.75
Do	1911	1.50	.80	.06		.12			2.30	1.60	.22	.29	1.23	
Faith Creek	1907							1.87	3.00	2.97				
Fort Egbert	1903	.58	.81	.54	.12	1.38	.57	2.40	.97	2.97				
Do	1905					.33	1.95	1.52	2.72	3.38	2.96	.93	.68	
Do	1906		.14	2.19	00	.54	.51	2.54	1.28	.01	1.71	.51	.07	
			1.0	11.0							.46	8.5	1.0	
Do	1907	1.45	.21	0	.25	.40	1.89	1.48	1.98	1.45	1.12	.40	.31	10.94
		2.0	2.0	0	.15	.55					13.0	4.0		
Do	1908	.12	.25	.75	.10	1.02	2.16	2.47	1.02	1.48	.18	.82	1.09	11.46
		3.0	2.5	7.5	1.0						6.0	7.0	11.0	38.0
Do	1909	.16	.07	.11	.34	.28	2.35	1.77	.95	.88	.81	.30	.26	8.28
		2.0	1.0	1.0	2.0					6.1	11.7	3.0		
Do	1910	.83	.01	.53	.25	.28	1.05	2.28	2.63	2.98	.69	.25	.30	12.08
Do	1911	.27	.24	.39	.97	2.87	1.26	2.36	2.65	1.21	.13	.29	.80	13.44
Fort Gibbon	1903	.37	.73	1.14	.23	.16	.38	1.76		.48	.22	.33	Tr.	
Do	1904	.08	.55	.35	.09	.22	.33	1.95	3.80	.35	.39	.07	.70	8.88
Do	1905	.37	.47	Tr.	.32	.84	1.50	4.90	3.02	.59	.50	1.10	.18	13.79
Do	1906	.65	.20	.30	Tr.	1.00					[d].50	.99	.27	
		6.0	2.0	3.0							[d]5.0	9.9	2.7	
Do	1907	1.26		.53	0	.30		2.58	2.31	2.32	1.22	.03	.31	
		12.6		5.0	0					4.0	12.0	1.5		
Do	1908	.23	.26	.90	0	1.16		.96	1.13	1.60	.45	.08	.60	
		4.0	6.0	17.0	0					2.25	6.0		6.5	
Do	1909	.05	.10	.37	.39	1.51	.77	1.49	2.27	.90	.49	.46	.80	9.60
		.5	.5		2.2						4.8	4.6	8.0	20.6
Do	1910	1.23	.08	.60	.28	.69	.57	1.79	2.26	.74	.38		.59	
Do	1911	.94	1.63	.38	.77	1.53	.27	1.41	2.19	1.53	.44	.16		
Hot Springs	1909							1.76	3.19	.25	.44	1.10	2.26	
											4.4	11.0	22.6	
Do	1910	1.64	.03	.60	.20	.34	.76	[e]2.16		1.32				
		16.4	.3	6.0	2.0	3.4								
Kechumstuk	1904					1.80	.83	2.23	.94	.64	.30	.03	.23	
Do	1905	.90	.10	.05	.40	.20	1.58	.40	1.48	2.16	1.18	.36	.20	9.01
Do	1906	.36	.05	.06	.27	1.69	1.61	3.25	2.51	.51	.31	.29	.20	11.11
		4.0	.5	1.0	5.0						4.3	.5	3.0	18.3
Do	1907	.12	.20	.27	Tr.	1.30	2.03	1.60	2.14	.49	.72	.40		
		2.0	3.0	4.0		12.0				2.0	9.0	4.0		
Do	1908	0	0	.41	.40	1.78	1.77	2.30	2.22	1.35		.90	.20	
		0	0	5.0	4.0							9.0	2.0	
Do	1909	0	.30	.10	.20	0	3.66	3.39						
		0	.5	1.0		0								
Miller House	1909							2.98	1.26	.60	.93	.30	.30	
										4.0	8.0	3.0	3.0	
Do	1910				.20		1.94	2.37	.30	1.03				
North Fork	1905								1.91	1.86		.50	.20	
Do	1906	.70	.50	.10	.80	1.98	2.74	2.69	1.01	.72	.42	.55	.38	12.59
		7.0	5.0	1.0	8.0						3.2	4.5	4.5	33.2
Do	1907	.69	.28	.27	Tr.	1.34	1.92	1.57	3.19	2.0	1.40	.20		
		15.5	3.0	3.0		4.0				5.0	12.0	2.0		
Do	1908	.50												
		5.0	Tr.											
Poker Creek	1907								1.40	3.70	1.70	.25	1.09	
											24.0	3.3	6.8	
Do	1908		1.32		.42	.58	1.80	2.02	.99	2.45	.75	.35	.61	
			10.5		5.0					4.5	6.9	4.4	12.6	
Do	1909	.68	.09	.03	.42	1.11	1.22	2.01	2.01					
		8.8	2.0	.5	8.0	2.5								
Rampart	1905						1.33	1.99	2.19	1.70	1.20	1.43	.33	
Do	1906	.63	.08	.17	.04	.40	.15	1.86	2.40	.59	.61	.95	.33	8.21
		7.2	2.0	1.8	.5							10.2	3.5	25.2
Do	1907	1.17	.44	1.17	.02	.44	1.64	2.29	3.38	2.52	.65	.55	1.26	15.53
		12.0	4.5	12.8	2.5							6.3		

[a] Fortymile district.
[b] Seventymile district.
[c] Eagle district.
[d] October 7 to 31.
[e] July 16 to 31.

Monthly precipitation, in inches, at stations in Yukon-Tanana region, 1903–1911—Con.

Station.	Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Rampart	1908	1.08	0 52	0.81	0.58	0.82	1.38	1.13	0.46	1.56	0.39	0.73	1.14	10.60
		11.5	6.9	8.1	......	......	......	......	......	......	5.1	3.6	16.8	52.0
Do	1909	.09	.10	.37	.51	1.04	.85	2.01	1.41	.36	1.14	.35	1.99	10.22
		1.4	1.2	6.2	5.6	......	......	......	......	1.5	14.4	3.6	20.2	54.1
Do	1910	.84	.08	.36	.07	.20	.98	.71	.62	.43	.45	.26	.32	5.32
		11.1	.8	4.7	1.0	......	......	......	......	......	6.0	3.5	5.0	32.1
Do	1911	1.05	2.20	.31	.75	.48	.34	.43	1.12	.79	.57	.21	......	......
Summit road house	1907	......	......		......	......	......	2.71	3.27	a3.33	......	......	......	......
Tanana Crossing	1904	......	......	......	......	.76	......	.78	.89	1.06	.15	.10	.90	......
Do	1905	.24	.08	.18	.00	.14	......	.37	2.95	......	1.40	.60	......	......
Do	1906	.30	.00	Tr.	......	......	......	......	......	......	......	......	......	......

a September 1 to 22.

WATER POWER.

The records of stream flow gathered at points showing the greatest possibility for water-power development have been briefly summarized in the table below. In comparing the columns showing days of deficient discharge for several years on any stream, allowance should be made for the difference in the length of periods and also for the part of the season covered by the records. Ordinarily the longer the period the greater will be the number of days of deficient discharge for any given number of horsepower and the less favorable will be the comparison with some other year in which the records extend over a shorter length of time. Also the days of deficient discharge will be a greater percentage of the total number of days if the observations include only the low-water months.

The table gives the horsepower (80 per cent efficiency) per foot of fall that may be developed at different rates of discharge and show the number of days on which the discharge and the corresponding horsepower were respectively less than the amounts given in the columns for "discharge" and "horsepower."

Estimated discharge and horsepower for Chatanika River and Birch Creek for 1907–1911.

Discharge in second-feet.	Horsepower (80 per cent efficiency per foot fall).	Days of deficient discharge.										
		Chatanika River below Faith Creek.				Chatanika River below Poker Creek.					Birch Creek below Clums Fork.	
		June 21 to Sept. 30, 1907.	July 13 to Sept. 30, 1908.	May 25 to Sept. 25, 1910.	May 24 to Sept. 24, 1911.	June 20 to Oct. 14, 1907.	May 16 to Oct. 21, 1908.	May 9 to Oct. 5, 1909.	May 17 to Oct. 29, 1910.	May 6 to Nov. 5, 1911.	June 8 to Sept. 30, 1910.	June 9 to Sept. 28, 1911.
22	2	......	......	......	0	......	......	......	......	......	......	......
28	2.5	......	......	......	6	......	......	......	......	......	......	......
33	3	0	......	......	14	......	......	......	......	......	......	......
44	4	13	......	0	22	......	......	......	......	......	......	0
55	5	16	......	14	25	......	......	......	......	......	......	3
66	6	29	......	29	36	......	......	......	......	......	......	8
77	7	39	0	34	45	......	......	......	......	0	......	10
88	8	47	2	37	54	......	......	0	0	4	......	13
99	9	52	4	39	62	......	......	2	2	11	......	19
110	10	56	19	45	67	......	......	5	3	24	0	20
132	12	69	35	47	71	......	......	17	22	30	5	28
154	14	73	57	54	74	0	......	26	40	41	8	31
176	16	77	58	64	76	5	0	27	49	44	12	34
198	18	78	65	69	77	17	5	39	55	59	14	38
220	20	82	66	79	79	27	27	46	60	66	15	53

FAIRBANKS DISTRICT.

DESCRIPTION.

The Fairbanks district extends about 60 miles to the north of Fairbanks and is from 40 to 50 miles wide. The greater part of it lies in the lower Tanana basin, but a portion to the northwest drains directly to the Yukon. Generally speaking, the district embraces three divisions—a low, broad alluvial plain, a moderately high dissected plateau, and a mountain mass.

The low, broad plain forms the bottom lands of the lower Tanana Valley, which in this section is divided into several parts by the Tanana and its slough like channels. The main slough starts near the mouth of Salcha River, about 30 miles above Fairbanks, and diverts a portion of the Tanana waters. Its course is northward along the foothills of the plateau, and it receives Chena River about 9 miles above Fairbanks. The plain is swampy and is well covered with timber along the banks of the streams. In the vicinity of Fairbanks it has a general elevation of about 500 feet above sea level.

The plateau is drained by streams tributary to Tanana River which flow through rather broad, unsymmetrical valleys, chiefly extending in a northeast-southwest direction. Their bottom lands range in elevation from 500 to over 2,000 feet above sea level, and the dividing ridges are in general 1,000 to 3,000 feet above the stream beds. That portion of the plateau discussed in this report is drained principally by Little Chena and Chatanika rivers. The upper region of these drainage basins is crosscut by a zigzag range, which separates the Yukon from the Tanana drainage.

The mountain mass north of this plateau forms what might be termed the apex of the divide between the Tanana and the Yukon drainage basins; its highest points reach altitudes 4,000 to 5,000 feet above sea level, and its corrugated slopes are drained principally by tributaries of Yukon River.

All drainage areas tributary to the Tanana are similar in character. The streams have little slope except near their source and flow over wide gravelly beds in shifting and tortuous courses, keeping to one side of the valley. Most of the channels have rather steep banks that form approaches to broad, level bottom lands which extend 1,000 to 4,000 feet or more before they meet the abrupt slopes of the dividing ridges. The drainage basins are 4 to 15 miles wide and are cut up by small tributary streams that flow through deep and narrow ravines.

A large portion of the area is covered with a thick turf, known as tundra, which is wet, spongy, and mossy and ranges in thickness from 6 inches to 2 feet. In some localities this is meadow-like, producing a rank growth of grass and a variety of beautiful wild flowers. Ground ice is found beneath this tundra in many places, particularly on the northern slopes, where the scanty soil supports little timber or other vegetation. The soil of the southern slopes is for the most part clay, underlain by a mica schist which affords suitable ground for ditch construction. When stripped of its mossy covering and exposed to the sun it thaws rapidly, so that the plow and scraper can be used to advantage.

Above altitudes of 2,000 to 2,200 feet practically the only vegetation is a scrubby bushy growth which attains a height of 2 to 4 feet. In general the country below this altitude is timbered by spruce and birch, with scattered patches of tamarack and willow along the banks of the smaller streams. The timber increases in density and size toward the river bottoms, where the prevailing growth is spruce, much of which attains a diameter of 18 to 24 inches.

The Fairbanks mining district lies between Little Chena and Chatanika rivers. It embraces an area of about 500 square miles and extends 30 miles north of Fairbanks, which is situated on Chena Slough nearly 12 miles above its confluence with the Tanana. Most of the producing creeks rise in a high rocky ridge, of which Pedro Dome, with an elevation of about 2,500 feet, is the center. At least half of the mines are located at an elevation of over 800 feet, and 25 per cent are over 1,000 feet above sea level.

GAGING STATIONS AND MEASURING POINTS.

The following list gives the locations at which gaging stations were maintained or discharge measurements made in 1911 in the Fairbanks district:

Gaging stations and measuring points in the Tanana River basin, Fairbanks district, 1911.

- Chena River drainage basin:
  - Chena River above Little Chena River.
  - Little Chena River below Fish Creek.
  - Fish Creek below Solo Creek.
  - Fish Creek at mouth.
  - Bear Creek at road crossing.
  - Miller Creek at mouth.
- Chatanika River drainage basin:
  - Chatanika River below Faith Creek.
  - Chatanika River below Poker Creek.
  - McManus Creek at mouth.
  - Smith Creek above Pool Creek.
  - Pool Creek at mouth.
  - Faith Creek at mouth.
  - Charity Creek above Homestake Creek.
  - Homestake Creek at mouth.
  - Hope Creek at mouth.
  - Sourdough Creek 1 mile above mouth.
  - Poker Creek above Caribou Creek.
  - Caribou Creek at mouth.
- Beaver Creek drainage basin:
  - Beaver Creek above Roy Creek.
  - Big Champion Creek at mouth.
  - Little Champion Creek at mouth.
  - Nome Creek below Moose Creek.
  - Moose Creek above Ophir Creek.
  - Ophir at Discovery claim.
  - Roy Creek 5 miles above mouth.
  - Roy Creek 2 miles above mouth.
  - Bryan Creek 2 miles above mouth.
  - Trail Creek 2 miles above mouth.

CHENA RIVER DRAINAGE BASIN.

Chena River drains the area lying between Chatanika River on the north, Birch Creek on the east, and Salcha River on the south. It has a length of about 100 miles and flows slightly south of west to the lowlands of the Tanana Valley, where it empties its waters into Chena Slough. The principal tributaries are West Fork and Little Chena River from the north and South Fork from the south.

Little Chena River and its tributaries Sorrels and Fish creeks drain the southern slope of the divide between Chatanika and Chena rivers from the headwaters of Smith and Flat creeks to Pedro Dome, a distance of about 25 miles. The drainage basin is irregular in shape and is crossed by a network of small, ramifying streams with precipitous slopes in their upper courses. The upper portion of the main stream is also steep, having a fall of 100 to 150 feet to the mile, but this slope decreases rather abruptly to about 18 feet to the mile in the vicinity of Elliott and Fish creeks.

Above Fish Creek the Little Chena flows through a rather broad, unsymmetrical valley, but below that stream it takes the center of a deep, rather narrow channel for about 10 miles, to Anaconda Creek, an important tributary which enters from the left. Below this point the valley gradually widens again until the stream reaches the lowlands tributary to Chena River, with which it unites 6 or 8 miles above the confluence of Chena Slough.

The principal tributaries of Fish Creek are Bear, Fairbanks, and Miller creeks.

Daily discharge, in second-feet, of Chena River and Fish Creek, 1911.

Day.	Chena River above Little Chena River.[a] [Drainage area, 1,440 square miles.]					Fish Creek below Solo Creek.[b] [Drainage area, 21.5 square miles.]			
	June.	July.	Aug.	Sept.	Oct.	June.	July.	Aug.	Sept.
1	....	1,220	529	1,210	1,340	....	29	5.3	28
2	....	1,640	507	1,230	1,360	....	30	5.1	42
3	....	1,740	472	1,440	1,240	....	26	5.3	25
4	....	1,690	465	1,520	1,210	....	36	4.3	22
5	....	2,690	465	1,440	1,150	....	39	4.3	18.8
6	....	2,450	465	1,360	1,100	....	27	3.9	18.4
7	....	1,940	465	1,290	1,000	....	24	3.9	16.2
8	....	2,030	453	1,220	970	....	24	8.5	16.2
9	....	1,790	450	1,160	883	....	12.3	7.1	15.5
10	....	1,570	450	1,030	858	....	10.3	18.0	16.0
11	....	1,310	450	1,000	808	....	21	27	16.2
12	....	1,200	619	958	783	....	26	16.6	16.2
13	....	1,120	1,510	1,020	755	....	14.4	16.6	15.0
14	....	1,060	1,400	1,050	764	....	13.4	....	14.4
15	....	1,020	1,500	1,050	718	....	10.3	....	....
16	....	964	4,550	1,000	718	....	10.3	50	....
17	....	873	6,120	1,030	650	....	8.5	44	....
18	......	812	5,610	947	634	....	8.5	40	....
19	....	783	5,360	936	634	....	7.6	34	....
20	....	727	4,340	910	611	18.8	6.8	28	....
21	....	691	3,420	883	588	18.8	6.8	22	....
22	2,170	691	2,840	883	569	16.6	6.8	19.3	....
23	2,020	675	2,420	873	536	12.3	6.0	18.8	....
24	1,860	658	2,210	803	536	11.3	6.0	15.5	....
25	1,720	634	1,810	822	536	10.3	5.3	15.5	....
26	1,540	611	1,640	981	514	9.4	5.3	14.4	....
27	1,430	588	1,500	1,020	522	6.8	6.0	14.4	....
28	1,310	573	1,410	1,140	500	6.8	6.8	14.4	....
29	1,220	573	1,410	1,270	500	6.8	6.0	14.0	....
30	1,110	566	1,360	1,370	....	21.0	5.3	14.0	....
31	....	554	1,270	....	....	....	5.3	14.0	....
Mean	1,600	1,140	1,850	1,090	793	12.6	14.5	....	20.0
Mean per square mile	1.11	.792	1.29	.757	.551	.586	.674	....	.930
Run-off (depth in inches on drainage area)	.37	.91	1.49	.84	.59	.24	.78	....	.24

[a] The discharges of Chena River are only approximate.
[b] The discharges of Fish Creek are based on a fairly well defined rating curve.

Miscellaneous measurements in Chena River drainage basin, 1911.

Date.	Stream and locality.	Drainage area.	Discharge.	Discharge per square mile.
		Sq. miles.	*Sec.-ft.*	*Sec.-ft.*
Aug. 6	Little Chena River below Fish Creek	22.8	32	0.14
6	Fish Creek at mouth	90.2	15.3	.17
6	Bear Creek at road crossing	12.8	2.8	.22
6	Miller Creek at mouth	16.7	1.5	.090

CHATANIKA RIVER DRAINAGE BASIN.

Chatanika River is formed by the junction of Faith and McManus creeks, which drain the high ridge constituting the divide between the lower Tanana and Yukon basins. The river flows southwestward in a winding course through a long and rather narrow valley and unites with the Tolovana from the east about 30 miles above the confluence of that stream with the Tanana. Its course lies mostly to the west side of the valley, which is from half a mile to 7 miles wide and about 80 miles long. The drainage area of the river above its mouth is approximately 1,300 square miles.

Below the junction of Faith and McManus creeks the stream has a shifting, gravelly bottom. In low and medium stages it flows in a series of pools and rapids in a channel 75 to 200 feet wide; during the high-water period it may spread through several channels covering a width of 100 to 400 feet. This high-water channel is usually well defined by steep, alluvial banks ranging from 8 to 10 feet in height.

Below Poker Creek, a tributary from the right about 40 miles downstream from the junction of Faith and McManus creeks, the valley widens and the bottom lands become marshy and swampy. From the left the Chatanika receives Cleary, Eldorado, Dome, and Vault creeks and other less important streams from the mining district proper. Below these tributaries the valley narrows to a gorgelike channel, which it follows for about 10 miles; below this the dividing ridges disappear and the stream meanders through the low swampy grounds north of Tanana River. About 10 miles from its mouth Goldstream Creek, its largest tributary, joins it from the left.

The average elevation of the divides in the upper drainage area of the Chatanika is between 3,000 and 4,000 feet above sea level, and the altitude of the ridges bounding the valley on the east and west is about 2,000 feet. Below an altitude of 1,800 to 2,000 feet the slopes are heavily timbered.

The tributary streams from the right are short and precipitous, flowing through V-shaped valleys; those from the left have less precipitous courses and broader valleys and gradually lose themselves in the rather broad expanse of swamplike bottom lands.

Smith Creek is the principal tributary of McManus Creek and enters it from the south about a mile above Faith Creek. Pool Creek joins Smith Creek from the east about a mile above McManus Creek.

Monthly discharge of Chatanika River, 1907–1911.

Chatanika River Below Faith Creek.

[Drainage area, 132 square miles.]

Month.	Discharge in second-feet.				Run-off (depth in inches on drainage area).
	Maximum.	Minimum.	Mean.	Mean per square mile.	
1907.					
July 17–31	96	55	67.8	0.514	0.28
August	205	72	125	.947	1.09
September	1,990	119	342	2.59	2.89
The period, 76 days	1,990	55	178	1.31	4.26
1908.					
May 12–20	1,340	320	598	4.53	1.85
July 13–31	200	82	131	.992	.70
August	270	95	137	1.04	1.20
September	530	102	208	1.58	1.76
The period, 89 days	1,340	82	241	1.82	5.51
1910.					
May 25–31	683	320	473	3.58	.93
June	2,000	118	377	2.86	3.19
July	293	48	86.1	.652	.75
August	1,010	49	197	1.49	1.72
Sept. 1–25	430	141	233	1.77	1.65
The period, 124 days	2,000	48	235	1.78	8.24
1911.					
May 24–31	1,010	408	691	5.23	1.56
June	836	140	441	3.33	3.72
July	334	28	101	.765	.88
August	1,280	24	146	1.11	1.27
Sept. 1–24	125	53	79.8	.604	.54
The period, 124 days	1,280	24	228	1.73	7.97

Chatanika River Below Poker Creek.

[Drainage area, 456 square miles.]

1907.					
June 20–30	250	192	228	0.500	0.20
July	283	167	211	.463	.53
August	1,160	216	428	.939	1.08
September	3,160	300	954	2.09	2.33
Oct. 1–14	860	232	506	1.11	.47
The period, 117 days	3,160	167	496	1.08	4.61
1908.					
May 16–31	4,120	1,730	2,730	5.99	3.56
June	2,280	283	984	2.16	2.41
July	942	204	332	.728	.84
August	455	192	284	.623	.72
September	1,160	266	461	1.01	1.12
Oct. 1–21	342	179	234	.513	.40
The period 159 days	4,120	179	699	1.53	9.05

Monthly discharge of Chatanika River, 1907–1911—Continued.

Chatanika River Below Poker Creek—Continued.

Month.	Discharge in second-feet.				Run-off (depth in inches on drainage area).
	Maximum.	Minimum.	Mean.	Mean per square mile.	
1909.					
May 9–31	3,620	474	1,870	4.10	3.51
June	1,220	152	416	.912	1.02
July	833	219	414	.910	1.05
August	1,740	179	530	1.16	1.34
September	219	130	151	.331	.37
Oct. 1–5	110	92	103	.226	.04
The period, 150 days	3,620	92	598	1.31	7.33
1910.					
May 17–31	1,900	600	944	2.07	1.16
June	3,260	248	686	1.50	1.67
July	822	104	196	.430	.50
August	2,720	95	481	1.05	1.21
September	1,410	298	553	1.21	1.35
Oct. 1–29	352	123	208	.456	.49
The period, 166 days	3,260	95	472	1.04	6.38
1911.					
May 6–31	3,500	1,170	2,550	5.59	5.41
June	1,760	283	818	1.79	2.00
July	566	109	276	.605	.70
August	1,740	88	372	.816	.94
September	422	147	262	.575	.64
October	330	87	167	.366	.42
Nov. 1–5	101	87	94.8	.208	.04
The period, 184 days	3,500	87	677	1.48	10.15

Daily discharge, in second-feet, of Chatanika River, 1911.[a]

Day.	Chatanika River below Poker Creek. [Drainage area, 456 square miles.]							Chatanika River below Faith Creek. [Drainage area, 132 square miles.]				
	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	May.	June.	July.	Aug.	Sept.
1	......	1,760	379	104	323	330	87	......	795	250	28	90
2	......	1,100	566	101	338	300	87	......	518	290	28	125
3	......	1,330	467	94	422	267	98	......	612	334	28	113
4	......	1,170	413	91	370	245	101	......	645	226	24	113
5	......	1,200	379	88	319	245	101	......	518	239	24	101
6	3,100	1,200	379	88	308	212	......	......	836	239	24	97
7	3,000	1,320	338	88	273	207	......	......	612	232	24	90
8	3,480	831	422	97	260	207	......	......	434	140	24	90
9	3,500	850	319	101	241	207	......	......	357	109	26	80
10	2,560	786	379	120	235	196	......	......	311	87	40	80
11	2,160	600	387	170	235	191	......	......	290	68	90	80
12	2,120	582	467	220	251	181	......	......	200	87	70	80
13	2,200	666	293	201	241	181	......	......	460	75	53	76
14	2,560	626	308	229	235	181	......	......	549	68	58	70
15	3,020	768	373	1,040	229	181	......	......	612	57	1,280	61
16	2,800	1,180	267	1,740	212	181	......	......	732	57	436	70
17	2,940	1,060	315	1,140	201	181	......	......	756	57	436	70
18	3,280	1,110	221	1,120	194	147	......	......	434	57	327	61
19	3,300	1,240	194	799	194	104	......	......	580	54	232	61
20	3,420	1,020	160	577	191	121	......	......	489	43	177	53
21	3,260	812	147	467	194	127	......	......	450	40	147	61
22	2,680	593	147	387	194	104	......	......	334	38	125	61
23	2,300	467	147	346	176	101	......	......	334	34	113	61
24	2,220	379	140	308	158	101	......	408	277	34	101	70
25	2,220	379	136	283	147	101	......	716	232	30	101	......

[a] The discharges at these stations are based on well-defined rating-curves.

Daily discharge, in second-feet, of Chatanika River, 1911—Continued.

Day.	Chatanika River below Poker Creek. [Drainage area, 456 square miles.]							Chatanika River below Faith Creek. [Drainage area, 132 square miles.]				
	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	May.	June.	July.	Aug.	Sept.
26	2,300	330	136	267	273	101	......	1,010	200	34	90	......
27	1,980	300	136	267	338	114	......	922	200	34	90	......
28	1,780	293	147	267	379	101	......	549	169	30	90	......
29	1,670	283	140	260	379	101	......	680	140	28	80	......
30	1,390	308	121	235	358	87	......	489	154	28	80	......
31	1,170	......	109	235	......	87	......	756	......	28	80	......
Mean	2,550	818	276	372	262	167	94.8	691	441	101	146	......
Mean per square mile	5.59	1.79	.605	.816	.575	.366	.208	5.23	3.33	.765	1.11	......
Run-off (depth in inches on drainage area)	5.41	2.00	.70	.94	.64	.42	.04	1.56	3.72	.88	1.27	......

Daily discharge, in second-feet, of McManus and Faith creeks, 1911.[a]

Day.	McManus Creek at mouth. [Drainage area, 80 square miles.]					Faith Creek at mouth. [Drainage area, 51 square miles.]			
	May.	June.	July.	Aug.	Sept.	June.	July.	Aug.	Sept.
1	....	322	94	12.0	34	....	139	17.0	39
2	....	368	140	12.0	60	....	115	17.0	49
3	....	368	170	12.0	53	....	167	17.0	43
4	....	322	107	12.0	48	....	105	15.2	43
5	....	322	152	12.0	44	....	81	14.0	37
6	....	414	152	12.0	39	....	74	14.0	43
7	....	278	133	12.0	39	....	81	14.0	43
8	....	255	67	12.0	39	....	65	14.0	43
9	....	233	44	12.0	30	....	59	14.0	37
10	....	190	30	15.0	30	....	47	20	37
11	....	190	27	24	34	....	37	62	37
12	....	233	44	19.6	30	....	43	49	37
13	....	255	34	17.0	24	....	39	37	35
14	....	211	27	19.6	24	....	35	39	32
15	....	220	24	354	24	....	32	750	32
16	....	255	27	203	30	422	35	243	32
17	....	264	24	203	30	444	35	243	32
18	....	233	24	140	27	313	35	153	30
19	....	233	24	94	24	355	32	99	28
20	....	190	17.0	78	24	313	28	81	28
21	....	163	17.0	60	24	293	26	65	28
22	....	140	17.0	48	24	218	24	56	28
23	....	107	17.0	44	24	200	24	52	30
24	508	94	17.0	39	30	167	22	49	32
25	602	72	15.0	39	....	139	20	49	....
26	626	72	17.0	39	....	115	20	43	....
27	508	67	17.0	39	....	120	20	43	....
28	438	48	15.0	39	....	95	18.8	43	....
29	438	48	12.0	30	....	77	17.0	37	....
30	322	67	12.0	30	....	81	17.0	37	....
31	438	....	12.0	30	....	....	17.0	37	....
Mean	485	208	49.3	55.2	32.9	223	48.7	78.2	35.6
Mean per square mile	6.06	2.60	.617	.690	.411	4.37	.955	1.53	.698
Run-off (depth in inches on drainage area)	1.80	3.00	.71	.80	.38	2.44	1.10	1.76	.61

[a] The discharges at these stations are based on well-defined rating curves.

Daily discharge, in second-feet, of Smith and Pool creeks, 1911.

Day.	Smith Creek above[a] Pool Creek. [Drainage area, 17.0 square miles.]				Pool Creek at mouth.[b] [Drainage area, 14.0 square miles.]			
	June.	July.	Aug.	Sept.	June.	July.	Aug.	Sept.
1	....	16.8	2.1	6.2	....	32.0	1.5	7.0
2	....	16.8	2.1	7.5	....	38.0	1.5	9.0
3	....	28.0	1.4	6.2	....	38.0	1.5	7.2
4	....	24.0	2.1	6.2	....	32.0	1.5	7.2
5	....	28.0	2.1	6.2	....	45.0	1.5	5.6
6	....	18.6	2.1	6.2	....	32.0	1.5	9.0
7	....	24.0	2.1	6.2	....	45.0	1.5	9.0
8	....	16.8	2.1	6.2	....	32.0	1.5	7.2
9	....	8.9	2.1	6.2	....	17.7	1.5	7.2
10	....	6.2	2.8	4.9	....	15.4	2.8	5.6
11	....	6.2	2.8	4.9	....	9.0	2.8	5.6
12	....	6.2	2.8	4.9	....	8.0	2.8	5.6
13	....	4.9	2.8	3.8	....	7.0	2.8	4.0
14	....	4.9	3.8	2.8	....	6.0	4.0	4.0
15	....	4.9	50.0	4.9	....	5.6	77.0	7.2
16	16.8	4.9	26.0	4.9	35.0	4.0	38.0	7.2
17	24.0	3.8	28.0	....	38.0	4.0	41.0	....
18	16.8	3.8	16.8	....	32.0	4.0	23.0	....
19	16.8	3.8	13.5	....	32.0	4.0	17.6	....
20	13.5	3.8	10.3	....	26.0	4.0	13.1	....
21	13.5	2.8	8.9	....	20.0	4.0	10.9	....
22	10.3	2.8	8.9	....	15.4	4.0	10.9	....
23	7.5	2.8	7.5	....	20.0	2.8	9.0	....
24	8.9	2.8	6.2	....	20.0	2.8	7.2	....
25	7.5	2.8	6.2	....	17.7	2.8	7.2	....
26	6.2	2.8	4.9	....	20.0	2.8	5.6	....
27	4.9	2.1	6.2	....	17.7	1.5	7.2	....
28	4.9	2.1	4.9	....	15.4	1.5	7.2	....
29	4.9	2.1	4.9	....	15.4	1.5	7.2	....
30	11.9	2.1	4.9	....	26.0	1.5	7.2	....
31	....	2.1	4.9	....	....	1.5	7.2	....
Mean	11.2	8.47	7.94	5.51	23.4	13.2	10.5	6.74
Mean per square mile	.659	.498	.467	.324	1.67	.943	.750	.481
Run-off (depth in inches on drainage area)	.37	.57	.54	.20	.93	1.09	.86	.29

[a] The discharges of Smith Creek below 25 second-feet are well defined.
[b] The discharges of Pool Creek prior to July 15 are based on one discharge measurement and comparative hydrographs with Smith Creek and are only approximate. Subsequent to July 15 they are well defined below 10 second-feet.

Miscellaneous measurements in Chatanika River drainage basin, 1911.

Date.	Stream and locality.	Drainage area.	Discharge.	Discharge per square mile.
		Sq. miles.	*Sec.-ft.*	*Sec.-ft.*
June 14	Charity Creek above Homestake Creek	....	35.0	....
July 16	.....do	....	5.5	....
Aug. 3	.....do	....	2.1	....
June 14	Homestake Creek at mouth	5.6	42.0	7.50
July 16	.....do	5.6	2.4	.43
Aug. 3	.....do	5.6	1.1	.20
July 16	Hope Creek at mouth	20.3	10.1	.50
Aug. 3	.....do	20.3	4.5	.22
July 14	Sourdough Creek 1 mile above mouth	15.1	4.5	.30
9	Poker Creek above Caribou Creek	24.5	7.4	.30
9	Caribou Creek at mouth	17.8	3.1	.17
June 19	Chatanika ditch at Poker Creek road crossing	....	24.0	....
30	.....do	....	21.0	....
July 1	.....do	....	20.0	....
8	.....do	....	26.0	....
8	.....do	....	23.0	....
Aug. 7	.....do	....	16.8	....

BEAVER CREEK DRAINAGE BASIN.

Beaver Creek drains an area of 5,360 square miles lying north of Chatanika River between Preacher Creek on the east and Tolovana River and Hess Creek on the west. It joins the Yukon from the south about 40 miles below Birch Creek and nearly opposite Hosiana River. It is formed by the junction of Big Champion and Little Champion creeks, whose headwaters interlock with those of Preacher Creek. It flows westward for about 25 miles, when it makes a right-angle turn around the southern extremity of the White Mountains and gradually assumes a northeasterly course, which it follows until it leaves the foothills and enters the flats of the Yukon, where it makes an abrupt turn to the northwest and meanders in a tortuous course to its mouth.

The average fall between Nome Creek and Fossil Creek is about 12 feet to the mile. The principal tributaries, named in order downstream, are Roy, Bryan, Brigham, Fossil, Willow, and Mascot creeks on the right limit and Nome, Trail, Wickersham, and Victoria creeks on the left limit.

Ophir Creek is the largest branch of Nome Creek and enters it from the south about a mile above Beaver Creek.

Daily discharge, in second-feet, of Nome Creek above Ophir Creek, 1911.[a]

[Drainage area, 76 square miles.]

Day.	July.	Aug.	Sept.	Day.	July.	Aug.	Sept.
1		17.9	39	21	23.0	93.0	
2		17.0	79	22	35.0	66.0	
3		16.5	98	23	27.0	55.0	
4		15.1	74	24	30.0	47.0	
5		15.1		25	25.0	39.0	
6		14.2		26	23.0	36.0	
7		14.0		27	25.0	36.0	
8		14.0		28	37.0	39.0	
9		15.0		29	26.0	35.0	
10		18.8		30	22.0	39.0	
				31	18.8	37.0	
11		50.0					
12		45.0		Mean	30.6	95.4	
13	45.0	30.0		Mean per square mile	.403	1.26	
14	39.0	32.0	37	Run-off (depth in inches on drainage area)	.28	1.45	
15	33.0	538.0	36				
16	35.0	499.0	35				
17	45.0	394.0					
18	40.0	328.0					
19	28.0	220.0					
20	25.0	142.0					

[a] The discharges of Nome Creek below 60 second-feet are well defined.

Miscellaneous measurements in Beaver Creek drainage basin, 1911.

Date.	Stream and locality.	Drainage area.	Discharge.	Discharge per square mile.
		Sq. miles.	*Sec.-ft.*	*Sec.-ft.*
July 10	Beaver Creek above Roy Creek	357	328	0.92
11	Big Champion Creek at mouth	122	137	1.12
11	Little Champion Creek at mouth	67	58	.87
14	Nome Creek below Moose Creek	24.9	19.2	.77
9	Ophir Creek at Discovery claim	22.1	5.5	.25
10	.....do	22.1	4.6	.21
11	.....do	22.1	13.8	.62
12	.....do	22.1	57	2.58
12	.....do	22.1	47	2.13
13	.....do	22.1	28	1.27
Aug. 9	.....do	22.1	.81	.037
July 11	Roy Creek 5 miles above mouth	5.8	3.8	.66
10	Roy Creek 2 miles above mouth	16.5	6.6	.40
10	Bryan Creek 2 miles above mouth	60.6	64	1.06
10	Trail Creek 2 miles above mouth	37.0	7.9	.21

SALCHAKET DISTRICT.

DESCRIPTION.

The Tanana precinct, which includes the Salchaket district, embraces the area drained by the Tanana and its tributaries from and including Salcha River to a point on Tanana River south of Lake Mansfield. The larger streams included in this area are Salcha, Goodpaster, Volkmar, and Healy rivers from the north and Delta River from the south.

TANANA RIVER DRAINAGE BASIN.

Tanana River rises near the international boundary line and flows in a general northwesterly direction for about 440 miles to its junction with Yukon River at Fort Gibbon.

The river in general follows the north side of the valley and is one maze of channels and islands. At McCartys, just above the mouth of Delta River, which is 95 miles from Fairbanks by the Government road, it flows in three channels except at extreme low water, when the middle one is dry. During the summer of 1909 the Alaska Road Commission installed ferries on the right and left channels and bridged the center one.

Salcha River rises opposite the head of South Fork of Birch Creek, about 25 miles from the Yukon. The average fall of the river from the Splits to the mouth is 10 feet to the mile, and from a point about 2 miles from the summit of the divide at the headwaters it averages 19 feet to the mile. At the mouth, which is 40 miles from Fairbanks, a ferry, post office, store, and road house are located and good accommodations are at hand for the traveler. Redmond Creek enters the Salcha from the south about 15 miles above the mouth. Junction and Mosquito creeks, which join to form Redmond Creek, drain an area 6 to 8 miles north of the Tanana and parallel to it.

Little Salcha River, which is tributary to the Tanana from the east, enters the river at a point midway between the town of Salchaket and the Salcha telegraph station.

Miscellaneous measurements in Salchaket district, 1911.

Date.	Stream and locality.	Drainage area.	Discharge.	Discharge per square mile.
		Sq. miles.	*Sec.-ft.*	*Sec.-ft.*
June 25	Salcha River at Salchaket	2,170	3,910	1.80
26	....do	2,170	2,950	1.36
27	....do	2,170	2,890	1.33

CIRCLE PRECINCT.

DESCRIPTION.

The area north of the Yukon-Tanana divide between longitude 143° 40′ and 146° 50′ is known as the Birch Creek district of the Circle precinct. Generally speaking, it consists of two geographic divisions—a low, broad alluvial plain and a dissected plateau.

The northwestern portion of the low, broad plain forms the bottom lands of the Yukon Flats north of Crazy Mountains; the southeastern portion is an irregular area surrounded by a low ridge along the Yukon, the Crazy Mountains, and the range of hills 20 to 40 miles farther south. This portion is cut by Birch and Crooked creeks; it is well timbered along these streams and contains large areas of meadow-like swamp land that furnish forage for both summer and winter use.

The plateau division, whose longer diameter trends east and west, lies between two distinct ridges—the eastern extensions of the White Mountains. The ridge to the south is high and barren and forms the main Yukon-Tanana divide; that to the north is lower, irregular, and barren, and separates the upper tributaries of the Birch Creek basin from the lower, and is itself divided by the deep canyon-like gorge through which Birch Creek flows on its way to the Yukon.

At elevations of 2,000 feet or more above sea level the country is as a rule barren and rocky; below this altitude, especially in the flats where Birch and Crooked creeks join, considerable timber is found.

GAGING STATIONS AND MEASURING POINTS.

The following list gives the locations at which gaging stations were maintained or discharge measurements made in 1911 in the Circle district:

Gaging stations and measuring points in Circle district, 1911.

- Birch Creek drainage basin:
  - Birch Creek below Clums Fork.
  - Birch Creek above Sheep Creek.
  - Birch Creek at Fourteenmile House.
  - Clums Fork at mouth.
  - Wolf Creek 1 mile above mouth.
  - Buckley Bar Creek at mouth.
  - Sheep Creek at mouth.
  - South Fork of Birch Creek above Big Windy Creek.
  - South Fork of Birch Creek below Big Windy Creek.
  - Big Windy Creek at mouth.
  - North Fork of Birch Creek drainage basin:
    - North Fork of Birch Creek above Twelvemile Creek.
    - North Fork of Birch Creek below Twelvemile Creek.
    - Ptarmigan Creek at mouth.
    - Golddust Creek at mouth.
    - Butte Creek at mouth.
    - Bear Creek at mouth.
    - Twelvemile Creek below South Fork.
    - North Fork of Twelvemile Creek at mouth.
- Crooked Creek drainage basin:
  - Crooked Creek at Central House.
  - Porcupine Creek above ditch intake.
  - Porcupine Creek below Bonanza Creek.
  - Bonanza Creek below ditch intake.
  - Bonanza Creek ditch at intake.
  - Bonanza Creek ditch below Porcupine Creek ditch.
  - Mammoth Creek above Miller Creek.
  - Independence Creek at Claim "No. 9 above."
  - Miller Creek at mouth.
  - Boulder Creek at road crossing.
  - Deadwood Creek above Switch Creek.

BIRCH CREEK DRAINAGE BASIN.

Birch Creek flows into Yukon River at a point almost exactly on the Arctic Circle and about 25 miles directly west of Fort Yukon. Its mouth is about 5 miles west of the confluence of Chandalar River with the Yukon.

The drainage comes almost entirely from the south and west through a complex system of watercourses, and in outline the basin is extremely unsymmetrical. The headwaters interlock with those of Little Chena and Chatanika rivers and flow eastward for about 60 miles to the junction of the South Fork, where the stream makes an abrupt turn northward. About 12 miles beyond this point it leaves the mountainous country and enters the lowlands of the Yukon, through which it sluggishly meanders for over 100 miles, roughly paralleling the Yukon at a distance varying from 10 to 20 miles.

The principal tributaries from the south and east are Clums Fork and South Fork. From the north and west the North Fork and Harrison, Crooked, and Preacher creeks are the chief branches. The headwaters of the South Fork rise opposite those of Salcha and Charley rivers.

Monthly discharge of Birch Creek at Fourteenmile House for 1908 to 1911.

[Drainage area, 2,150 square miles.]

Month.	Discharge in second-feet.				Run-off (depth in inches on drainage area).
	Maximum.	Minimum.	Mean.	Mean per square mile.	
1908.					
June 26-30	1,190	1,020	1,090	0.507	0.09
July	2,630	847	1,140	.530	.61
August	1,620	825	1,080	.502	.58
Sept. 1-29	6,070	900	2,150	1.00	1.08
The period, 96 days	6,070	825	1,423	1.48	2.36
1909.					
May 15-31	9,970	3,320	5,930	2.76	1.74
June	8,640	1,800	3,410	1.59	1.77
July	8,280	960	2,200	1.02	1.18
August	3,020	974	1,830	.851	.98
September	960	730	799	.372	.42
Oct. 1-2	792	792	792	.368	.03
The period, 141 days	9,970	730	2,510	1.17	6.12
1910.					
May 13-31	6,620	3,200	4,790	2.23	1.58
June	6,000	1,100	2,500	1.16	1.29
July	5,400	551	1,430	.665	.77
August	1,880	432	950	.442	.51
September	3,280	1,040	1,620	.753	.84
Oct. 1-6	1,140	1,080	1,090	.507	.11
The period, 147 days	6,620	432	2,010	.935	5.10
1911.					
May 15-31	15,300	4,120	8,190	3.81	2.41
June	9,490	1,010	3,740	1.74	1.94
July	3,260	262	987	.459	.53
August	2,060	208	609	.283	.33
September	587	418	501	.233	.26
Oct. 1-23	614	198	379	.176	.15
The period, 162 days	15,300	208	2,050	.953	5.62

Daily discharge, in second-feet, of Birch Creek, 1911.

Day.	Birch Creek below Clums Fork.[a] [Drainage area, 600 square miles.]				Birch Creek above Sheep Creek.[b] [Drainage area, 873 square miles.]				Birch Creek at Fourteenmile House.[c] [Drainage area, 2,150 square miles.]					
	June.	July.	Aug.	Sept.	June.	July.	Aug.	Sept.	May.	June.	July.	Aug.	Sept.	Oct.
1	......	541	62	205	4,030	722	102	230	......	9,490	1,140	246	472	454
2	......	1,120	60	228	3,150	1,190	99	250	......	7,380	1,310	246	510	520
3	......	1,530	55	272	3,630	2,330	93	275	......	6,070	2,330	236	510	560
4	......	1,220	55	280	3,310	1,630	102	292	......	5,780	3,260	230	510	587
5	......	1,080	55	261	3,490	1,510	93	264	......	5,600	2,720	230	510	614
6	......	733	50	205	3,630	1,040	90	247	......	6,200	2,720	224	510	571
7	......	1,080	50	208	3,730	1,240	84	242	......	6,870	2,180	216	510	520
8	......	691	50	205	2,590	916	82	220	......	4,980	2,180	202	510	454
9	1,590	428	80	198	2,660	563	87	210	......	4,080	1,570	202	510	384
10	1,550	341	90	192	2,200	366	96	205	......	3,660	1,230	208	472	343
11	1,260	312	147	215	1,770	304	150	247	......	3,090	994	224	440	290
12	1,300	500	182	261	1,730	379	195	304	......	2,930	937	269	418	269
13	1,480	320	211	290	2,410	316	230	316	......	2,930	834	367	463	280
14	1,410	232	235	290	2,050	269	300	328	......	3,030	672	375	550	256
15	1,690	215	604	261	2,320	220	900	310	4,160	3,090	643	384	535	256
16	1,640	182	1,370	235	2,530	195	1,920	304	4,520	3,710	603	1,200	486	327
17	1,860	162	1,010	162	2,430	195	1,370	286	8,450	3,710	535	2,060	463	409
18	2,270	147	878	125	3,630	185	1,290	280	11,900	4,980	487	1,900	440	384
19	1,660	131	691	120	2,560	166	880	252	15,300	5,150	454	1,620	454	343
20	1,320	115	520	110	2,050	148	898	247	14,600	3,750	427	1,260	501	269
21	1,000	110	405	115	1,470	134	519	230	12,000	2,820	409	1,080	520	224
22	845	108	312	125	1,170	130	419	210	8,800	2,260	367	972	550	202
23	733	98	272	147	988	124	346	195	5,720	1,840	335	800	587	198
24	721	90	239	170	952	111	292	236	4,120	1,640	327	685	571	......
25	615	90	215	192	782	105	280	269	5,480	1,600	305	550	550	......
26	476	93	215	261	610	111	247	304	9,630	1,380	297	510	520	......
27	578	90	210	450	705	111	236	497	10,500	1,140	280	486	535	......
28	628	86	208	500	722	105	242	617	7,590	1,100	280	486	501	......
29	451	86	208	......	610	118	236	689	6,520	1,070	262	486	472	......
30	526	72	205	......	705	111	230	657	5,600	1,010	262	463	454	......
31	......	68	208	......	......	108	230	......	4,320	......	262	463	......	......
Mean	1,160	389	295	224	2,150	486	398	307	8,190	3,740	987	609	501	379
Mean per square mile	1.93	0.648	0.492	0.373	2.46	0.557	0.456	0.352	3.81	1.74	0.459	0.283	0.233	0.176
Run-off (depth in inches on drainage area)	1.58	.75	.57	.39	2.74	.64	.53	.39	2.41	1.94	.53	.33	.26	.15

[a] The discharges are based on a well-defined rating curve below 800 second-feet.
[b] These discharges are based on a rating curve that is well defined for all stages.
[c] The rating curve for this station is fairly well defined below 8,000 second-feet.

Miscellaneous measurements in Birch Creek drainage basin, 1911.

Date.	Stream and locality.	Drainage area.	Discharge.	Discharge per square mile.
		Sq. miles.	*Sec.-ft.*	*Sec.-ft.*
Aug. 1	Clums Fork at mouth	172	24	0.14
July 30	Wolf Creek, 1 mile above mouth	50.8	4.2	.083
27	South Fork of Birch Creek above Big Windy Creek	217	24	.11
27	South Fork of Birch Creek below Big Windy Creek	320	53	.17
27	Big Windy Creek at mouth	99.2	26	.26

NOTE.—The above measurements probably indicate about the lowest run-off for the season.

Daily discharge, in second-feet, of Buckley Bar and Sheep creeks, 1911.

Day.	Buckley Bar Creek at mouth. [a] [Drainage area, 10.6 square miles.]				Sheep Creek at mouth. [Drainage area, 46.7 square miles.]			
	June.	July.	Aug.	Sept.	June.	July.	Aug.	Sept.
1		1.0	0.34	0.78				8.2
2	25	1.1	.34	.76	101			
3	14.5	9.4	.34	.74			2.5	
4	12.2	6.5	.32	.74				
5	11.1	4.6	.32	.74			2.0	
6	11.4	3.2	.32	.74		38		
7	8.2	2.8	.33	.76				
8	6.2	2.4	.34	.78	[b] 208			
9	5.4	1.7	.32	.80	78			7.6
10	4.2	1.2	.34	.82				
11	3.6	1.1	.34	.83	53		9.8	
12	3.1	1.2	.34	.96				
13	3.6	1.0	.34	1.2			8.2	
14	3.6	.92	.34	1.2			10.2	12.7
15	3.4	.88	.92	1.2		8.2	34	
16	2.8	.74	2.0	1.2				12.2
17	6.2	.74	1.9	1.1				
18	12.5	.70	1.8	1.1	[b] 255			
19	7.9	.65	1.6	1.0			50	23
20	5.4	.65	1.4	1.0		5.1		
21	3.1	.65	1.1					
22	2.7	.65	.90					
23	2.2	.62	.83				16.0	
24	1.9	.59	.78		51			
25	1.6	.52	.76					
26	1.4	.52	.74					
27	1.4	.46	.70			4.0		15.1
28	1.4	.39	.72		26			
29	1.1	.36	.74				10.2	
30	1.1	.36	.83			3.3		12.2
31		.36	.78					
Mean	5.61	1.55	.780	.922				
Mean per square mile	.529	.146	.074	.087				
Run-off (depth in inches on drainage area)	.59	.17	.09	.10				

[a] These discharges are well defined for all stages. [b] Approximate.

NORTH FORK OF BIRCH CREEK DRAINAGE BASIN.

Eagle and Ptarmigan creeks, whose headwaters are opposite those of Crooked Creek, join to form North Fork of Birch Creek. Below the junction North Fork takes a southwestward course for about 7 miles, to the mouth of Twelvemile Creek, where it turns abruptly to the south and follows that direction for about 8 miles. Here its waters unite with those of Harrington Fork to form Birch Creek proper, which flows east to its confluence with South Fork, a distance of approximately 45 miles.

Beginning at the head, the main tributaries from the north are Fish, Bear, and Twelvemile creeks. From the south, in the same order, Golddust and Butte creeks are the only important streams.

Daily discharge, in second-feet, of North Fork of Birch Creek, 1911.

Day.	North Fork of Birch Creek above Twelvemile Creek.[a] [Drainage area, 88 square miles.]				North Fork of Birch Creek below Twelvemile Creek.[b] [Drainage area, 141 square miles.]			
	June.	July.	Aug.	Sept.	June.	July.	Aug.	Sept.
1	....	550.0	14.0	24	....	900	20.0	33
2	....	388.0	12.0	31	....	630	19.6	39
3	....	210.0	12.0	39	....	290	19.6	40
4	....	263.0	12.0	48	....	310	19.6	41
5	....	161.0	12.0	44	....	240	19.0	42
6	....	331.0	10.0	44	....	420	19.0	44
7	....	161.0	12.0	35	....	290	20.0	43
8	....	91.0	12.0	28	....	160	20.0	41
9	....	58.0	14.0	28	....	100	20.0	39
10	....	53.0	14.0	24	....	80	20.0	43
11	....	53.0	14.0	31	....	66	23.0	56
12	223	53.0	14.0	35	544	65	20.0	60
13	388	35.0	14.0	35	627	54	21.0	60
14	475	35.0	14.0	39	602	45	24.0	65
15	505	35.0	58.0	39	704	45	72.0	54
16	431	35.0	83.0	39	744	41	144.0	56
17	460	24.0	83.0	31	842	35	130.0	48
18	431	24.0	70.0	31	684	34	132.0	44
19	402	24.0	64.0	28	550	32	120.0	41
20	340	21.0	58.0	28	401	32	110.0	37
21	280	18.3	53.0	28	350	30	90.0	39
22	270	21.0	48.0	24	276	27	80.0	37
23	260	18.3	44.0	31	272	26	70.0	39
24	200	16.2	39.0	35	251	24	60.0	40
25	180	16.2	31.0	35	199	23	50.0	41
26	170	16.2	28.0	31	176	23	40.0	54
27	240	16.2	24.0	35	287	24	34.0	75
28	160	16.2	24.0	31	182	22	32.0	81
29	110	14.0	24.0	....	125	22	32.0	75
30	170	14.0	18.3	....	199	21	31.0	74
31	....	14.0	18.3	....	....	21	30.0	....
Mean	300	89.9	30.6	33.2	422	133	49.7	49.4
Mean per square mile	3.41	1.02	.348	.377	2.99	.943	.352	.350
Run-off (depth in inches on drainage area)	2.41	1.18	.40	.39	2.11	1.09	.41	.40

[a] Discharges well defined below 250 second-feet.
[b] Discharges fairly well defined for all stages.

Miscellaneous measurements in North Fork of Birch Creek drainage basin, 1911.

Date.		Stream and locality.	Drainage area.	Discharge.	Discharge per square mile.
			Sq. miles.	*Sec.-ft.*	*Sec.-ft.*
July	18	Ptarmigan Creek at mouth	19.0	4.6	0.24
	18	Golddust Creek at mouth	9.5	3.6	.38
	18	Butte Creek at mouth	9.2	3.5	.38
	18	Bear Creek at mouth	12.4	4.3	.35
July	17	Twelvemile Creek below South Fork	22.6	5.9	.26
Aug.	3	....do	22.6	4.3[a]	.19
	14	....do	22.6	4.8	.21
July	17	North Fork of Twelvemile Creek at mouth	22.9	5.5	.24
Aug.	3	....do	22.9	2.6[a]	.11
	14	....do	22.9	7.5	.33

[a] Probably about the minimum for the season.

CROOKED CREEK DRAINAGE BASIN.

Crooked Creek, which is formed by the junction of Mammoth and Porcupine creeks, meanders through a rather broad valley for about 30 miles and discharges its waters into Birch Creek about 10 miles above the Fourteenmile House. Not far below the Central House the valley loses its identity in the flats of Birch Creek.

Mastodon and Independence creeks unite to form Mammoth Creek, which receives Miller Creek about 2 miles below this junction from the west. The total length of Mammoth Creek is less than 4 miles.

Deadwood and Boulder creeks are tributaries from the south, below and above the Central House, respectively. They follow parallel courses about 3 miles apart, with a length of about 18 miles.

Albert Creek, the principal tributary from the north, drains the southern slope of the Crazy Mountains.

Daily discharge, in second-feet, of Crooked, Independence, and Miller creeks, 1911.

Day.	Crooked Creek at Central House.[a] [Drainage area, 161 square miles.]				Independence Creek at Claim "No. 9 above."[b] [Drainage area, 8.6 square miles.]				Miller Creek at mouth.[c] [Drainage area, 10.5 square miles.]			
	May.	June.	July.	Aug.	June.	July.	Aug.	Sept.	June.	July.	Aug.	Sept.
1	......	416	111	5.3	......	54.0	1.6	3.6	......	8.5	0.9	0.9
2	......	332	200	5.0	......	164.0	1.6	4.1	......	14.7	.9	.9
3	......	292	695	5.0	......	58.0	1.6	3.1	......	44.0	.9	.9
4	......	273	591	4.8	......	170.0	1.3	2.6	......	44.0	.9	.9
5	......	304	560	4.5	......	71.0	1.3	2.6	......	26.0	.9	.9
6	......	481	374	4.5	39.0	32.0	1.3	2.2	......	14.7	.9	.9
7	......	374	353	4.5	48.0	11.8	1.3	1.9	26.0	8.5	.9	.9
8	......	229	218	4.5	45.0	7.8	1.3	1.6	26.0	8.5	.9	......
9	......	292	174	4.5	35.0	5.3	1.3	1.3	26.0	5.3	.9	......
10	......	243	104	4.5	28.0	3.6	1.9	2.2	14.7	3.0	.9	......
11	......	194	68	4.5	21.0	3.1	1.9	3.6	14.7	3.0	.9	......
12	......	184	68	4.5	42.0	4.1	1.9	......	14.7	5.3	.9	......
13	......	273	68	4.5	35.0	3.1	1.9	......	26.0	3.0	.9	......
14	......	265	51	4.5	48.0	3.1	2.2	......	14.7	3.0	.9	......
15	......	281	38	4.5	63.0	2.6	4.1	......	26.0	3.0	.9	......
16	......	266	36	23.0	79.0	2.6	3.1	......	26.0	3.0	3.0	......
17	......	273	38	26.0	140.0	2.6	3.1	......	26.0	3.0	5.3	......
18	......	416	38	30.0	119.0	2.6	2.6	......	44.0	3.0	5.3	......
19	......	353	32	20.0	71.0	2.6	2.6	......	26.0	1.6	5.3	......
20	......	266	32	23.0	42.0	2.6	2.2	......	14.7	1.6	3.0	......
21	......	218	30	23.0	35.0	2.6	2.2	......	23	1.6	3.0	......
22	......	200	30	23.0	23.0	2.2	2.2	......	14.7	1.6	3.0	......
23	......	174	24	17.0	26.0	2.2	2.2	......	14.7	1.6	.9	......
24	......	174	12.2	14.6	28.0	2.2	1.9	......	14.7	1.6	.9	......
25	......	146	10.0	12.2	21.0	2.2	1.9	......	14.7	1.6	.9	......
26	......	128	10.0	12.2	14.7	1.9	1.9	......	11.3	1.2	.9	......
27	......	128	8.1	12.2	10.6	1.9	1.9	......	8.5	1.2	.9	......
28	......	120	8.1	10.4	6.7	1.9	2.6	......	8.5	1.2	.9	......
29	312	115	8.5	12.2	51.0	1.6	2.6	......	8.5	.9	.9	......
30	266	111	6.5	10.4	30.0	1.6	2.6	......	14.7	.9	.9	......
31	254	......	6.2	8.5	......	1.6	3.1	......	......	.9	.9	......
Mean	277	251	129	11.2	44.0	20.3	2.10	2.62	19.1	7.13	1.60	.90
Mean per square mile	1.72	1.56	.801	.070	5.12	2.36	.244	.305	1.82	.679	.152	.086
Run-off (depth in inches on drainage area)	.19	1.74	.92	.08	4.43	2.72	.28	.12	1.62	.78	.18	.02

[a] The rating curve for Crooked Creek is well defined below 300 second-feet.
[b] Discharges fairly well defined below 50 second-feet.
[c] Rating curve well defined for all stages.

Daily discharge, in second-feet, of Porcupine, Bonanza, and Deadwood creeks, 1911.

Day.	Porcupine Creek below Bonanza Creek.[a] [Drainage area, 39.9 square miles.]				Bonanza Creek above ditch intake.[b] [Drainage area, 7.9 square miles.]				Deadwood Creek above Switch Creek.[c] [Drainage area, 21.3 square miles.]			
	June.	July.	Aug.	Sept.	June.	July.	Aug.	Sept.	June.	July.	Aug.	Sept.
1	......	175.0	3.2	3.0	......	34.0	2.0	2.0	50.0	23.0	1.6	1.6
2	......	148.0	3.0	3.1	......	35.0	2.0	2.1	61.0	30.0	1.6	1.4
3	......	184.0	3.4	3.3	......	47.0	2.0	2.3	56.0	48.0	1.6	1.2
4	......	172.0	3.0	3.4	......	40.0	2.0	2.4	72.0	35.0	1.6	1.2
5	89	168.0	2.7	3.4	41.0	41.0	1.7	2.4	70.0	35.0	1.4	1.2
6	142	139.0	2.7	4.1	36.0	34.0	1.7	2.4	95.0	30.0	1.2	1.2
7	107	129.0	2.6	3.8	34.0	32.0	1.6	2.4	50.0	26.0	1.4	1.2
8	94	73.0	2.4	3.7	30.0	24.0	1.6	2.3	50.0	17.2	1.6	1.2
9	91	41.0	2.3	3.5	34.0	13.7	1.5	2.3	50.0	13.5	1.8	1.2
10	71	24.0	2.5	3.7	28.0	10.0	1.5	2.3	45.0	7.5	1.5	1.2
11	57	27.0	2.1	5.0	20.0	8.9	1.5	3.3	40.0	6.2	1.2	1.2
12	61	32.0	2.0	4.7	24.0	8.5	1.4	3.3	40.0	5.4	1.2	1.2
13	95	23.0	2.4	5.2	34.0	6.5	1.4	3.5	45.0	5.4	1.2	1.2
14	92	16.7	3.0	......	33.0	5.8	2.0	......	50.0	5.4	2.2	1.2
15	128	12.6	3.6	......	38.0	5.2	2.2	......	61.0	4.8	3.3	1.2
16	119	7.4	4.5	......	36.0	5.0	3.2	......	50.0	4.1	4.6	1.2
17	121	9.2	8.7	......	40.0	4.8	4.0	......	30.0	6.7	4.1	1.2
18	120	8.4	20.0	......	36.0	4.4	4.2	......	48.0	5.4	3.3	1.2
19	121	5.3	13.0	......	36.0	3.9	3.2	......	50.0	4.1	3.0	1.2
20	84	5.9	8.7	......	30.0	3.5	3.0	......	30.0	3.7	2.7	1.2
21	81	7.0	3.9	......	32.0	3.3	2.5	......	26.0	3.3	2.4	1.2
22	69	6.6	3.8	......	28.0	3.1	2.4	......	21.0	3.3	2.1	1.2
23	72	6.1	3.4	......	28.0	3.1	2.4	......	21.0	3.3	1.8	1.2
24	66	7.0	3.3	......	29.0	3.0	2.3	......	21.0	3.1	1.6	1.2
25	51	6.9	3.2	......	23.0	2.9	2.2	......	17.2	2.9	1.4	1.2
26	45	6.8	3.1	......	20.0	2.8	2.1	......	13.5	2.2	1.2	1.2
27	52	6.4	3.1	......	22.0	2.7	2.1	......	13.5	2.7	1.4	1.6
28	36	6.5	2.7	......	15.2	2.5	2.1	......	10.5	2.3	1.6	1.6
29	45	5.0	3.1	......	17.0	2.3	2.1	......	10.5	1.9	1.4	1.6
30	76	3.6	3.1	......	22.0	2.2	2.1	......	13.5	1.6	1.2	1.6
31	......	3.1	3.1	......	......	2.1	2.1	......	......	1.6	1.4	1.6
Mean	84.0	47.3	4.25	3.84	29.5	12.8	2.20	2.54	40.4	11.1	1.92	1.27
Mean per square mile	2.11	1.19	.107	.096	3.73	1.62	.278	.322	1.90	.521	.090	.060
Run-off (depth in inches on drainage area).	2.04	1.37	.123	.046	3.61	1.87	.32	.16	2.12	.60	.10	.07

[a] These discharges include water diverted by ditch and are well defined below 60 second-feet.
[b] Approximate.
[c] Discharges fairly well defined below 50 second-feet.

Daily discharge, in second-feet, of Bonanza Creek ditch, 1911.

Day.	Bonanza Creek ditch at intake.				Bonanza Creek ditch at outlet. [a]			
	June.	July.	Aug.	Sept.	June.	July.	Aug.	Sept.
1	....	27.0	1.7	1.7	....	28.0	0	3.0
2	....	30.0	1.7	1.8	....	39.0	0	3.0
3	....	22.0	1.7	2.0	....	33.0	0	3.0
4	....	28.0	1.7	2.1	....	36.0	0	3.0
5	22.0	37.0	1.4	2.1	....	35.0	0	3.0
6	24.0	33.0	1.4	2.1	36.0	33.0	0	3.0
7	26.0	31.0	1.3	2.1	33.0	34.0	0	3.0
8	24.0	23.0	1.3	2.0	33.0	20.0	0	3.0
9	27.0	13.2	1.2	2.0	32.0	16.5	0	3.0
10	25.0	9.5	1.2	2.0	33.0	11.2	0	3.0
11	19.1	8.4	1.2	3.0	28.0	11.2	0	....
12	21.0	8.0	1.1	3.0	27.0	6.6	0	....
13	29.0	6.1	1.1	3.2	34.0	6.1	0	....
14	28.0	5.5	1.7	....	34.0	4.0	0	....
15	30.0	4.9	1.9	....	37.0	3.7	0	....
16	31.0	4.7	2.8	....	35.0	8.0	0	....
17	30.0	4.5	3.6	....	36.0	3.7	0	....
18	32.0	4.1	3.8	....	37.0	6.6	0	....
19	32.0	3.6	2.8	....	36.0	4.9	0	....
20	29.0	3.2	2.7	....	34.0	0	0	....
21	29.0	3.0	2.2	....	34.0	0	4.0	....
22	27.0	2.8	2.1	....	33.0	0	3.0	....
23	27.0	2.8	2.1	....	28.0	0	3.0	....
24	28.0	2.7	2.0	....	28.0	0	3.0	....
25	22.0	2.6	1.9	....	24.0	0	3.0	....
26	19.1	2.5	1.8	....	18.6	0	2.3	....
27	21.0	2.4	1.8	....	18.6	0	2.3	....
28	14.5	2.2	1.8	....	14.0	0	3.0	....
29	16.3	2.0	1.8	....	13.5	0	3.0	....
30	21.0	1.9	1.8	....	30.0	0	3.0	....
31	....	1.8	1.8	....	....	0	3.0	....
Mean	25.2	10.8	1.88	2.24	29.9	11.0	1.05	3.00

[a] Water turned out of lower section of ditch from July 20 to Aug. 20.

NOTE.—The above discharges are only approximate because of insufficient measurements to determine the effect of various changes made in channel conditions.

Miscellaneous measurements in Crooked Creek drainage basin, 1911.

Date.	Stream and locality.	Drainage area.	Discharge.	Discharge per square mile.
		Sq. miles.	*Sec.-ft.*	*Sec.-ft.*
July 20	Porcupine Creek above ditch intake	17.8	2.7	0.15
20	Bonanza Creek ditch below Porcupine ditch	....	3.3	
Aug. 16	.....do	....	3.6	....
July 19	Mammoth Creek above Miller Creek	27.0	12.4	.46
22	.....do	27.0	7.1	.26
Aug. 15	.....do	27.0	3.1	.11
July 23	Boulder Creek at road crossing	38.8	1.9	.049

THE RAMPART AND HOT SPRINGS REGIONS.

By Henry M. Eakin.

INTRODUCTION.

The Rampart and Hot Springs gold-placer districts comprise the greater part of the triangular area lying between Yukon and Tanana rivers west of longitude 150°. The Rampart district lies north of the divide, on Minook Creek and its tributaries; the Hot Springs district includes the basins of Baker and Patterson creeks, which flow directly into the Tanana, and American Creek, which flows into Fish Lake. The region comprises also the territory lying within a few miles of the Yukon as far west as longitude 154°, which is included in order to cover the basins of Grant, Illinois, and Mason creeks, tributaries of the Yukon from the north below the mouth of the Tanana.

During the season of 1911 the writer made a geologic reconnaissance of the region outlined above and learned the facts here presented. This report, however, is intended to present only the results of this study that pertain to the general geology and mining activities of the region, the more intricate geologic and physiographic problems being left for treatment in a more complete report, now in preparation, which will be accompanied by geologic and topographic maps.

GEOGRAPHY.

The Rampart-Hot Springs region lies near the geographic center of Alaska, between longitudes 150° and 154°, adjacent to Yukon and Tanana rivers, which join near its center. (See geologic sketch map, Pl. XIII.)

The drainage of the region is all tributary to the Yukon and Tanana. The largest of the secondary streams is Tozitna River, perhaps 100 miles long, which enters the Yukon from the north about 15 miles below the mouth of the Tanana. The other streams of the region are relatively small, the largest being only about 20 miles long.

The greater part of the Rampart-Hot Springs region has strong topographic relief. Elevations of 2,000 to 4,000 feet are common, and the valleys are usually steep sided and are carried with low gradients well back into the hills, where they head abruptly. In the lower parts of the smaller valleys and along the larger streams extensive lowlands are developed.

The climate of the region is that prevalent in the interior of Alaska, being semiarid and marked by great seasonal variations in temperature. Continuous observations for a year at Rampart and supplementary records for shorter periods indicate an annual precipitation of 11.96 inches. A longer period of observation might alter this figure somewhat, but not enough to show more than a very scanty rainfall.

The annual temperatures of the region are summarized by Brooks[1] in a recent report. Concerning the interior province of Alaska, which includes the area under discussion, he says: "The average winter temperature in this province is —5° to —10°, with a minimum of —65° to —76°. For the summer months of June, July, and August the mean is 50° to 60° and the recorded maximum 90°."

The open season in the Rampart-Hot Springs region commences between the 1st and the 10th of May and ends between the 1st and the 15th of October.

Timber suitable for fuel and some suitable for lumber grows in all the valleys of the region. Spruce is the most important kind, being more widely distributed than any other and in places supplying logs that measure more than 2 feet in diameter. Cottonwood and birch are also valuable, especially near Hot Springs, where the trees are unusually large. A few tamarack were noted on some of the Yukon tributaries, and willow and scrub alder thrive beside the streams and on the higher slopes. Probably four-fifths of the timbered areas have been burned over in the last decade, and the supply has been correspondingly reduced.

Agricultural products, including the ordinary vegetables and a variety of grains, are grown successfully. The Government agricultural station at Rampart is experimenting with these products with encouraging results.

The mining districts support several small settlements. Rampart on the Yukon and Hot Springs on a slough of the Tanana supply merchandise and business facilities to their respective districts. There are two other settlements in the Hot Springs district—Tofty on Sullivan Creek and Glen on a tributary of Baker Creek. A few cabins and road houses are grouped on the bank of the Yukon near the mouth of Grant Creek, of the Gold Mountain district. The largest settlement of the region is Tanana, on the right bank of the Yukon near the mouth of Tanana River. It is the connecting point

[1] Brooks, A. H., The Mount McKinley region: Prof. Paper U. S. Geol. Survey No. 70, 1911, p. 199.

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SPRINGS REGIONS.

for the Yukon and Tanana River routes and the seat of Fort Gibbon, a United States military post.

TRANSPORTATION.

Easy access to all parts of the region is afforded by Yukon and Tanana rivers, which are navigated by a fleet of well-equipped steamboats during the open season, usually from early June to the last of September. The freight rates from Seattle depend on the nature of the commodity and the routing, as indicated in the following table:

Freight and passenger rates from Seattle to towns in Rampart-Hot Springs region.

[Based on tariffs of 1910–11.]

Town.	Route.	General merchandise, per ton.	Lumber, per M.	Forage per ton.		Passenger rates	
				Hay.	Grain.	First class.	Second class.
Rampart	Skagway	$82–$115	$77.50	$83.00	$77.00	$111.00	$80.00
	St. Michael	58	87.00	58.00	58.00	115.00	90.00
Tanana	Skagway	84–117	79.50	85.00	79.00	115.00	81.00
	St. Michael	50	75.00	50.00	50.00	110.00	85.00
Hot Springs	Skagway	89–125	84.50	90.00	84.00	125.00	90.00
	St. Michael	55	82.50	55.00	55.00	115.00	90.00

Local freight rates from river points to the creeks vary with road conditions and the seasons of the year. In both the Rampart and Hot Springs districts some excellent roads are maintained. The rapid development of the Sullivan Creek placers within the last two years has demanded additional road improvements, which were being pushed during the summer of 1911. The summer rate on goods from Hot Springs to Tofty, a distance of 12 miles, was 5 cents a pound, and considering the difficulties of the journey this charge was not unreasonable. When the road now under construction is completed the summer rate will probably be reduced to about the present winter rate, 1½ cents a pound.

All the river communities are in touch with the United States military telegraph, the lines of which are shown on the map (Pl. XIII). Local telegraph lines give service in the Rampart and Hot Springs districts. Regular United States mail service extends to all the settlements in both winter and summer.

Labor was plentiful during the summer of 1911, wages being $5 a day and board. This amounts to a total expense of about $6.50 a day for each man.

GENERAL GEOLOGY.

OUTLINE.

The base of the geologic column in the Rampart-Hot Springs region is represented by a series of metamorphic rocks. Although mainly of sedimentary origin, igneous flows are common in some of its members, and locally it contains granitic intrusives. Differences in original constitution and in degrees of alteration have resulted in wide divergence between the rock types included in the series. It is probably in the main of Paleozoic age, but it may also include Mesozoic beds. The metamorphic series is overlain locally by Tertiary beds and broadly by those of Quaternary age. Granitic intrusives are distributed widely through the region in small, discontinuous areas. They are accompanied by a complex system of dikes, which are probably related to them genetically.

METAMORPHIC SERIES.

The metamorphic series can be arranged in four lithologic divisions, each division including a different group of rock types that are constantly associated over a considerable area. The areas occupied by the several groups are distinguished on the map (Pl. XIII).

The northernmost area of the other rocks is occupied by a group of greenstones, derived from ultrabasic flows and tuffs that are mainly of a diabasic character. With these basic rocks are associated considerable areas of rhyolite and a smaller quantity of slate, chert, and impure limestone.

South of the greenstone area, between Yukon and Tanana rivers and the Gold Mountain district, are areas occupied by a more highly metamorphosed group characterized by an abundance of crystalline limestone and a variety of schists. The latter are mainly quartzite schists, but include also quartz-mica schists, garnet schist, greenstone schist, and calcareous, graphitic, and feldspathic schists. The greenstone and feldspathic schists grade into less metamorphosed types that are clearly of igneous origin. Some of the quartzose schists are apparently sheared cherty rocks, which were developed through replacement of original limestones. The micaceous and garnetiferous schists are associated with permatite dikes and quartz veins and comprise only a small part of the mass of the group.

From the foregoing description it is apparent that the limestone and schist groups have suffered both regional and contact metamorphism, and that, so far as their physical condition indicates, they are older than the greenstones and the other groups that remain to be described.

The third area of metamorphic rocks includes most of the Hot Springs district and reaches northeastward beyond the limits of the quadrangle. It is occupied by phyllites, quartzites, and schists less altered than the limestone-schist group and apparently overlying them.

South of the last area and occupying the big bend of Tanana River southeast of Baker Flat is the fourth group of the metamorphic rocks, which includes highly contorted red and green slates, sandstones, and fine conglomerates.[1]

TERTIARY SEDIMENTS.

Several small isolated areas of Tertiary sediments occur in the region adjacent to Yukon River. These rocks rest unconformably upon the various members of the older formations and yield fossil plants and invertebrates of Eocene age.

QUATERNARY SEDIMENTS.

Unconsolidated silts and gravels mantle much of the region. The former are believed to be mainly of lacustrine origin and they are assigned provisionally to the Pleistocene epoch. The gravel deposits are of two types—a widespread deposit of variable thickness underlying the silts, and the fluviatile deposits of the modern flood plains. All of the unconsolidated sediments of the region have been included under the same pattern in mapping.

IGNEOUS ROCKS.

The oldest igneous rocks of the region are probably the flows and tuffs of the metamorphic series now altered to greenstones.

Prior to the principal deformation of the metamorphic series, extensive intrusions of granite occurred in the Gold Mountain region and farther west. These intrusions are now represented by gneisses and feldspathic schists in the prominent range of mountains that extends southwestward along the Yukon from a point near the head of Mason Creek.

At a much later period (late Mesozoic or early Tertiary) extensive intrusions of granite occurred in discontinuous areas widely scattered over the region, accompanied by the formation of an elaborate system of dikes, ranging in composition from granites, aplites, and acid pegmatites to gabbros and diorites.

ECONOMIC GEOLOGY.

IMPORTANT MINERALS.

Gold is the only mineral whose occurrence in the Rampart-Hot Springs region has proved to be of economic importance. It has been mined profitably in both the Rampart and the Hot Springs districts and is known to occur at a number of other localities.

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[1] Brooks, A. H., The Mount McKinley region: Prof. Paper U. S. Geol. Survey No. 70, 1911, p. 75.

Tin occurs with the gold in the placers of Sullivan Creek, and small quantities have been recovered incidentally to the gold mining. So far, however, no serious attempt has been made to recover any large part of the tin ore, and only a small quantity has been shipped.

Lignitic coal occurs in the Eocene beds near Rampart, but no seams thick enough for profitable mining have been found.

GOLD.

HISTORY OF PROSPECTING AND MINING.

Placer gold was discovered in the Rampart quadrangle probably as early as 1893. The first discoveries were made on Minook Creek and its tributaries, and since 1896 systematic mining has been done in this district. Later, as the area being prospected increased, placers were located and mines developed on the tributaries of Baker Creek along the northern border of the flats, and still later on Sullivan Creek and neighboring streams tributary to Patterson Creek.

Prospecting on the tributaries of the Yukon and Tanana west of the productive areas has revealed the presence of gold at several places. (See map, Pl. XIII). Although much ground is held on some of these streams, especially in the Gold Mountain region, the presence of gold in commercial quantities has not been demonstrated. In the Gold Mountain region this may be largely due to the facts that very little beyond annual assessment work is being done and that this work is largely of a futile character.

The scene of greatest activity in mining in the Rampart quadrangle has shifted southward with successive discoveries. The Rampart district yielded its greatest output in 1906 and 1907. The placers along the north margin of Baker Flats reached their maximum production about the same time but have not fallen off so rapidly since. The Patterson Creek locality has steadily increased its production since operations were begun, the season of 1911 recording the largest output in its history.

Value of gold produced in the Rampart district.

1896 to 1904	$616,000
1904	90,000
1905	80,000
1906	120,000
1907	125,000
1908	75,000
1909	100,000
1910	43,000
1911	32,000

Value of gold produced in the Hot Springs district.

1902 to 1904	$262,900
1904	145,500
1905	120,000
1906	180,000
1907	175,000
1908	150,000
1909	325,000
1910	325,000
1911	785,000

SOURCE OF THE GOLD.

The distribution of the gold in the Rampart-Hot Springs region is definitely related to the metamorphic rocks. The bedrock in the Rampart district is the lower part of the greenstone group, which includes besides greenstones a variety of more or less altered slates, cherts, and impure limestones. The Hot Springs district, from American Creek to the Baker Creek placers, lies within the slate-quartzite-schist area, and the placer ground of Quail Creek, which heads against Little Minook Creek, is a continuation of the same area.

Quartz veins are so plentifully distributed in the older rocks of the entire region that a greater abundance in the areas yielding the placers can hardly be asserted. But although as a rule the quartz veins are barren of visible mineralization, there is some evidence that in the placer districts they are gold bearing. On Little Minook a vein 6 feet wide is said to yield gold on being crushed and panned. In the Sullivan Creek placers the richer ground is thought by the operators to be marked by an unusual abundance of quartz veins. In both districts nuggets composed partly of quartz are common. In the Gold Mountain district is a quartz vein known to be auriferous, but an unsuccessful attempt has proved that it is not of sufficient extent or richness to be mined profitably.

Although there is evidence that much of the placer gold comes from quartz veins, another source is suggested for a part of it at least in the Hot Springs region. Nuggets from What Cheer Bar near Glen include fragments of black slate. The tailings of one of the Sullivan Creek mines contained a piece of quartzite having tiny stringers of gold running along its cleavage planes. On these creeks it would appear that the gold was deposited in the available spaces in the country rock, wholly without gangue minerals. The formations comprising the country rock in all the placer districts contain members that are very rich in carbonaceous material. Carbon is believed to influence the precipitation of gold under certain conditions, and it seems possible that the distribution of gold in the region may be related in some degree to that of the carbonaceous beds.

Still another source of gold may be the hematite deposits in the neighborhood of the granite areas near Hot Springs and Roughtop Mountain. Brecciated zones of the country rock ranging from a few inches to several feet in width have received deposits of hematite. Samples taken from these deposits in both localities are said to yield steady assay returns of several dollars a ton in gold. Although this is an unusual mode of occurrence for gold, the hematite deposits may possibly be auriferous, but further sampling, including entire cross-cuts of minable bodies of the ore, will be required before their economic value will be established.

AURIFEROUS GRAVELS.

The auriferous gravel deposits of the Rampart-Hot Springs region, considered in their relation to modern topography, are of two types—stream gravels, forming the beds and flood plains of modern streams, and terrace gravels, situated above the present valley floors. Some of the terrace gravels cover benches that undoubtedly owe their origin to the present streams, but the relation of others to streams is doubtful.

STREAM GRAVELS.

The stream gravels have yielded the greater part of the production of the Rampart district, the operations on all the creeks except Hunter being confined to them. On Hunter Creek only a small part of the production has come from this source. The stream gravels of the district are shallow as a rule; on Minook Creek they are from a few feet to 15 or 20 feet thick, and on the smaller streams the range is even less, the usual thickness being about 6 or 8 feet. The gravels are usually covered with a deposit of muck and silt, which thickens as the sides of the valley are approached. It appears that the valleys were at one time more or less completely filled with silt, a large part of which has since been removed. Near the courses of the streams, where the removal has been most complete, open-cut methods are employed; but nearer the valley walls, where the overburden is very heavy, drifting becomes necessary.

In the Hot Springs district a large part of the production from the streams tributary to Baker Creek has come from the stream gravels. The deposits of this type are similar to those of the Rampart district, except that they are generally overlain by a much thinner overburden of silt or muck. The stream gravels of the Patterson Creek group have not been productive. They carry gold in small quantities, but are nowhere rich enough to be mined profitably.

TERRACE GRAVELS.

Terrace gravels occur in both the Rampart and the Hot Springs district. In the Rampart district well-defined benches occur on Minook and Hunter creeks.

The Hunter Creek benches lie along the valley walls and may represent stages in the downcutting of the stream. The lowest bench is only 15 or 20 feet above the stream, as a rule, and has been the principal source of the gold. Its bedrock surface is irregular, in some places sloping downward away from the stream toward the valley wall. The actual surface always slopes upward toward the margin of the valley, this being especially noticeable in the vicinity of lateral streams. The upper part of this bench deposit seems to be composed largely of materials delivered to the main valley by its tributaries in the form of alluvial fans of varying steepness. The deposits of the lower terrace of Hunter Creek are minable by open-cut methods along their streamward margins, being made up, as a rule, of 3 to 6 feet of gravel, with a few feet of muck as overburden. The notable thickening of the overburden toward the margins of the valley limits the extent to which such methods are applicable.

Rather indefinite remnants of terraces occur at various elevations along the sides of Minook Valley, but only the lower bench, which resembles that of Hunter Creek, has been productive.

The ridges between the eastern tributaries of Minook Creek are peculiarly flat-topped and rise in a succession of broad steps to the eastward from 600 to 800 feet above the level of Minook Creek. In part they carry gravel deposits that have proved, locally at least, to be gold bearing. Prospecting has revealed various depths of the deposits at different places, the greatest being more than 100 feet. The materials of most of them include fragments of the local country rock, more or less worn, yellow clays or silts, and scattered quartzite bowlders, some of great size, which are foreign to the immediate neighborhood. Only very low values have been reported from these deposits, and their elevated position, even if they should prove to contain larger amounts of gold, would render their exploitation very difficult.

In the Hot Springs district bench gravels have been productive on most of the gold-bearing streams tributary to Baker Creek, and practically all of the Patterson Creek placers are in deposits that have no evident relation to the present streams.

The peculiar type of bench deposits characteristic of the Hot Springs district is illustrated by What Cheer Bar. This deposit skirts the point between Eureka and Pioneer creeks, about 250 feet above and 2,000 feet up the side of the valley from the latter stream. A space 2,000 feet long and from 150 to 200 feet wide has been mined and the resulting cut reveals the general character of the deposit. What Cheer Bar is a flattened space on a gently sloping valley side, which formerly bore auriferous gravels ranging in depth from 3 to 10 feet. The gravels range in size from fine material up to bowlders several feet in diameter. In its long direction the bench has no perceptible grade, but crosswise, in the direction of Pioneer Creek, it slopes at a grade which was found suitable for the sluice boxes but which is less than the general slope of the hillside. At the uphill side of the bench the bedrock rises at a steeper angle nearly to the surface and then flattens to the general slope of the hillside. The bowlders found in the deposit are mostly of quartzite with some conglomerate, both known to occur within the basin of Pioneer Creek and perhaps in the hill on which the bench is developed. Other benches that carry a little gold occur on the hillside above What Cheer Bar, and farther up the valley of Pioneer Creek on the same hillside similar deposits have been productive.

A heavy deposit of gravel occurs along the north side of Baker Flats west of Eureka Creek, apparently unrelated in its origin to the present streams, which flow transversely across it. Although, as a rule, this deposit has proved of too low a tenor to be worked, it carries some gold and probably has been the source of much of the gold found in the gravels of the streams where they cross it.

In the Patterson Creek locality shallow gravels are worked by open-cut methods on Quartz Creek and Tofty Gulch. The deposit on Quartz Creek, known as Homestake Bar, is about a quarter of a mile from the creek on a slightly sloping hillside. It consists of 3 or 4 feet of gravels overlain by 3 feet of yellow silt. The gravels are little worn, except a thickness of about 1 foot next to bedrock. The entire hillside is covered with deposits similar to those being worked except that they carry less gold. The workable deposit extends horizontally along the hillside, and there are no surface indications to show its extent. However, the bedrock slopes at a lower angle toward the creek than the surface of the ground, and at the uphill margin it rises more sharply, forming a so-called "rim." The "rim" seems to mark the limit of the richer deposit. The ground is worked by groundsluicing and pick-and-shovel methods.

On Tofty Gulch a considerable open cut has been made on a bench on the hillside about 1,000 feet from Sullivan Creek. The deposit consisted of 4 to 6 feet of gravel covered by several feet of yellow silt and black muck. Large bowlders were very common in the top layers of the gravel, some being found in the lower part of the silt. The black muck contained a great quantity of remains of trees, which added considerably to the difficulty and expense of mining. In working the deposit the top layers of muck and silt were groundsluiced off, dynamite being employed to break up the tangle of wood débris in places, after which the gravels were carried to the sluice boxes with a steam scraper.

The other placers of Sullivan Creek and those of Cache Creek are deeper, being from 30 to 75 feet below the surface. They are worked by drifting, machinery being employed to hoist the gravel to the surface. The thickness of the gravel deposits ranges from 10 to 35 feet, the remaining depth being made up by an overburden of silt. At one place between Cache and Sullivan creeks a thickness of 90 feet of silt is said to have been penetrated in sinking an unsuccessful prospecting shaft. The gravels include some well-worn materials, but are mostly made up of angular fragments of the country rock. In fact, it is often difficult to distinguish the surface of the bedrock because it is so closely resembled by the fragmental deposits. One prospect hole was abandoned on reaching a lens of these deposits, but when deeper holes revealed rich gravels near by, the shaft was sunk deeper, and on reaching the true bedrock workable gravels were found.

The better worn materials are usually of the most resistant types, a hard vitreous quartzite being common. Many bowlders of this type, too large to handle, are encountered in all the drifts; in some 5-foot drifts all the vertical space is taken up by a single bowlder. However, as these bowlders are generally more or less isolated, they present no serious difficulty to the miner.

Most of the bedrock surface is considerably weathered, being brecciated and carrying gold to a depth of a foot or more. The bedrock in all the deeper mines has the form of a succession of flat benches that rise one after another toward the higher ground. The richest gravels are commonly found near the uphill margin of the benches.

The auriferous gravels of American Creek are somewhat similar to the bench gravels of the Patterson Creek locality. The later discoveries are reported to be on bench ground rather than in the stream gravels. The depths range from 10 to 20 feet. The gravels are worked by drifting, and so far no steam machinery has been used in hoisting.

On Grant Creek and some of its tributaries and on Illinois Creek, in the Gold Mountain district, good prospects are reported to have been found, but so far no valuable deposits have been discovered. Prospecting is seriously hindered by the great depth of the gravels in much of the district and by live water where they are thawed. On Illinois Creek a hole is said to have been sunk 133 feet and then abandoned, on account of live water, without having reached bedrock. The hole is said to have penetrated several beds containing a little fine gold.

On Grant Creek the results have been much the same, holes sunk from 30 to 135 feet having been abandoned on account of live water. The only holes sunk to bedrock on Grant Creek are about 2½ miles above its mouth and are about 30 feet deep. A few holes about 20 feet deep have been driven on Lynx Creek, the principal eastern tributary of Grant, discovering a foot of gravel on bedrock, which is said to have yielded at the rate of $10 or $12 a yard. After a little drifting had been done the works were abandoned. On American Gulch, a small tributary of Grant Creek near its head, the gravels are said to yield the best prospects found in the region, some estimates putting the values as high as $1 a square foot of bedrock. The gravels are 10 to 12 feet deep and are thawed. The construction of a bedrock drain, which has been unsuccessfully attempted, would doubtless permit more definite knowledge of the deposit to be gained.

WATER SUPPLY.

With the exception of Minook Creek and its tributaries, Hunter and Hoosier creeks, the streams of the Rampart and Hot Springs districts afford a very scanty supply of water for mining. Hunter Creek usually furnishes water sufficient for two 3-inch nozzles under a 150-foot head; and in time of freshets, of course, the discharge is much greater. Its recorded minimum flow[1] is 3.7 second-feet, or about 150 miners' inches, and its maximum, 27 second-feet, or more than 1,000 miners' inches. Hoosier Creek is very nearly the same size. Little Minook Creek carries less than a sluicehead during much of the drier part of the season.

Eureka Creek at its mouth has a discharge similar to that of Hunter Creek. About half of this is contributed by Pioneer Creek and about a fourth by the main head of Eureka above Pioneer. None of the tributaries of Patterson Creek at the locality of the mines furnishes sufficient water for constant sluicing during much of the summer, and pumping is commonly resorted to at most of the plants.

MINING.

RAMPART DISTRICT.

General statement.—Active mining in the Rampart district during 1911 was limited to Hunter and Little Minook creeks of the Big Minook basin and Quail Creek, a tributary of Troublesome Creek. In general, a lower tenor of gravels was encountered than in former years, and the difficulties experienced in exploiting them were greater owing to an increase of the overburden as the valley walls were approached and to obstruction to the disposal of tailings due to former operations.

Hunter Creek.—On Hunter Creek two hydraulic plants were operated during the summer of 1911. A steam hoist was installed on Dawson Creek, a tributary of Hunter, but owing to an accident was abandoned for the summer. A single claim was worked in a small

[1] Covert, C. C., and Ellsworth, C. E., Water-supply investigations in the Yukon-Tanana region, Alaska, 1907 and 1908; Water-Supply Paper U. S. Geol. Survey, No. 228, 1909, pp. 58–98; also Ellsworth, C. E., Water supply of the Yukon-Tanana region, 1909: Bull. U. S. Geol. Survey No. 442, 1910, pp. 270–281.

way with pick and shovel. About 12 men were employed on four claims a part of the summer.

Little Minook Creek.—On Little Minook Creek five claims were worked to some extent during the year. The operations included winter drifting on two claims, and the use of two splash dams during the summer employing about 7 men.

Quail Creek.—This creek was not visited by the writer. It was learned, however, from the miners near Rampart that four splash dams were operated most of the summer, employing from 8 to 12 men at different times.

HOT SPRINGS DISTRICT.

General statement.—The year 1911 witnessed a marked decrease in mining operations in the part of the Hot Springs district tributary to Baker Creek contrasted with an increased activity in the Patterson Creek camp. In the former locality Thanksgiving, Omega, Pioneer, Eureka, and Hutlinana creeks were active. In the latter mining was in progress on Sullivan, Cache, Quartz, and American creeks.

Thanksgiving Creek.—In the early summer about 20 men were employed on Thanksgiving Creek at groundsluicing and shoveling in. Later in the season operations were at a standstill owing to lack of water.

Omega Creek.—A single claim is reported to have been worked on Omega Creek in 1911, drifting and hoisting being done by hand. The ground was about 16 feet deep, and the results were said to be satisfactory.

Eureka Creek.—A steam scraper was employed in open-cut work on Eureka Creek near the mouth of Boston Creek. On the upper part of Eureka a claim was worked by means of a splash dam. Eight or 10 men were employed on this creek.

Pioneer Creek.—Four men were employed at shoveling in on the bench ground of What Cheer Bar, on the right limit of Pioneer, a little above its mouth. Two or three claims were being worked higher up on Pioneer, but were not visited. About 15 men were said to be employed in the summer workings on Pioneer.

Hutlinana Creek.—Four men operated two splash-dam outfits on the upper part of Hutlinana Creek during the summer. Nothing definite was learned of their success.

Sullivan Creek.—The greatest activity in the whole region was in the Sullivan Creek locality. Six steam hoists, employing about 150 men, were in operation most of the summer. The claims range in depth to bedrock from 30 to 70 feet, most of the overburden being yellow silt and the rest gravel and black muck.

The gold is usually in the bottom 2 or 3 feet of gravel and in the shattered bedrock. The tenor of the gravels expressed in terms of the area of bedrock uncovered ran from about 50 cents a square foot to more than $20. Selected pans from the pay streak of the richest claim are reported to have carried $10 to $15 in gold. The tenor of the gravels actually removed ranged from about $3.50 a yard to very much higher figures, as may be inferred from the rich pans described above.

The costs of mining vary with conditions on the different claims and the management employed. Many of the plants were compelled to pump water for sluicing, which adds considerably to the expense for fuel and cost of upkeep. The lowest estimate of the cost of operation was 35 cents a square foot of bedrock, which is equivalent to about $2.50 a yard of gravel. Under some conditions the costs were probably double this amount.

Valuable gravels were discovered during the summer on a claim adjacent to those being worked and further prospecting will very likely disclose a still wider distribution of pay in this locality.

Cache Creek.—Three steam hoists were operated on Cache Creek in the early part of the summer, but at the time of the writer's visit two had shut down. The third plant was employing about 25 men, but had only a small amount of ground remaining to be worked. The general mining conditions are similar to those of Sullivan Creek, the pay gravel being at a depth of 50 feet and the water supply requiring the use of the pump for sluicing.

Quartz Creek.—A single plant was operating on Quartz Creek The ground is on a bench on the right limit of the creek and is shallow, allowing the use of open-cut methods. A large area had been stripped by groundsluicing off a covering of moss and about 3 feet of muck, and two men were shoveling in. The gravel deposit is from 1 to 2 feet deep and consists mostly of angular, little-worn material, except very near bedrock. Although the entire waters of the creek were diverted into the ditch they were sufficient for sluicing less than half the time. There is said to be much ground along this bench which could be profitably worked if sufficient water could be had for hydraulic mining, but which can not be worked by the more expensive hand methods.

American Creek.—Discoveries of placer gold on American Creek, a small stream flowing into Fish Lake about 15 miles west of the Patterson Creek mines, were reported early in 1911. Active prospecting during the summer located pay gravel on at least four claims, from one of which a considerable production is reported. A hand windlass was used in hoisting the gravel, the ground being only 12 or 15 feet deep on most of the claims. Thirty to 50 men were on the creek most of the summer and preparation was being made for extensive work in both prospecting and mining during the winter.

TIN.

Smoothly rounded pebbles of cassiterite, the oxide of tin, occur in the placers of the Sullivan Creek group in company with the gold. The neighboring placers on Cache and Quartz creeks are barren of the mineral, so that the area in which it occurs is small, being less than a mile in its longest direction. In quantity, the tinstone or stream tin, as it is commonly called, varies with the gold, the placers commonly being rich or lean in both minerals. In the richest spots as much as half a pound of tin to the pan is reported, which at the present price of the ore would give the gravels a value, not allowing for costs of mining or transportation, of $18 to $20 a yard, according to assay.

Gravels that contain as little as 9 pounds of cassiterite to the yard are being profitably mined in the York region, Alaska. There can be little doubt that a great part of the gravels mined on Sullivan Creek carry as high a content of tin and that some may run much higher. But on account of the inconvenience that the presence of the tin ore occasions in the separation of the gold it is deemed a nuisance by the miners of the district rather than a possible resource.

The bedrock source of the tin has been the subject of a great deal of speculation, and considerable effort has been spent in trying to locate it. The search has been made in the region around Roughtop Mountain rather than the neighborhood of the placers, under the impression that only an area of igneous rock could supply the mineral. Although it is true that in its typical occurrence in bedrock there is an evident relation of the ore to some igneous rock from which the tin-bearing solutions probably emanated, cassiterite may also occur in quartz veins and small dikes at some distance from any large igneous mass. There is a strong likelihood that the tin of the placers has not been brought a great distance to its present position but that it has been derived from veins and dikes of the country rock that have been eroded from the same area in which the tin-bearing placers are found. Bedrock prospecting in the vicinity of the mines is difficult, owing to the thick covering of gravel and silt. A closer scrutiny of the bedrock exposed in the mines and in the neighboring hills is desirable, especially of the quartz veins and micaceous dikes, which may possibly be tin bearing. Should any angular and little-worn cassiterite be found in the gravels it would be good evidence of a bedrock deposit near at hand. That the quartz veins of the Sullivan Creek area are probably the source of the tin as well as of a large part of the gold is indicated in the structure of the ore, which is in the form of a recemented breccia. The fragments composing the breccia are vein quartz; the cementing material is principally cassiterite. Blue and brown tourmaline and small quantities of fluorite also fill spaces between the quartz fragments in some of the specimens. From this structure it is inferred that the quartz veins were originally formed barren of the other minerals along the joint planes of the country rock, and that subsequent dynamic stresses caused movement along these planes and the brecciation of the quartz veins. These stresses were possibly due to the injection beneath the region of an igneous mass which may have furnished the tin-bearing emanations from which the ores were derived.

THE RUBY PLACER DISTRICT.

By A. G. Maddren.

INTRODUCTION.

The recent activity in the Ruby gold-placer district is, in a measure, a renewal of interest on a larger scale in a district that has received a small amount of attention from gold seekers since 1907. Late in the summer of that year a report was circulated along the Yukon that prospects of placer gold had been discovered on Ruby Creek, a southern tributary of the Yukon about 3 miles long. The discovery was made at the mouth of the creek in some fine gravel at the level of the spring high-water mark of the Yukon.

The accessibility of the locality, especially from Tanana, Rampart, and Fairbanks, attracted many men there during the later part of 1907, who, without making any actual discoveries, located extensive tracts as placer-mining ground. Most of those who came at that time were not prepared to remain longer than a few weeks. Only about 30 men remained in the vicinity of Ruby Creek during the winter of 1907–8. Some of these prospected with the crude facilities at hand on various creeks within easy reach of the Yukon. A number of holes were dug during the winter, largely with the aid of three small steam boilers, but the result of these operations was apparently not encouraging, for by July, 1908, most of the men had left the district and the only property then worked was Discovery claim, on Ruby Creek. Mining was renewed on this claim in 1909 and 1910 and carried on for a month or so in the early part of each summer, while there was enough water to sluice with, and several thousand dollars worth of gold was thus taken out of an open cut.

During the summer of 1911 the report of new discoveries attracted a large number of persons to this district. A new settlement named Ruby, the population of which has fluctuated between several hundred and a thousand or more persons, was established on the south bank of the Yukon at the mouth of Ruby Creek, the town site being on Discovery claim. The accessibility of this district, due to its location on the lower central part of the Yukon, the main route of transportation into the interior of Alaska, undoubtedly led to this influx of population.

The actual discoveries of placer gold up to the time of the latest reports, however, do not seem to indicate that this will be a new bonanza field, but they have been interpreted by some to indicate the existence in this vicinity of much more extensive deposits of gold-bearing gravel. Whatever may prove to be the fact the community is in excellent condition to open up rapidly to a producing stage any mining ground that may be prospected thoroughly enough to demonstrate its value. Ground that would not pay to mine in many other districts in the Yukon Valley should be profitable here because of the accessibility of the district. It is reported that active preparations are now being made for the commercial development of several properties.

The writer[1] spent seven days in making a hasty examination of this district in July, 1908. In 1910 the most mountainous part of the district, lying along the divide between the basin of Nowitna River and the basins of the Yuko and North Fork of the Innoko, was traversed topographically by a survey party under C. G. Anderson. H. E. Birkner, a member of this party, made some geologic observations along the route traveled. The following statement is based on the above official investigations, supplemented by information derived from various sources, but especially from notes on the most recent developments furnished by Mr. Harry G. Abercrombie, accompanied by a sketch map of the drainage of the district, showing the names of the creeks. A drainage map of the district (Pl. XIV) has been prepared, which is based on Mr. Anderson's survey, 1910, and Mr. Abercrombie's sketch map.

GEOGRAPHY.

LOCATION AND EXTENT.

The area known as the Ruby placer district (see map, Pl. XIV), from the name of the small stream on which gold was first discovered in it, lies along the south bank of Yukon River, about 175 miles below the town of Tanana and 110 miles above Nulato, the two nearest large settlements on the Yukon. On the northwest it is bounded by the valley of Yuko River and on the southeast by the valley of Nowitna River. That part of the Kaiyuh Mountains included in the Ruby district may be deemed to extend southward to Twin Butte Mountain. This mountain, whose elevation is about 1,700 feet, is situated about 32 miles south of the Yukon and is separated from what may be considered as northerly outliers of the Kuskokwim Mountains by a

[1] Maddren, A. G., Gold placers of the Ruby Creek district: Bull. U. S. Geol. Survey No. 379, 1909, pp. 229–233; and The Innoko gold-placer district, Alaska, Ruby Creek area: Bull. U. S. Geol. Survey No. 410, 1910, pp. 75–80.

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saddle some 4 or 5 miles wide, whose elevation is about 600 feet above sea level. This low pass lies about 8 miles east of Twin Butte Mountain and separates a western headwater of Solatna River, named Long Creek, from an eastern headwater of the North Fork of the Innoko, which drains the southeastern flanks of Twin Butte Mountain. As thus bounded the Ruby district embraces an area extending about 35 miles from north to south and about 30 miles from east to west, and includes about 1,000 square miles of territory.

RELIEF.

For a distance of 10 miles along the south bank of the Yukon the Ruby Creek area is made up of rolling hills, from 400 to 600 feet high, which border the river, forming rock bluffs 200 or 300 feet high. These hills may be considered as forming the northeast end of the Kaiyuh Mountains, which extend for about 175 miles toward the southwest to lower Innoko River. The Ruby Creek hill country is noteworthy as being the only tract on the south side of Yukon River between Tanana River and Bering Sea, a distance of over 800 miles, where highlands of the older rocks and bluffs of consolidated bedrock form the immediate bank of the Yukon. The south side of the Yukon throughout all the rest of this distance is bordered by low banks and here and there bluffs of unconsolidated alluvial silt, which covers the older hard-rock formations for distances of 5 to 20 miles or more back from the river. Southward from the vicinity of Ruby the rolling hills gradually rise to low, dome-shaped mountains, 1,500 to 2,000 feet in height. These mountains extend southwestward to the lower Innoko Valley as the Kaiyuh Range. Southeast of the Kaiyuh Range are northwestern outliers of the Kuskokwim Mountains, which are drained by the headwaters of Innoko River. There is a topographic connection between these two ranges about 35 miles south of Ruby, consisting of a low saddle ridge about 600 feet above sea level.

DRAINAGE.

The drainage of the Ruby district is of that type which may be expected to characterize a low, rolling, moderately mountainous region that has been gradually worn down to its present form during a long period by rather small streams having no great erosive power. None of the present streams carry much water; their grades are not steep, and the character of the relief that they have produced suggests that they have remained about as they now are since the Yukon cut through what appears to have been a bedrock barrier across its present channel in the vicinity of Ruby, or perhaps since an earlier time.

The streams that drain the Ruby district may be conveniently described in three groups—those which flow directly into the Yukon, those which flow eastward into the Nowitna, and those which flow westward into the Yuko and the North Fork of the Innoko. The groups will be considered in the order named.

Big Creek has its source 3 or 4 miles south of Ruby and discharges into the Yukon about 4 miles above the town. Independence Creek, whose open valley stretches along the western border of the Nowitna Flats about 5 miles east of Big Creek, enters the Yukon some 9 or 10 miles above the town of Ruby. These two streams drain the eastern part of the hilly country that borders the Yukon east of Ruby. The western part of this group of hills is drained by Ora Creek, which empties into the Yukon about 5 miles below Ruby, on the eastern edge of the Yuko Flats. South of these creeks a considerable area of the hills is drained by the headwaters of Main Creek, which also enters the Yukon after flowing westward across the Yuko Flats. Ora and Main creeks are said to discharge into a slough that leaves the Yukon just below the Ruby Bluffs.

Big and Ora creeks, as has just been stated, drain opposite sides of the Ruby Hills. North of the divide that separates their upper basins from the channel of the Yukon lies a strip of hilly country, from 2 to 3 miles wide and about 10 miles long, that extends along the south bank of the Yukon, the bluffs already mentioned overlooking the river. These bluffs are separated by small valleys which run at right angles to the Yukon and which are occupied by creeks from 1 to 3 miles in length. These short streams that drain directly into Yukon River, named from east to west, are Flat, Center, Melozi, Ruby, Short, and Hannah creeks. They all have a very scanty water supply. South of the headwaters of Main Creek the Ruby Hills rise to low, dome-shaped mountains, which form a divide between waters that flow eastward into the Nowitna and those that flow westward into the Yuko and thence into the Yukon.

Nowitna River discharges into the Yukon from the south about 36 miles above or east of the town of Ruby, after meandering across wide flats that extend southward from the Yukon for 30 miles or more. Westward from these wide flats broad strips of bottom land extend up the valleys of the larger tributaries of the Nowitna, reaching well back into the low mountains. These valleys are separated by the low, partly timbered ridges and foothills of the northeastern end of the Kaiyuh Range. A large western tributary of the Nowitna, named the Solatna, has its sources on the southeastern slopes of this part of the Kaiyuh Mountains, and its principal headwaters drain a considerable basin, which lies within them northeast of Twin Butte Mountain. The western headwaters of the Solatna, the chief of which is Long Creek, arise southwest of the divide on the northeast side of which the above-mentioned streams have their sources. The largest streams whose sources are in the Ruby district flow eastward into the Nowitna Flats between the Solatna and the Yukon. These streams, named in order from north to south, are Beaver, Flint, Trail, and Quartz creeks.

The latest discoveries of placer gold are on Long Creek, and some of its dozen or more tributaries, one near its head named Bear Pup and one near its mouth named Midnight being the most promising; also on Flint Creek and its headwaters, Glen and Birch; and on Trail Creek, which lies southeast of Flint.

Yuko River discharges into the Yukon about 23 miles below or west of Ruby. The Yuko, like the Nowitna, meanders in its lower course across broad flats containing sloughs and small lakes. These flats are bounded on the east and south by the northwestern flanks of the Kaiyuh Range and are traversed from east to west by several large streams that rise within the part of the range that is included in the Ruby district. The largest of these streams is the East Fork of Yuko River. A low divide south of the Yuko Valley separates it from the valley of the North Fork of the Innoko. The pass across this divide makes a wide break between that part of the Kaiyuh Mountains constituting the Ruby district and the southwestern extension of this range. The southwestern part of the Ruby district is drained by creeks that flow into the North Fork of Innoko River. Most of these streams have their sources on the western and southern flanks of Twin Butte Mountain.

VEGETATION.

Spruce, birch, cottonwood, aspen, alder, and willow are the principal woody plants. Spruce is the only tree available for use as lumber, and only on the flats and lower slopes near the larger streams does it grow large enough to be suitable for this use. On the hills and higher mountain ridges practically all of it is small and scrubby, although in favorable spots individual trees attain a good growth, especially high up in some of the gulches. Most of the mountains of elevations above 1,500 feet have open summits. Some tangled growths of stunted trees in the saddles along divides are so thick as to make it necessary to chop a trail through them for the passage of pack horses. Most of the spruce of cabin-log or lumber size stands in groves, interspersed with swampy meadows and brushy tracts of willows and alders on the Nowitna and Yuko flats, especially along the banks of streams.

Willow and alder grow thickly not only on the flats but also along the bottoms and slopes of nearly all the valleys and gulches within the mountains, reaching above the limit of spruce growth. They extend across many divides and up the slopes of mountains quite to their summits. At the higher elevations, however, their growth is not so vigorous as on the lower levels.

White birch is scattered among the spruce, both along the streams and on the slopes. Aspen grows on the drier hillsides in characteristic clumps, and cottonwood is found along the sluggish reaches of the streams, in places in considerable groves, especially on the flats of the Yukon.

GEOLOGY.

The bedrock of the hills and low mountains of the Ruby district comprises various old, altered sedimentary rocks, crystalline and cherty limestone, garnet-mica schists, quartzite schists, and mica-quartz schists being the most common. Much of the mica-quartz schist has a texture so fine that it may well be termed coarse-grained slate or phyllite.

These rocks are fairly well exposed in the bluffs along the Yukon and in a less satisfactory manner here and there on stream banks, valley slopes, crests of ridges, and mountain summits. Throughout most of the district, however, the bedrock is covered with vegetation and its small outcrops are so poor and so widely scattered that it is impossible to judge whether any particular kind of these rocks is more abundant than the others. All kinds have been considerably changed by metamorphism but not so much as to obliterate their sedimentary origin and their arrangement. They are presumably to be correlated with lithologically similar formations that occupy large areas of the mineral belt between Yukon and Tanana rivers, 200 miles farther east.

Diabasic and dioritic rocks are associated with the altered sedimentary formations. These igneous rocks are widely distributed throughout the district, but apparently do not make up a large part of the bedrock. Whether the diabases are old lava flows interbedded with the sedimentary rocks or whether they have been intruded into them as sheetlike masses or dikelike bodies has not yet been determined. The diorites, however, are distinctly intrusive, for they cut across the bedding and structure of the sedimentary rocks in various directions as dikes, ranging in thickness from a few to several hundred feet, the narrow ones being the more abundant. In texture the diorites range from compact crystalline to moderately porphyritic.

The strikes of the sedimentary formations differ considerably, ranging from north-south to northeast-southwest, and the bedding dips away from the strike at angles varying from 30° to 45°. In some areas opposing dips have been observed, but in others the dips are all in one direction with reference to the general trends of the bedding, which for the most part range from 20° to 30° east of north and west of south. With the information now at hand it is not possible to state the nature of the folding that produced the structural attitudes noted above or the extent to which faulting or displacement accompanying the intrusion of igneous rocks may have contributed to the result.

The exposures in the bluffs along the Yukon show local zones of shearing and fracturing, the spaces in which have been filled by stringers and bunches of quartz. Near Flat Creek the shearing in the schists produced large openings, which are occupied by quartz lenses and stringers. On the surface these quartz deposits are of the lens or bunch type, having no uniform trend or thickness for any considerable distance. Two principal exposures of quartz were seen—one about 100 yards below the mouth of Flat Creek, which shows a maximum thickness of 4 or 5 feet on its face, and another about 100 feet below, which is several feet thick, but not very long. Assays of samples of quartz from these exposures are said to have shown considerable gold. In 1906 a tunnel, now caved in, was run in 150 feet, it is said, on the largest of these quartz deposits. After the work had progressed for a few feet it was found that the tunnel passed mostly through country rock, it being impracticable to follow the irregularities of the quartz stringers with a straight tunnel. In brief, the work done at this place has shown that the bodies of quartz are too irregular and too uncertain in extent to be mined by tunnels, and what has been demonstrated at this place will probably be found to be more or less true throughout the district. Other occurrences of quartz are indicated by the float lying on the hills farther south, but the attitude and extent of the quartz in bedrock here can not be so well observed as in the bluffs along the Yukon, owing to the disintegrated condition of its outcrops. From what is now known it is presumed that all of the quartz mineralization in the bedrock of this district is similar to that observed along the Yukon in that it does not occur in defined veins. Whether there is an intimate relation between the quartz mineralization and the dioritic intrusives is not clear. One large dike of medium-grained diorite about 200 feet wide crosses the schists diagonally to their strike and stands about vertical. It has been greatly sheared and has been shattered into blocks, the fracture and joint spaces between which have been recemented by quartz stringers or veins, the largest 6 inches wide. This structure indicates that structural and other changes that favored mineral segregation and deposition took place after at least some of the diorites had been intruded into the country rocks.

Besides occurring as noted above, the quartz is distributed in considerable amount through portions of the schists as small veinlets, leaflets, and blebs.

A large part of the placer gold of this district is probably derived from quartz that was mineralized in the manner indicated above, but the distribution of the gold-bearing minerals throughout the bedrock and the geographic relation of the gold to its bedrock source can not now be stated. However, the alluvial deposits that fill the bottoms of the valleys, with which the placer gold is locally associated, are for the most part moderate in quantity and thickness. They appear to be gradual accumulations produced by a meager drainage such as now prevails, and probably the placer gold has not been carried far from its bedrock source before being deposited in them. The rounded forms of the ridges and mountains suggest that the present aspect of the country is the result of a long and uniform erosion, perhaps moderately accelerated recently, with the result of giving some of the valleys in the more mountainous parts deepened V-shaped cross sections and steepened gradients to their headwater slopes.

PLACER-GOLD PROSPECTING.

When the news of the discovery of placer gold on Ruby Creek spread along the Yukon Valley in 1907, men hurried there, especially from Tanana, Rampart, and Fairbanks, and, following what is now the usual practice in new placer fields, located as placer ground practically all the alluvial bottom lands along the streams of this district. The locations included both association placer groups containing 160 acres and single 20-acre tracts. Large areas of the valley slopes also were located as so-called "bench claims." No discoveries of gold were made on 99 per cent of the claims thus located, and probably half of the location notices were never recorded. Some actual prospecting was done near Ruby during the winter of 1907–8, most of it on Ruby and Big creeks, although a few holes were sunk on Boston Creek and two of its headwater tributaries—Logger and Boston gulches. Prospecting was also done at the headwaters of the Solatna, which at that time were known as Beaver and Dome creeks. As this prospecting did not result in mining developments, except in a small way on Ruby Creek, not much information is at hand regarding the nature of the stream deposits, except those on Big and Ruby creeks. On Big Creek, where about 15 holes were dug to bedrock, the valley bottom is covered with alluvium to a depth of 15 to 60 feet, the deeper deposits apparently being near the upper part of the valley. These holes showed that washed gravel of the schistose country rocks lies on bedrock. It is from 1 to 7 feet thick and is overlain by sandy clay and muck. The gravel contains bowlders of igneous rocks and quartz, the largest a foot in diameter. A good deal of iron pyrite occurs with the gravel, either as washed grains or inclosed in or attached to some of the larger fragments of slaty bedrock. It is reported that colors of gold were found in all of the holes on Big Creek.

The unconsolidated valley deposits on Ruby Creek probably average about 15 feet in depth. They are composed of muck, loamy sands, patchy layers of flat schist and slate pebbles, and a good many water-rounded bowlders of igneous rocks. The bedrock is schist, slate, and limestone, in the form of rectangular blocks and slabs. The material handled in mining on Discovery claim consists of this loose, blocky limestone, flat pieces of coarse-grained mica slate similar to that seen above and below Ruby Creek on the Yukon, close-grained cobbles of diabase, and large heavy bowlders of medium-grained diorite similar to that seen in a large dike on the Yukon. These bowlders are from 12 to 18 inches in diameter and are well rounded. The whole is covered with a mantle of muck and silt. In most places this muck is underlain by finer wash made up largely of flattish slate pebbles mixed with loamy sand. This sand also fills the spaces between the blocky limestone fragments of the bedrock. Finer water-worn gravels, consisting of slate pebbles, mostly flat, are mixed with the sand and occur in patchy layers within it and on top of the blocky limestone. These layers of fine washed material do not appear to be very continuous or very thick. They carry most of the placer gold, which is in the form of flaky particles, none as large as bird shot. Owing to its fineness the gold is hard to save in the sluice boxes.

During the excitement of 1911 the staking of ground without first making discoveries was repeated over that part of the district where similar locations were first made in 1907 and was also greatly extended to the south. Most of the prospecting in the district is now being done on streams situated from 10 to 30 miles south of Ruby, and under the present favorable conditions, with plenty of men, equipment, and supplies at hand, there appears to be no doubt that the possibility that the district may afford good placer mining will be thoroughly tested.

The latest information in regard to the progress of mining developments in this district is to the effect that Flint Creek has not yielded very good results, except on the Nuahmah discovery bench claim, situated between Gold Run and Eldorado creeks. On this claim a crosscut 100 feet long, at a depth of 60 feet, has given returns for 40 feet that average $1 to the square foot of bedrock surface. The ground adjoining this bench claim is said to be about as good. No satisfactory colors have been found above or below this locality, and prospecting along Flint Creek has been practically discontinued.

Glen Gulch, a headwater tributary of Flint Creek, just north of Eldorado, shows prospects of 6 cents to the pan in 3 feet of gravel at its mouth, but appears to contain no pay streak on bedrock. Half a mile up Glen Gulch from its mouth gravels 4 feet deep and 12 to 14 feet wide yield from $3.50 to $4 to the square foot of bedrock surface, but the extent of the pay streak here has not been determined.

On Trail Creek, which is the first large stream southeast of Flint, pay gravels that are said to run $3 to the square foot of bedrock have been found 1 mile above and 2 miles below Discovery claim.

Discovery claim, on Long Creek, which was first located five years ago, now shows good prospects. Windy Bench, on the left or east side of Long Creek, a quarter of a mile below Discovery claim, contains gravels at a depth of 45 feet which runs $1.50 to the square foot of bedrock surface. The benches on the left of claim No. 7 below Discovery on Long Creek show prospects at a depth of 60 feet. Likewise the bench gravels on the left limit of claim No. 8 below Discovery on this stream carry, at a depth of 71 feet, good low-grade prospects of fine gold, and the left limit bench claim No. 12 below Discovery shows prospects at a depth of 76 feet.

Claim No. 2 above Discovery on Long Creek includes bench gravels that have been drifted into for 35 feet and found to carry $2 to the square foot, but the extent of this deposit is not known. Prospects of 15 cents to the pan have been found in one hole on claim No. 3 above Discovery on Long Creek, and on claim No. 4 above Discovery a crosscut of 20 feet prospected $6 to 20 pans of gravel. A nugget of $1.90 was found in this prospect.

Midnight Creek, a west-side tributary to Long Creek, about 5 miles in length, is reported to be promising. This branch comes in about 20 miles from the head of the main stream, where its flat valley bottom is several miles wide. On Discovery claim the pay gravels lie at a depth of 25 to 30 feet and are reported to carry as much as $4 in gold to the square foot of bedrock surface. Here 40 feet of drifting has been done, and it is said that tests of 15 cents to the pan may be obtained from gravels as high as 7 feet above bedrock. At last reports a large boiler was being installed on this claim to replace a prospecting boiler that had been on the ground, and it was the intention to start hoisting at once and take out a dump for spring sluicing. Immediately above and below this claim there are said to be good prospects on which lays have been let.

Small prospects which do not yet seem to be important enough to encourage mining have also been found on many other creeks in the district.

No work is now being done on any of the creeks that empty into the Yukon except one named Shovel Creek, which enters the river about 15 miles above Ruby, but it is said that no valuable deposits have yet been found on this stream. Prospecting is also being done in the upper basin of Yukon River and on the headwaters of the North Fork of the Innoko.

GEOLOGIC INVESTIGATIONS ALONG THE CANADA-ALASKA BOUNDARY.

By A. G. Maddren.

WORK OF THE BOUNDARY COMMISSION.

During the summer of 1911 the joint commission appointed and authorized by the Governments of Canada and the United States to locate and mark the boundary line separating British territory from Alaska advanced field operations northward along that part of the one hundred and forty-first meridian which extends from Porcupine River to the Arctic Ocean. This work was a direct continuation of the boundary survey that was carried northward from Yukon River to Porcupine River during the summers of 1909 and 1910. The commission expects to complete this part of the survey in 1912.

The 320 miles through which the one hundred and forty-first meridian extends between Yukon River and the Arctic Ocean is crossed about midway by Porcupine River, which thus separates the region into north and south subdivisions that form convenient units for geographic and geologic description. The southern subdivision, about 175 miles in length, may be designated the Yukon-Porcupine section, and the northern one, about 145 miles in length, the Porcupine-Arctic section.

Porcupine River is easily navigated by shallow-draft steamboats to New Rampart, an Indian trading settlement on the north bank of the river just east of the boundary line, or about 225 miles above its confluence with the Yukon near Fort Yukon. It thus affords a natural route for the transportation of supplies and makes it practicable to maintain a very convenient base of operations for both sections of the boundary at this point.

At the close of the field season of 1910 there still remained in the northern half of the Yukon-Porcupine section a stretch of about 80 miles south from the Porcupine, the final work of permanently placing the intermediate monuments at intervals of 3 to 5 miles and of clearing a strip 40 feet wide through the timbered portions along the line. There also remained the topographic mapping of a strip 2 miles wide on each side of the line for about 45 miles south from the Porcupine. Of this work the mapping was completed to Porcupine River in July, 1911, but, owing to unforeseen delays, the setting of the monuments and clearing through timber lacked 30 miles of reaching the Porcupine. This work will be completed in 1912.

In the meantime field work was commenced on the Porcupine-Arctic section at New Rampart in June, 1911, and continued northward until the middle of August. The one hundred and forty-first meridian was located to a point within 7 miles of the Arctic Ocean. The topographic mapping of the 4-mile strip along the line was completed for about 115 miles, or within about 30 miles of the Arctic coast. The boundary was marked with permanent bronze monuments at intervals of 4 or 5 miles over approximately 70 miles, or about half the length of the section north from the Porcupine, and the strip 40 feet wide was cleared through such timbered portions as occurred in this distance.

GEOLOGIC WORK.

Realizing that its well-equipped field organization afforded unusual facilities in this remote and rather inaccessible region for gathering much information not directly connected with the particular work of locating and marking the boundary line, the joint commission extended an invitation, which was readily accepted, to the geological surveys of Canada and the United States to send geologists to accompany the field parties during 1911 and 1912 and to examine the geology along the boundary from the Yukon to the Arctic.

The most satisfactory arrangement for making such a geologic examination in the two summers available appeared to be to assign one of the two sections of the line to each Government. The alternative plan, by which each Government should make observations side by side on Canadian and Alaskan territory, would not only have caused more or less duplication, but would also have compelled all the observers to traverse the whole length of both sections. Accordingly the Canadian geologists undertook to examine the southern, or Yukon-Porcupine, section and the United States geologists the northern, or Porcupine-Arctic, section.

During the field season of 1911 two Canadian geologists examined the part of the Yukon-Porcupine section extending from Orange Fork, the southernmost branch of Black River, northward to the headwaters of Salmontrout River, or approximately between 66° and 67° north latitude. They concluded their field work for the summer about 30 miles south of New Rampart and plan to continue it in 1912. The boundary-survey topographic map of the 4-mile strip, drawn on a field scale of 1 to 45,000, was used as a base on which the geologic data were platted. Reports on the geology along this section of the meridian will be published by the Canadian Geological Survey.

Two geologic observers from the United States Geological Survey commenced a field examination of the Porcupine-Arctic section at New Rampart in the second week of June, 1911, and carried their work northward approximately 100 miles, to the headwaters of Firth River, which flows into the Arctic Ocean. The observations were carried along simultaneously with the topographic mapping of the 4-mile strip on a field scale of 1 to 45,000, with contour lines at intervals of 100 feet. The geologic data observed over the surveyed area were platted upon tracings from the plane-table sheets which were furnished by the topographers at frequent intervals as the field work advanced.

It is planned to continue the geologic field work to the Arctic coast in 1912 and then to publish a report fully describing the geologic section along the boundary line from Porcupine River to the Arctic Ocean. From the character of the area examined so far it appears that the results will be primarily of stratigraphic rather than of mineralogic importance and will be interesting chiefly as a contribution to the study of the general geologic history of this northern region. Although some search for placer gold has been made about the headwaters of Old Crow River during the last few years by several prospectors, no mineral resources have been discovered in this region, and the existence of deposits of value within the immediate area examined does not appear probable.

GEOLOGY.

ROCK FORMATIONS.

A preliminary outline of the geologic results obtained during 1911 over the part of the section between Porcupine River and the upper basin of the Firth is herewith presented.

Four groups of sedimentary formations have been distinguished, and two types of igneous rocks are associated with what is apparently the oldest of these groups. Considered in what is thought, at present, to be the order of age from older to younger, these sedimentary groups are:

1. A group of quartzites, phyllites, and slaty shales of pre-Ordovician age, some of which are schistose, which have been intruded by masses of granitic rocks that locally cover considerable areas and also by some diabasic igneous rocks of much smaller extent.

2. A group of Carboniferous age, which is for the most part made up of heavily bedded limestones but which also comprises some shaly, sandy, and cherty members.

3. At least one formation of Upper Triassic age, composed of beds of sandy and limy shales containing marine fossils.

4. Another group of quartzites and shale slates, with some beds of conglomerate, which may be of Mesozoic age.

From this it seems that the varied and well-developed Paleozoic section that occurs along Porcupine River west of the one hundred and forty-first meridian is not represented along the 115 miles of the boundary extending northward from Porcupine River except by the pre-Ordovician quartzite and slate series and the Carboniferous limestones. Along the Porcupine Kindle[1] has found a quartzite and slate series which he considers, on stratigraphic grounds, to comprise the oldest rocks exposed in the Porcupine River section and to be of pre-Ordovician age. These are followed by Ordovician limestones; Silurian dolomites and shales; Devonian limestones, shales, and lavas; and Carboniferous shales and limestones, most of which are represented by formations of considerable thickness, containing fossils at many horizons. In fact, all these Paleozoic formations, except the pre-Ordovician quartzite and slate series and the supposedly Devonian igneous flows, contain enough fossil-bearing beds to establish their stratigraphic identity and relative position.

PRE-ORDOVICIAN ROCKS.

PORCUPINE RIVER.

Kindle's description of these rocks as they occur along Porcupine River[2] is as follows:

The oldest rocks exposed in the Porcupine River section are found in the vicinity of the international boundary. This series is well exposed in the steep slopes and cliffs facing the river at New Rampart House and outcropping continuously for 6 or 7 miles below there. It is composed largely of thin-bedded and very fine grained quartzites, which are bedded usually in thin strata 1 to 6 inches thick. Interbedded with the quartzites are considerable beds of black shale and limestone and thin beds of dolomites. The nearly universal color of the quartzites (as exposed along the river) is light gray or white, which gives them a strong resemblance to limestones. Occasional beds occur, however, which are specked with brown, and one 30-foot bed of dark-brown sandstone was observed in the river bank at New Rampart. Sulphide of iron is present in some of the beds, as is indicated by the accumulation of films of sulphur on protected rock faces. Where exposed to weathering the quartzite beds disintegrate to a fine white or cream-colored powder. This powder covers all the steep slopes where vegetation is absent, giving the appearance of great marl or clay beds at a little distance.

The black shales and slates occur usually as thin films alternating with limestone bands one-half inch to 3 inches thick. The presence of the limestone, although it comprises the bulk of these beds, is not evident in the weathered

[1] Kindle, E. M., Geologic reconnaissance of the Porcupine Valley Alaska: Bull. Geol. Soc. America, vol. 19, 1908, pp. 315–338.

[2] Kindle, E. M., op. cit., pp. 320–322.

exposures of steep slopes, where the intensely black shale or slate fragments are apt to conceal the light-colored thin limestone strata, giving the whole the appearance of a shale or slate formation. Below New Rampart House 1 mile a set of these black beds 500 or 600 feet thick is interbedded in the quartzite series. The quartzites are well exposed in the gorge of the small stream [Sunaghun Creek] entering the Porcupine at New Rampart House. The creek section exposes here 1,000 feet or more of the quartzite series, which is uninterrupted by other beds. The sharp contrast of the exposures of the intensely black slate-limestone beds and the white quartzites is one of the most striking scenic features of the Upper Rampart gorge near the boundary. Some dolomites also occur in the quartzites, but they play a subordinate rôle as regards their importance in making up the total mass of the series.

Metamorphism is not pronounced in this series [as exposed along the Porcupine], but the argillaceous sediments are noticeably more altered than those of the higher [Paleozoic] horizons. In the latter the shaly phase is found, as a rule, while in the former [pre-Ordovician series] the shales have been altered to slates or slatylike slickensided films where they are in very thin sheets interleaved with limestones, as generally happens.

It is difficult to make any estimate of the thickness of these beds without detailed work. The prevailing westerly dip, which continues for about 6 miles below New Rampart House, points to a great thickness for the series, but the possibility of faulting and of close folding in a part of the series leaves some uncertainty in regard to the actual thickness. Five thousand feet would seem to be a conservative estimate, and it is probable that a much greater thickness is represented.

No fossils have been found in these rocks, consequently their age can only be stated with reference to that of the oldest paleontologically determined beds of the section—the Ordovician. That they antedate the Ordovician in age is indicated by the fact that no series corresponding to them in lithologic features occurs in the portion of the geologic section lying above the Ordovician. The several main divisions of the Paleozoic section from the Ordovician to the Carboniferous have been recognized on the Porcupine by their fossils.

This series of rocks continues along the Porcupine east of the boundary for 10 or 12 miles. As exposed in the Upper Rampart bluffs along this part of the river it presents much the same lithologic character as is shown by the exposures along the river bluffs west of the boundary. The whitish and in places somewhat varicolored quartzites form an important part of the strata, as to the west, and individual members of the series appear to be more heavily bedded. The exposures of black shale slate for at least 5 or 6 miles immediately east of the boundary appear to be thicker and more numerous and to contain less limestone than those west of it. The greater number of thick exposures of these slates may be due to repetitions of some of the members by faulting, or there may really be a greater number of such members along this part of the river. That this sedimentary series has suffered more or less disruption in at least this part of the region is indicated by the fact that it has been intruded, both across and along the bedding, by dikes and sheets of diabase, several of which, 20 to 40 feet thick, are well exposed along the north-side river bluffs a short distance above New Rampart. Slaty cleavage is common and some schistose structure has been developed locally.

Along the eastern border of the section exposed in the Upper Ramparts limestones again become more abundant. One very highly contorted black shale and limestone member several hundred feet thick is well exposed in the river bluffs about 10 miles above New Rampart, where it shows alternating limestone and shale beds from 1 to 2 feet thick, about equal both in number and total thickness. Above this locality the limestone outcrops along the river become discontinuous, then less and less close, and in a short distance they disappear beneath an extensive terrane of partly consolidated clays and sands of probable Tertiary age, which fill a large basin-like expanse of the Porcupine Valley east of the Upper Ramparts. The disconnected outcrops along the upper 2 or 3 miles of this part of the river are different in character from those below. They are made up mostly of more or less massive limestone and granular to fine-textured dolomites which may prove on detailed examination not to be closely related to the pre-Ordovician series of rocks, but rather to one or more of the Paleozoic formations which occur southwest of this series on the Alaskan side of the boundary.

Northward from the Porcupine there are noticeable color variations, apparently due to differences in weathering, between the outcrops of the quartzites and the shale slates along the river and their exposures on the higher ridges and mountains away from the river. In the bluffs of the Porcupine the quartzites are prevailingly whitish with a small percentage of varicolored pinkish, purplish, and brownish beds; whereas away from the river the same rocks are mostly dull white and light to dark gray and contain some iron-stained brown beds. The shale slates along the Porcupine are for the most part black, some of them intensely so, but away from the river bluffs these rocks, although in some beds predominantly black and dark gray, show in others banded bright reds and purples, dark to pale greens, and light drabs or grays.

SOUTH OF PORCUPINE RIVER.

The same pre-Ordovician quartzite and slate rocks which occur along Porcupine River in the vicinity of the one hundred and forty-first meridian are reported by the Canadian geologists to extend southward from the river along the boundary for 25 to 30 miles.

Farther south along the meridian, between 66° and 67° north latitude, the same observers examined in more detail a group of quartzites and shale slates of very similar lithologic character, which on this indefinite basis they tentatively correlated with the pre-Ordovician series of rocks along Porcupine River. This group appears to overlie unconformably formations of Ordovician, Silurian, and Carboniferous age similar to those exposed along Porcupine River below or southwest from New Rampart. The unconformity appears to be marked both by discordance of bedding and by a more or less well-developed basal conglomerate. This discordance with the underlying Carboniferous and the meager evidence afforded by a few unsatisfactory fossils of indefinite character indicate that this group of quartzite, slate, and conglomeratic sediments may be of Mesozoic age.

A group of rocks of this same general character, whose stratigraphic relations to some Carboniferous limestones near by may be close but are not very apparent, occupy an area just west of the one hundred and forty-first meridian 37 to 52 miles north of Porcupine River. (See p. 313.) It seems very probable that there are in this region two groups of quartzite and shale slate rocks of very similar lithologic character but of entirely different geologic ages; but, if so, the fact can be proved only by further field study of the area as a whole.

NORTH OF PORCUPINE RIVER.

Porcupine River to Old Crow Mountains.—Northward from Porcupine River the pre-Ordovician series of interbedded quartzites and shale slates extends for about 6 miles to the headwaters of Sunaghun Creek, which discharges into the river at New Rampart. On the upper part of Sunaghun Creek the sedimentary series is interrupted by massive granites which are known to have an uninterrupted north-south extent of about 23 miles along the one hundred and forty-first meridian. No information is at hand regarding the occurrence or distribution of the granites or the quartzite and slate series for more than 4 or 5 miles westward from the boundary. It is supposed, however, that the granites at least may extend westward or northwestward for a number of miles. The quartzite and slate series extends only about 7 miles below the boundary on Porcupine River. Whether it extends farther west north of the Porcupine is not known.

Eastward from the one hundred and forty-first meridian these granites are known to extend for at least 10 or 12 miles as the backbone of the Old Crow Mountains, a short range whose bare summits rise about 2,000 feet above Porcupine River and form the southwestern rim of the basin of Old Crow River, separating the drainage of the latter stream from that of the Porcupine to the south. Granitic intrusive rocks are known to extend across lower Old Crow River 40 miles east of the boundary, about 12 miles above its mouth, or 6 miles north from the Porcupine in a direct line. It seems probable that this occurrence may be an eastward continuation of the granite belt of the Old Crow Mountains. How far east of Old Crow River these granites may extend and what their relation may be to the Cretaceous sedimentary formation on the Porcupine 8 miles above the mouth of Old Crow River are not known. Further examination may prove that these granites are not only a continuous belt of intrusion, but that they may cut the Cretaceous sedimentary rocks just mentioned and are therefore younger. The granite is more or less porphyritic, a fact which may indicate that it is of deep-seated origin.

So far as known the disruption of the country rocks which accompanied the intrusion of this wide belt of granite has not brought to view, along either its southern or its northern borders in the vicinity of the one hundred and forty-first meridian, the base of the pre-Ordovician quartzite and slate series or any older formations that may underlie them. This seems to add weight to the opinion that the quartzite and slate series of this part of the area may be the oldest known sedimentary series in this region. However, the Canadian geologists who examined the section along the one hundred and forty-first meridian between 66° and 67° north latitude, and also hastily traversed the remaining 30 miles northward to Porcupine River, have been led by their observations to suggest tentatively that all the quartzite, shale, and slate rocks which occur along the boundary for 100 miles south from the Porcupine are of the same age and are Mesozoic rather than Paleozoic or older. They base their opinion on the facts (1) that over the southern half of this 100 miles they found a group of quartzites and shale slates, including some beds of conglomerate (one of which seems to be basal), unconformably overlying Ordovician, Silurian, and Carboniferous formations, and (2) that the quartzite and slate series along the Porcupine appears to be lithologically similar to the rocks farther south. The quartzite and shale slate series that extends some 20 miles along, about 30 miles south from, and 6 miles north from Porcupine River, appears, however, to be distinguished from the supposedly Mesozoic quartzite and shale slate group that occurs from 30 to 100 miles south of this river, by the fact that the former contains some intrusive diabase in the form of dikes and sheets, whereas the latter contains what appears to be a basal and perhaps several other beds of conglomerate. If the series along Porcupine River is the same as the group to the south it does not seem unreasonable to expect that the former would contain at least some of the conglomerate members or some of the underlying Ordovician, Silurian, or Carboniferous formations characteristic of the southern area, and that, if it does contain them, they would be exposed by displacement along the borders of so extensive a break in the sedimentary formations as that which must have accompanied the intrusion of the granite that extends from 6 to 29 miles north of the Porcupine. No such conglomerates or other beds, however, are known to occur.

The pre-Ordovician rocks between Porcupine River and the granite belt 6 miles to the north are not severely metamorphosed, either regionally or by contact alteration along the border of the intrusive rock. The quartzites are, for the most part, very thoroughly and compactly cemented; locally, however, they are somewhat schistose. Most of the shale beds have developed more or less slaty cleavage, and some of them have become typical slates. Contact metamorphism along the immediate southern border of the granite mass is not intensely developed, and the effects of the intrusive rock do not seem to have extended out into the sedimentary rocks for more than a few hundred yards.

Old Crow basin.—North of the granites which extend along the one hundred and forty-first meridian for 23 miles is a belt of intimately associated quartzite schists, intensely plicated micaceous phyllites, and foliated slates, which extends from south to north for about 8 miles. This group of highly metamorphosed sedimentary rocks appears to be lithologically equivalent to the pre-Ordovician series of quartzites and shale slates that occur along Porcupine River south of the granite belt. Although the presence of subordinate amounts of limestone and intrusive diabase has not yet been recognized in these schists, they apparently differ from the rocks along the Porcupine only in the amount of metamorphic alteration they have undergone. In general this metamorphism appears to be of the regional type in that the rocks in a belt of considerable width have been more or less altered. Yet there seems to be a gradual transition from a thoroughly schistose condition of the sedimentary rocks near the granite contact to a less altered condition several miles away from the granite and a fading out of the schistose aspect in the rocks of the same kind a few miles farther north, so that the strata along the northern part of the belt, 7 or 8 miles from the granite contact, are very similar in texture and general appearance to the semimetamorphosed pre-Ordovician series along Porcupine River south of the granite belt. This difference in the degree of metamorphic alteration, shown by what appear to be rocks of the same sedimentary series exposed along opposite sides of this massive granitic intrusion, may have resulted simply from the position of the break through which the granites were intruded. If this break was just south of an old axis of deformation along which regional metamorphism had already been developed for a width of several miles, it would have separated a highly altered belt on the north from a semimetamorphosed zone on the south, and little contact-metamorphic alteration might have been produced by the granite along either border. On the other hand, however, the massive deep-seated intrusion may have caused strong and widespread contact metamorphism in the country rocks now exposed along the northern border and for some reason may have failed to affect the rocks on the southern margin to any marked degree. Perhaps faulting and crumpling, some evidence of which seems to be shown in the repeated occurrence of what may be the same quartzite and shale slate beds along Porcupine River, modified the intrusive effects along the southern border.

Ammerman Mountain.—More or less altered sedimentary rocks, comprising quartzites, phyllites, slates, and a small amount of highly crystalline limestone, intruded by a mass of granite, make up Ammerman Mountain. These rocks are similar to and appear to be the same as the pre-Ordovician rocks that flank the north and south sides of the wide belt of granite forming the Old Crow Mountains to the south. The granite of Ammerman Mountain, although not extensive, is of a massive character. Whether it is connected in any way with the wide granite belt to the south is not known. However, there is a strong general resemblance in the intrusives themselves, in the country rocks intruded, and in the contact-alteration effects produced. There may be a deep-seated underlying connection between these two granite masses.

The Ammerman Mountain mass extends across the boundary in an east-west direction about 67 miles north of Porcupine River, or 12 miles north of Old Crow River. Although its highest summits rise only about 3,400 feet above sea level, they stand out somewhat prominently by contrast with the widespread lowlands of the upper Old Crow basin, whose level surface, over which are scattered many large and small lakes, extends for a considerable distance from its southern and western flanks at an elevation of 1,200 to 1,500 feet. The main headwaters of Old Crow River flow from the north and northwest around the western flanks of Ammerman Mountain and then southeastward through the Old Crow basin and cross the one hundred and forty-first meridian about 55 miles north of Porcupine River. The meridian crosses the Ammerman Mountain group through a saddle 2,600 feet in elevation between two of the highest summits, each of which is about 3.400 feet above the sea.

From the divide of this saddle a semicircular basin about 2 miles wide opens out southward. The bedrock over the bottom and lower slopes of this basin for 1½ miles is granite. To the north, east, and south the granite seems to be confined within the basin, but to the west it extends along the south flank of the mountain for several miles. The upper slopes on either side, the higher summits to the east and west, and the saddle connecting these summits around the northern margin of this basin are composed of the sedimentary country rocks, for the most part quartzites and quartzite schists, with some thin beds of phyllites or slates and one or more narrow disconnected bands of crystalline limestone. All these sedimentary rocks are locally very schistose for some distance from the borders of the granite mass, but seem to be less intensely altered a mile or so away from the contact. They are, however, strongly metamorphosed along the southeastern rim of the basin.

About the summit half a mile northeast of the granite contact in this basin considerable vein quartz is present in a network of stringers. These vary from a few inches to several feet in thickness and are deposited along some irregular fractures in the blocky schistose quartzite country rock. For the most part they are made up of clear crystalline quartz, but some of them contain a little pyrite and some of the weathered fragments are stained with iron oxide. No other mineralization seems to have occurred. A little prospecting for placer gold done several years ago along the bed of the stream that drains the basin to the south and in the valley of Thomas Creek, a larger stream, which also flows southward and empties into the Old Crow about 6 miles east of the boundary, is said to have yielded a few colors of gold. No mining, however, has resulted from the reported discoveries.

North of Ammerman Mountain the gray quartzites give way to coarse-textured black and gray slates which extend 2 miles or more immediately east of the boundary for about 4 miles north and apparently disappear beneath a heavy series of Carboniferous limestones. West of the boundary the northern flanks of Ammerman Mountain are made up of a phyllite slate bedrock similar to that on the east, but with possibly more quartzite members; 3 miles west of the boundary, however, the gray quartzite phase gradually changes to phyllites and slates with only a few beds of quartzite, and bedrock of this character extends to the west end of the mountain, where it descends to Old Crow River 6 miles west of the boundary. One dikelike body of granite, observed on the south side of a saddle about 3 miles west of the boundary, is probably an offshoot from the mass that forms the lower slopes of the southern flank of the mountain.

All the sedimentary rocks of Ammerman Mountain are provisionally considered to belong to the pre-Ordovician quartzite, phyllite, and slate series which occurs along Porcupine River in the vicinity of the one hundred and forty-first meridian and extends northward from that river for about 37 miles.

The granites of Ammerman Mountain are likewise considered to belong to the same general mass of intrusives as those associated with the similar altered sedimentary rocks in the wide belt to the south.

North of Ammerman Mountain.—About 40 miles north of Ammerman Mountain, along the west side of Firth River, the one hundred and forty-first meridian crosses another area of considerable width that is apparently occupied by a series of more or less metamorphosed quartzites, phyllites, and slates, which bear a striking resemblance to some phases of the rocks of the Ammerman Mountain and Porcupine River areas. Only about 2 miles of the southern part of this northern belt, lying on the southern slopes of Tub Mountain, was hastily observed in 1911. The rocks of this mountain are gray quartzite schists, gray phyllites and slates, some layers of which contain pyrite, reddish-purple slates, pale-green and gray slates, and a considerable thickness of black shale slates which weather into shingle and flaky fragments. These rocks occupy a belt about 2 miles wide down the southern slope of Tub Mountain in the order named above. The black shale slate member shows the widest surface outcrop, being about a mile in width, and the varicolored members occupy the upper slopes of the mountain almost to its summit, where the phyllites and schistose quartzites occur.

The southern border of this series seems to be in fault contact with the northern margin of a widespread series of massive Carboniferous limestones (see p. 310), which extend south for nearly 40 miles, or within a few miles of Ammerman Mountain. The limestones show much contorted folding along this part of their northern border and the black shale slates with which they are in contact are much crumpled and disturbed. The structure of the contact seems to be that of either an overturned fold or an overthrust fault.

Southwest of Old Crow basin.—The southwest side of the Old Crow basin opposite the west end of Ammerman Mountain is occupied by an upland area about 10 miles square made up, for the most part, of a number of broad, round-topped, gentle-sloped ridges of irregular arrangement with intervening wide saddles and basins. The northeastern flank of this upland is named Yankee Ridge. The general trend of this ridge, which is about 5 miles long and 1 mile broad, is northwest and southeast, and its highest parts stand about 1,000 feet above the Old Crow Valley, whose gravel-covered floor is here about 2 miles broad. The Old Crow flats between Yankee Ridge and Ammerman Mountain are markedly contracted compared to their wide expanse above and below this place. The wide, flat valley area above or northwest of Yankee Ridge and Ammerman Mountain may well be termed the headwater basin of the Old Crow, in distinction to the much more extensive main Old Crow basin below, to the southeast. This headwater basin bounds the upland area on the north and is bounded by the flats of the main Old Crow basin on the west. The upland area is separated from the mountains to the south by the wide, flat valley of Casey Fork, a large west-side tributary of the Old Crow which rises 15 or 20 miles west of the boundary and joins the main river about 3 miles below the boundary. From 10 to 15 miles west of Old Crow River this upland appears to connect by several gradually rising ridges with the foothills of a low range of mountains, which forms the watershed between the west-side drainage of this part of the Old Crow basin and the east-side drainage of the upper part of Coleen River. In fact, this upland area may be considered an eastward extension of the foothills which lie between Casey Fork and the northwestern headwaters of Old Crow River.

The eastern half of this upland is rather thickly covered, except over the higher hilltops, by a growth of spruce timber, most of which is scrubby and stunted, and a thick undergrowth of willow and alder brush and moss, which obscures most of the bedrock. Within 5 or 6 miles of Old Crow River the only outcrops of bedrock are on the highest parts of the ridges. So far as known rocks of Carboniferous age form the bedrock of all this upland area except Yankee Ridge, the bedrock of which may be of Devonian age.

DEVONIAN (?) ROCKS.

All the exposed bedrock of Yankee Ridge seems to be a greenish semischistose rock, apparently chloritic, which contains considerable magnetite distributed throughout its mass in the form of small crystals. In the weathered outcrops these rocks part into more or less flaggy slabs along what may be closely set structural planes, which strongly resemble bedding in their parallelism and uniform direction of strike and dip. Their strike averages about N. 50° W. and they dip 50°–65° SW. In massive unweathered exposures, however, these parting planes are not so apparent. In places there is between the stronger planes of separation a secondary wavy crinkling such as occurs in many phyllites and fine-grained quartzite schists.

The relations of the rocks exposed in Yankee Ridge are obscure. Their condition suggests that they have been subjected to the same metamorphic changes as the sedimentary rocks of Ammerman Mountain, but their actual contact with these rocks has not been observed, for bedrock is not exposed across the Old Crow Valley. Nor can their contact with an extensive area of Carboniferous limestone outcropping on several low ridges 3 to 6 miles to the south and west be observed, for there is a wide basin-like depression between, across which all the bedrock is covered by a heavy growth of moss and brush.

It is probable, however, that the greenstone rocks are older than the Carboniferous limestones. They may be a more schistose phase of somewhat similar rocks which occur on Porcupine River at the lower end of the Upper Ramparts, about 45 miles below the boundary, and which are considered to be of Devonian age. Their southwest dip may be an indication that they pass beneath the Carboniferous limestones which occupy the western part of the Old Crow basin just south of them.

CARBONIFEROUS ROCKS.

There are two areas of Carboniferous rocks along the one hundred and forty-first meridian within the 110-mile stretch north from Porcupine River that has been examined. The southern area lies west of upper Old Crow River, about 60 miles north of Porcupine River; the other extends for about 40 miles, from a point several miles north of Ammerman Mountain, or about 70 miles north of the Porcupine, within 2 miles of Tub Mountain.

West of Old Crow River.—As has been already briefly stated, the Carboniferous rocks west of upper Old Crow River appear to make up all the bedrock of at least the eastern half of the timbered upland previously described with the exception of Yankee Ridge. The several low ridges that extend for about 5 miles southward from Yankee Ridge to Casey Fork show practically no definite exposures of bedrock except on their highest parts, and even there the rocks have been considerably disrupted by weathering and are more or less covered by vegetation; consequently wide intervals, about which no information can be gathered and only inferences can be made, occur between outcrops. The few exposures observed on these hilltops are of a bluish-gray semicrystalline limestone that contains fossil corals and brachiopods of Carboniferous age.

About 6 miles west of Old Crow River and 4½ miles southwest of Yankee Ridge stands the highest point on this upland, a bare cone named Horse Hill, whose elevation is several hundred feet greater than that of all the other hills within 6 or 7 miles. Horse Hill is made up of rocks which contain fossils of Carboniferous age, but which differ somewhat lithologically from the limestones of the low ridges to the east and northeast. It may be that there are two formations of Carboniferous age in this area. The rocks of Horse Hill consist of sandy and limy shales and impure limestones, most of which are very thinly bedded. The beds along its lower eastern slopes are of a yellowish-buff sandy rock with conspicuous reddish banding and some layers or streaks of pyrite, usually altered to hematite. The coloration is no doubt due to the iron content of some of the beds. Above the buff, sandy beds is a considerable thickness of more massive tough dark-gray beds alternating with softer layers.

This formation seems to extend southeast and northwest. Rocks of similar lithologic appearance were seen along the base of the mountains that lie south of Casey Fork just west of the boundary, or about 12 miles southeast of Horse Hill; but as they have not yet been shown to contain fossils and as continuity with the rocks of Horse Hill can not be traced across the alluvium-filled valley of Casey Fork they are not known to be the same.

North of Ammerman Mountain.—The Carboniferous rocks that extend northward along the one hundred and forty-first meridian for nearly 40 miles north of Ammerman Mountain appear to make up, with the exception of two known occurrences of Triassic rooks, practically all of the country rock in this distance. They are known to extend 5 or 6 miles east and west from the meridian in a number of places, and they appear to be very widely distributed in this region. In general the rocks of this belt are lithologically similar throughout, being composed for the most part of massive gray, drab, blue, and black limestones, some members of which contain a large proportion of chert. In texture they vary from fine and close grained to coarsely crystalline. The series no doubt is made up of several formations, but these have not yet been distinguished. Apparently enough fossiliferous members have been found to justify at least the provisional grouping of all these rocks in one series. So far no depositional breaks have been recognized, but severe folding and probably faulting seem to be indicated. Some of the folding, especially in the northern part of the belt, appears to be of the overturned type. It is not improbable that overthrust faulting has also occurred. It is tentatively suggested that to such faulting are due the involved positions of the Upper Triassic rocks with relation to the normally underlying Carboniferous rocks of this belt.

The southernmost outlier of this Carboniferous series caps a broad-topped ridge, about 2 miles west of the boundary, that extends northward about 3 miles from Ammerman Mountain. About a mile of the phyllite and slate bedrock that flanks the north side of Ammerman Mountain intervenes between these limestones and the quartzites of the mountain. East of the boundary about 4 miles of the phyllite and slate bedrock lies between the quartzites of Ammerman Mountain and the Carboniferous limestones. The contact of the limestones with the slates and phyllites along their southern border is not visible in this vicinity, because of a heavy mantle of rock débris and moss. It appears, however, that the limestones overlie and are structurally unconformable with the more metamorphosed, supposedly pre-Ordovician quartzite, phyllite, and slate series of Ammerman Mountain. From their southern border northward for 12 miles to the southern slopes of the wide valley of upper Firth River the limestones make up the bedrock of a broad, moderately mountainous highland that forms the watershed between the headwater basin of the Old Crow on the west and that of Thomas Creek, a long northern headwater tributary of the Old Crow, on the east. Both streams have sources that rise within a few miles of upper Firth River, which flows from west to east across the boundary 17 miles north of Ammerman Mountain. The summits on this broad north-south divide are 2,500 to 2,700 feet in elevation and the saddles connecting them 2,000 to 2,400 feet. In general this highland belt may be said to have an average height of about 2,500 feet.

No very good fossiliferous beds have been found in the limestones between Firth River and Ammerman Mountain, but fragmentary remains indicate the Carboniferous age of the rocks.

Firth River basin.—About 18 miles north of Ammerman Mountain the boundary crosses the gravel-filled valley basin of upper Firth River a few miles east of the junction of the three large valleys of its chief headwaters, which rise in a group of high mountains 30 to 40 miles to the west and northwest. This basin has been named on the maps the Valley of Three Rivers. It is 3 to 4 miles wide from north to south and about 8 miles from east to west. Its elevation above sea level is about 1,700 feet. Firth River flows from this high interior valley basin in a general direction a little east of north for 75 miles and discharges into the Arctic Ocean about 25 miles east of the one hundred and forty-first meridian. Its descent to the coastal plain is said to occur mostly through a series of canyons 50 or 60 miles above its mouth.

The larger part of the Firth River basin west of the main river and north of its upper valley is occupied by moderately rugged mountains. The one hundred and forty-first meridian passes over a number of irregular ridges, most of which are more than 3,000 feet high, with high peaks rising to elevations of 4,000 to 5,000 feet. Practically all these mountains, so far as examined, for 25 miles north from the boundary at the Valley of Three Rivers, are made up of limestones of various kinds. Some of these limestones contain Carboniferous fossils and, so far as has been distinguished, all except an Upper Triassic formation (described below) belong to a single Carboniferous series. This Carboniferous limestone series seems to terminate along its northern border in unconformable contact with a series of semimetamorphosed quartzites, phyllites, and slates which closely resemble the similar rocks of Ammerman Mountain and are supposed to be of pre-Ordovician age.

TRIASSIC ROCKS.

Several miles south of the northern border of the Carboniferous rocks just described and about 8 miles west of the one hundred and forty-first meridian marine fossils of Upper Triassic age occur in a formation that is made up largely of black shales and impure thin-bedded shaly limestones, but possibly contains some massive limestones. This formation appears to be involved by profound folding and possibly faulting with the intimately associated Carboniferous limestones in such a manner that its position is now apparently beneath the older formations. At least, this is the tentative view now held as a result of the preliminary examination made in 1911.

Similar Upper Triassic rocks are situated approximately 1 mile west of the one hundred and forty-first meridian about 5 miles south of the upper Firth River basin or Valley of Three Rivers. These are likewise associated with the massive Carboniferous limestone series and in the field examination of 1911 were considered possibly to underlie them. The outcrops from which the Triassic fossils were obtained are poorly exposed. Beds of impure flaggy limestone interbedded with sandy shales, which have not been observed in contact with the older series. They lie in the wide valley head of one of the extreme northern headwaters of Old Crow River. These rocks were not recognized elsewhere in this basin by fossils, but some black limy shales of somewhat similar appearance occur along the foot of the eastern slopes of the basin several miles to the southwest.

MESOZOIC (?) ROCKS.

Between the belt of schists whose northern border is 37 miles north of Porcupine River and the valley of Casey Fork, about 15 miles farther north, extends a group of mountains whose summits are about 3,000 feet above sea level and are 2 to 5 miles west of the boundary, which passes across their eastern flanks. These mountains are made up almost entirely of massively bedded quartzites with a small amount of interbedded shale slates and several beds of conglomerate, one of which seems to occupy a position at or near the base. The quartzites are for the most part fine grained, hard, and dense, and have a sugar-like fracture. They are predominantly white or light gray in color, but also show varicolored shades of pink, red, and brown. The shale beds are darker colored and are somewhat metamorphosed, showing slaty cleavage. The conglomerates, so far as observed, are made up of hard pebbles of white quartzite and white vein quartz in a coarse gritty matrix. The pebbles of quartz may well have been derived from veins which occur in the schists to the south, but no pebbles of schist were noted; neither were there seen any granite pebbles which might have come from the granites farther south, nor limestone pebbles that might have been derived from the Carboniferous formations north of Casey Fork. More extended examination, however, may disclose pebbles derived from these presumably older rocks. Only a few small and poorly exposed outcrops of conglomerate have been observed, and no statement of their thickness, extent, or development as a whole can be given. In some places the conglomerate contains a large percentage of matrix material in which the pebbles are somewhat separated or scattered, but in other outcrops it is composed of a more compact mass of pebbles with only a small percentage of finer matrix.

If it were not for the beds of conglomerate, the much smaller development of the beds of shale slate, and the more massive bedding of the quartzites, this series would differ little from the pre-Ordovician series along Porcupine River to the south, or from the less metamorphosed phases of the schists farther south, which are now considered to be altered equivalents of the quartzite, phyllite, and slate series of Porcupine River.

Because of the conglomerate member at or near the base of these rocks, their apparently unconformable position upon the supposedly schistose equivalents of the pre-Ordovician quartzite, phyllite, and slate series along their southern border, their marked dissimilarity to any of the known Paleozoic series which are well developed to the southwest, and the fact that the uppermost Paleozoic rocks (the Carboniferous) lie just north of Casey Fork, these rocks between Casey Fork and the Porcupine are considered to be possibly of Mesozoic age and to represent the apparently somewhat similar series that has been observed by the Canadian geologists to occupy considerable areas from 30 to 100 miles south of Porcupine River, where rocks of this general character, with a conglomerate member at their base, unconformably overlie formations of Ordovician, Silurian, and Carboniferous age.

As already suggested (p. 303) it seems very probable that two somewhat similar series, of widely different geologic age, the predominant rocks of which are white quartzites, may occur in this general region, the older being pre-Ordovician and the younger Mesozoic, and that under some of the conditions of their occurrence in proximity to each other they may be more or less confused.

THE ALATNA-NOATAK REGION.

By Philip S. Smith.

INTRODUCTION.

In the open season of 1911 a party from the Geological Survey visited the Alatna-Noatak region (see Pl. XV) and obtained the information concerning the mineral resources of the region presented in this report. A more complete account of the geology, based on a more thorough examination of the notes and specimens collected, is in preparation, but will not be published for a year or more. No productive mining has yet been done in the region, so that deductions concerning the future of this industry must be based mainly upon analogies with known productive camps elsewhere in northwestern Alaska.

GEOGRAPHY.

RELIEF AND DRAINAGE.

Alaska has been divided by Hayes, Brooks, and others into four large geographic provinces which, from south to north, have been called the Pacific Mountain system, the Central Plateau region, the Rocky Mountain region, and the Arctic Slope region. The Alatna-Noatak region lies almost entirely within the limits of the Rocky Mountain system. Although mainly of mountainous topography the region is so diversified by highlands and lowlands that in places the reason for assigning the country to the Rocky Mountain system would not be evident to a traveler contemplating only the immediate details without regard to their larger relations.

The Alatna River valley has a general northwest-southeast trend. It is about 140 miles long and is somewhat narrow in proportion to its length. This basin consists of two topographically rather distinct parts—a southern, carved in relatively weak rocks, having subdued topographic features, and a northern, carved in more resistant rocks, characterized by rugged mountains. In the southern part the valley floor is a wide gravel-filled lowland in which the stream, from one-quarter to one-eighth mile in width, meanders extensively. Here and there rocks outcrop on either side of the river, but although the current is too strong to allow rowing there are no obstructions to navigation for shallow-draught boats.

The mountain province extends northward from Helpmejack Creek. In the part of its course that lies in this province the river flows on a flood plain that ranges in width from 1½ miles in the southern part to only a few feet in the northern, the stream itself reaching in places a maximum width of one-eighth mile. For 40 miles north of Helpmejack Creek the course of the river is very sinuous, although the valley is straight. Farther up the stream meanders less and the course of the valley is nearly straight. Under ordinary conditions the river is navigable by canoes as far as camp July 23, but in its upper 25 miles its gradient is so steep that it is an almost continuous succession of riffles. Several rather large tributaries that drain the unexplored country to the east and west enter the Alatna in this province. A stream in one of these valleys in the central part of the mountainous region was ascended to its head and was found to have its source in several small glaciers. None of the glaciers was more than 2 miles long, but all of them appear to be the shrunken remnants of more extensive glaciers that once occupied much of the Alatna Valley.

The slopes from the streams to the top of the ridges are everywhere steep; in the smaller, newer valleys they are the result of normal erosion, but many of the slopes of the larger valleys have been oversteepened by glaciation. The detritus that has fallen from the cliffs above or has been deposited by agencies formerly operative is a prominent feature on the lower slopes. Higher on the hillsides this mantle becomes thinner until on the steeper slopes exposures of bedrock dominate. The ridges are narrow and range in elevation from 4,000 to 8,000 feet. The crests are undergoing rapid degradation by erosion, so that they nowhere preserve any considerable area of an earlier topography.

The Noatak Valley in the main trends east and west, though in its lower part it makes an abrupt bend and has a nearly north-south course. One of the most notable features of the region adjacent to the Noatak is the succession of highlands and lowlands through which the river flows. At the headwaters of the Noatak there is the same mountainous region as at the head of the Alatna. This province is about 75 miles long and is characterized by lofty mountains, many small glaciers, and steep slopes. The river, which is about 300 feet wide, has cut a meandering channel through ancient gravels in a flood plain that is about 2 miles wide at its western end. Farther downstream the mountains gradually recede from the river, which in this lower stretch flows through a lowland 70 miles long and 10 to 35

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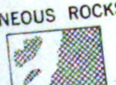
IGNEOUS ROCKS



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Paleozoic to post-Mesozoic in age

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miles wide. Still farther downstream the mountains on the north and south again converge, and the river flows in a rather narrow valley through a range of hills from 3,000 to 4,000 feet high. This mountainous topography extends along the river for about 60 miles. The western end of this part of the river valley is marked by a narrow canyon, 600 to 800 feet deep, with rock walls on both sides of the stream. Below this canyon the hills again recede, and the river flows through another lowland, 50 miles long and 20 to 30 miles wide. This nearly flat lowland rises only a few hundred feet above the river and bears innumerable lakes on its surface. On the south this lowland abruptly terminates against a range of hills, 1,500 to 2,000 feet high, which form another distinct topographic province. The Noatak cuts through this range in a narrow gorge, 400 to 600 feet deep, the bedrock jutting into the river in fantastic pinnacles. These hills trend in general east and west and are from 10 to 15 miles wide. South of the hills the country near the river is low, in few places rising more than 200 feet above the sea and at its southern margin being submerged by the waters of Kotzebue Sound during periods of high water.

Throughout its course as far as camp July 28 the Noatak is navigable by canoes, and in this distance has few dangerous places. In the upper part of its course the stream has washed out of the gravel deposits through which it flows many large bowlders that make riffles which require careful watch. In the lowland north of the mountains near the mouth the stream splits up into so many channels that the depth of water in any one is not always sufficient to float a boat and therefore the course must be selected with care. Except at the very mouth of the river the current is so strong that little or no progress can be made upstream by rowing or sailing. Good tracking can usually be found, though the numerous meanders, with cut banks, make frequent crossing from side to side necessary.

Passes from the Noatak to the Colville on the north, to the Alatna on the east, and to the Kobuk on the south are known and have been traversed. One pass to the Colville lies between longitude 156° and 157°. (See map, Pl. XV.) At this place the divide is about 2,000 feet above and 7 miles distant from the Noatak, and floating water could probably be reached by a portage of not over 13 miles. Other passes, by way of Aneyuk River, may also occur, but they have not been examined. The pass used by the Survey expedition in crossing from Alatna River to the Noatak is about 13 miles in an air line between floating water, and the divide was 1,000 feet high, with small lakes on the summit. Another pass, farther up the Noatak, leads into a stream joining the Alatna about 8 miles below the one just described. It is much longer and more difficult and therefore not to be recommended. Opposite the higher pass of the Noatak there is a pass to the upper Reed River of the Kobuk drainage and another pass to the same stream is reported by way of the southern fork of the Noatak. Both of these are steep and difficult, but prospectors say that horses can be taken over them. Natives report that the valley of the large stream coming in from the south about 12 miles above Midas Creek affords a good pass into the Kogoluktuk and is much used by hunting parties. Other passes into the Kobuk farther downstream undoubtedly occur but have not been explored.

CLIMATE.

Instrumental climatic observations have not been made in the Alatna-Noatak region except at Allakakat, at the mouth of Alatna River. The records at this place show that the mean annual temperature is about 15° F. This temperature, however, is probably higher than that of the Alatna-Noatak region as a whole, for the observations were made at an elevation of only 500 feet and nearly a degree farther south than the greater part of the region considered in this report. As a result of this low temperature the country is icebound nearly nine months of the year, so that it is almost impossible to reach it from the United States much before the first of July. Ice in the lakes at the head of the Yukon basin prevents passenger boats from running until nearly the middle of June and from reaching the Alatna much before the first of July. The last boat down the Koyukuk usually leaves the head of the river by the first week in September. Approach to the region by Bering Sea and Kotzebue Sound is even later than by way of the Koyukuk, for Kotzebue Sound usually does not open before the first week or so in July and is likely to close before the end of September.

The annual precipitation at Allakakat is from 10 to 15 inches, which is probably less than that in the region as a whole, for, other things being equal, a low region like that near the recording station does not receive so much precipitation as highlands. Although precipitation in the region is small, much of it comes in summer and the traveler therefore gains an impression that it is greater than the actual amount. In 1911, for instance, 37 out of 64 days were partly rainy, but the rainfall on many of these days consisted of small showers, during which only 0.01 inch of rain fell. Much of the precipitation is snow, which may be expected during practically every month of the year in the hills and the higher mountains. In 1910 snow covered the high hills between the Kobuk and Noatak on July 14, and in 1911 the hills opposite the Alatna-Noatak pass were snow-covered on July 26. The snow that fell during these storms, however, remained only a few days.

POPULATION AND SETTLEMENTS.

The main settlement in the region is at Kotzebue. The Noatak mission, about 50 miles above the mouth of Noatak River, and Allakakat, on the Koyukuk, at the mouth of the Alatna, are the only important villages. Kotzebue is normally the home of a missionary and family, three or four traders, a few boatmen, and a settlement of natives, but after the breakup of the ice in the spring many whites and natives from the neighboring rivers and coast towns congregate there for trading and fishing, and a thousand or more people are camped along the beach or in the town. Mail service is maintained by boat every 10 days during the summer and by dog team once a month during the winter. The nearest telephone station is at Kiwalik, 80 miles to the south, and the nearest telegraph office is at Nome, 200 miles to the southwest. Travelers from Nome can reach Kotzebue in summer by the mail boat, a gasoline schooner. The trip takes about 3 days, as stops are made at way points, and the charges in 1911 were $25 apiece for passengers and $20 a ton for freight. Large vessels from the States can not approach Kotzebue nearer than Cape Blossom, an unprotected headland about 12 miles distant, because the channel is so narrow, crooked, and shallow that it can not be navigated by boats drawing more than 6 feet. Supplies of good quality and in sufficient quantities to meet the demand can be obtained in Kotzebue at prices but little higher than those in Seattle plus the freight charges.

Allakakat is the name of the mission of St. John in the Wilderness, on the Koyukuk, directly opposite the mouth of Alatna River, and Marsans, about a mile downstream, is the trading post. The two together form practically one settlement. At the mission is the missionary and the Government school-teacher and a small settlement of natives; at Marsans is the store and a few natives. The post office is at Bettles, but mail is delivered along the route. In summer communication is by boat and in winter by dog sledge that leaves the Koyukuk near the mission and reaches the Yukon near the mouth of the Tanana. The nearest telegraph station is at the Government post at Fort Gibbon.

The Noatak mission is on the west bank of the Noatak, on a gravel terrace. The settlement consists of a church, schoolhouse, and several well-built cabins belonging to whites and natives. It was practically deserted when visited by the Survey geologists, as the inhabitants spent the summer at Kotzebue. Farther downstream, however, the Survey party passed nearly a score of boats loaded with families bound for their homes at the mission.

It is almost impossible to estimate accurately the population during the summer, for many of the people are away on trading or hunting trips, but it seems fairly certain that less than 100 white people live in the basin of either the Alatna or the Noatak, including the settlements at Allakakat and Kotzebue. The general impression was that the total number of natives in the basin of the Alatna and the Noatak was not over 250. This would indicate that the total population is therefore not more than one person to 50 square miles of territory.

ANIMALS.

At the headwaters of both the Alatna and the Noatak game was fairly plentiful. In the mountains sheep were numerous, and natives make annual hunting trips from distant points to this region. In the low country in the Noatak basin, just west of the mountains, caribou are fairly numerous and are sought not only by natives from farther downstream but by those from the Kobuk as well. In this same region many signs of fox, wolf, and martin were seen along the banks of the river. Bear tracks were particularly plentiful along the bars north and east of the Noatak Mission as far as the canyon and evidently were made by large bears. In the central part of the Alatna Valley evidences of bear were observed, but they were not plentiful and only small black bears were seen. On the lakes and sloughs at the lower part of the Noatak hundreds of ducks, geese, cranes, and other birds were seen. Water birds are reported to be numerous also near the mouth of the Alatna. Flocks of ptarmigan were seen in the central part of the Alatna Valley and in the Noatak Valley near its mouth. From the number of animals seen it is believed that they could be relied on as food by prospectors.

Fish are abundant in the Alatna and probably also in the Noatak. Salmon are reported in the lower Alatna, and some were seen on native drying frames at the Noatak Mission. It is said that they run up as far as the Aneyuk. Most of the Noatak natives, however, go to Kotzebue for salmon fishing, as the fish are better in salt water than they are after they have gone a long distance in fresh water. Grayling and white fish are caught in the Alatna and the Noatak. The members of the 1911 expedition shot several pike in Lake Takahoola in the Alatna River basin. Although few of the streams were actually tried for fish, their similarity to other streams in northwestern Alaska that have been tested leads to the belief that prospectors and travelers could probably get enough fish for ordinary needs in most of them.

VEGETATION.

The vegetation of the Alatna-Noatak region is typically Arctic and sub-Arctic. In the lowlands, near the river, bushes are common, but toward the higher regions the vegetation gradually disappears until, on the steep slopes and the crest of the ridges, even grasses are practically absent. Spruce is found in the Alatna basin to within 3 or 4 miles of the stream leading to the Noatak portage. The trees in the southern part of the basin average 10 to 12 inches in diameter and extend up the slopes to an elevation of 1,000 to 1,500 feet, but the diameter and the elevation of the upper border of the tree zone gradually decreases upstream until at the irregular bend 13 miles below camp July 23 the diameter of the spruce is from 6 to 8 inches, and even the scattered trees do not extend more than 500 to 600 feet above the river. The northern limit of spruce is decidedly abrupt.

In the Noatak Valley the most eastern locality where spruce is found is about 10 miles east of the canyon. At this place spruce 8 inches in diameter appears as a narrow fringe along the well-drained banks of the river. Farther downstream spruce grows almost everywhere in the immediate vicinity of the river down to a point midway between the most southern hills and the mouth of the river, where it is again absent. Over much of the swampy lowland back from the streams, on the hill slopes, and in the entire area east of the canyon spruce is absent. This absence of timber is a decided handicap to development, for all lumber used in mining or in constructing cabins must be brought into the region.

The grass in the valley is sufficient for pack animals that are traveling, but not sufficient for the permanent pasturage of a large number of animals. Red-top grass is particularly abundant around old cabins and settlements, but although it grows luxuriantly it does not appear to afford as much nourishment as the tougher, smaller, less abundant grasses that grow on the lower hill slopes. Caribou moss is plentiful in the better drained lowland areas, especially those near Aneyuk and Cutler rivers, and on the hill slopes a short distance back from the coast. These hill slopes have been used as the feeding ground for the herd of reindeer that was introduced by the Government and that ranges between the mouth of the Noatak and Cape Kruzenstern.

Berries are generally plentiful in the low areas and form an important part of the local food supply of both the natives and whites. Blueberries, cranberries, currants, and salmon berries are the most abundant, and owing to the cold climate those picked in summer can be kept throughout the year without deterioration. It is said that the natives collect many berries after they have been frozen on the bushes, as they can then be knocked off with sticks and can be more easily cleaned of twigs and leaves.

DESCRIPTIVE GEOLOGY.

DIVISIONS OF THE ROCKS.

Most of the Alatna-Noatak region is still so little known that data are not available for a final statement of its geology, but certain general facts seem to have been sufficiently defined to warrant a general description. The rocks may be divided into three main classes—sediments, igneous rocks, and veins. The sedimentary rocks have been further divided into metamorphic rocks, Paleozoic sediments, Mesozoic and Tertiary rocks, and unconsolidated deposits. The igneous rocks have been divided into the metamorphic and nonmetamorphic rocks, and the veins might also be similarly grouped. Each of the larger groups has been indicated on the geologic map (Pl. XV), with the exception of the veins, which are too small to be shown. The four divisions of the sedimentary rocks have been distinguished by separate patterns, but all the igneous rocks have been shown in a single pattern.

SEDIMENTARY ROCKS.

METAMORPHIC ROCKS.

Metamorphic schists were seen only in the middle and upper parts of the Alatna and in the headwater part of the Noatak. The physical character of these rocks indicates that they are the equivalents of the Nome group of Seward Peninsula. This view is shared by Mendenhall, who studied similar rocks in the Kobuk region, to the south, for he says: "The rocks here described are regarded in a general way equivalent to those described by the writer in a previous paper[1] as the metamorphic series."[2] These rocks are the oldest in the region and have been deformed during at least two periods of mountain building.

Lithologically the metamorphic rocks are quartzose schists containing an abundance of chlorite, some muscovite, practically no biotite, and in many places considerable calcite. In color they range from greenish gray to nearly black. The green color is due to chlorite; the black color is usually caused by carbonaceous material. Here and there the schists have a brown, iron-stained appearance, due to the weathering of the iron sulphides that are disseminated through the rock. These sulphides appear to be of later origin than the schistose structure, for well-developed cubes, entirely unsheared and otherwise undeformed, were found in the schists at many places. The pyrite in the schist occurs not in veins but in cubes that are

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[1] Mendenhall, W. C., Reconnaissance in Norton Bay region, Alaska, in 1900: Special publication U. S. Geol. Survey, 1901, pp. 109–204.

[2] Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska, by way of Dall, Kanuti, Allen, and Kowak rivers: Prof. Paper U. S. Geol. Survey No. 10, 1902, p. 31.

scattered irregularly throughout the rocks. In addition to the disseminated sulphides there are others, closely associated with the quartz veins, which are everywhere numerous in the schist members and are described on pages 18–19.

Although the schists are dominantly quartzose in the lower part of the section they become more calcareous as they approach the thick overlying Paleozoic limestone. The relation of the schists to the overlying limestone has not been satisfactorily demonstrated. The much more deformed character of the schists suggests that an unconformable relation exists between the two groups, but the considerable difference in resistance to dynamic metamorphism of the two rocks makes other interpretations possible. Perhaps the fact that raises strongest doubt as to the unconformity between the schists and the next younger rocks is the notable increase in the calcareous content of the schists toward the top of the section.

No fossils have been found in the schists and consequently paleontologic evidence as to the age of these rocks is wanting. The apparent greater metamorphism and the stratigraphic position of this series warrants its assignment to the lower part of the geologic column. No known fact precludes the assignment of the schists to the early Paleozoic, but, on the other hand, nothing is known that would prevent their assignment to the pre-Paleozoic.

PALEOZOIC ROCKS.

Although it is possible that the metamorphic schists may be Paleozoic, it seems advisable to differentiate as Paleozoic a great thickness of sediments, ranging in lithology from shales and sandstones to limestones, which are much less metamorphosed and seem, on the whole, to be younger than the schists. These rocks have not been nearly so much sheared and metamorphosed, yet they present structures that are by no means simple but that have been so deformed that the series as outlined on the map may include representatives of both higher and lower horizons that have been infolded or infaulted. The delimitation of this series, as a whole, however, marks the areas of less metamorphosed sediments that overlie the schists.

The oldest part of the Paleozoic rocks recognized on Alatna River consists of the very thick limestones that form a belt about 20 miles wide in the central part of the basin. Throughout this distance the rock is almost uninterruptedly a bluish-white limestone, though it includes some dark carbonaceous phases. Many specimens of the limestone show evidence of recrystallization and brecciation. Bedding is usually difficult to discriminate, and although at a distance the structure appears to be relatively simple, close examination shows that it is complex. The general trend of this limestone is east-west, but the dip changes from north to south so frequently that numerous reduplications must occur.

In the Alatna River region no paleontologic evidence as to the age of this limestone was obtained, but a similar series of limestones on John River, which Schrader called the Skagit formation, yielded fossils that indicated that the rocks were not older than upper Silurian and not younger than lower Carboniferous.[1]

This is probably the same limestone that was seen on the headwaters of the Noatak and that forms some of the high, rugged peaks in the eastern part of the divide between Noatak and Kobuk rivers. It is also probably present near the gorge of the Noatak and in the hills near the mouth of the river, but fossils were not found in it at these places, and the correlation rests mainly upon the stratigraphic position and lithologic similarity.

In the vicinity of the Noatak canyon a dolomite forms part of the country rock south of the river. The fossils from this place were not diagnostic, but the dolomitic composition of the rock suggests correlation with the only dolomite horizon known in Seward Peninsula, which is of upper Silurian age, is widespread throughout Alaska, and is everywhere dolomitic. Dolomite is also exposed in the lower gorge of the Noatak where the stream crosses the range near the coast. It is underlain by calcareous schists whose contact with the dolomite is but poorly exposed. This dolomite is a compact, rather dense rock showing few of the solution markings that are common on the other limestones. It is usually whiter than the limestones and rarely contains fossils. At many localities it is brecciated, and at the outcrops near the canyon, where it occurs near intrusives, it exhibits some cherty phases.

Another important part of the series which is included here with the Paleozoic rocks but which on subsequent study will probably be differentiated from the other members is the sandstone, quartzite, and limestone series in the central part of the Noatak basin, from the western part of the lowland near Aneyuk River westward to the canyon. These rocks are less metamorphosed than the other Paleozoic rocks, but have been much deformed and closely appressed, and show overturned folds and thrust faults. Although cleavage and jointing have been produced by the forces to which these rocks have been subjected, the bedding has in few places been entirely obliterated, and as a result most outcrops clearly show both bedding and cleavage.

The rocks are dark grayish to green on fresh exposures, at a distance appearing almost as light as some of the limestones. Some

[1] Schrader, F. C., A reconnaissance in northern Alaska across the Rocky Mountains, along Koyukuk, John, Anaktuvuk, and Colville rivers, and the Arctic coast to Cape Lisburne, in 1901; Prof. Paper U. S. Geol. Survey No. 20, 1904, p. 57.

shales that form part of this series are nearly coal black and others are light green. The prevailing tone, however, is dark, and the rocks can not be readily recognized at any great distance either by their color or by their physical characters. Generally speaking, however, the rocks are hard and form many of the higher hills in the area in which they occur.

Fossils have been collected from these rocks at several places, and the paleontologic determinations show that they are Carboniferous, probably Mississippian. This determination is of interest, as it shows that the rocks reported by Collier[1] in the Cape Lisburne region and by Schrader in the John River basin also occur in the intervening country.

Some shales and slates have been provisionally assigned to the Paleozoic rocks because of their interrelation with known fossil-bearing limestones and other rocks. These shales and slates differ from the schists in that they are not so highly metamorphosed and their original structures are better preserved. The thickest series of these rocks examined was found in the vicinity of Midas Creek. They are dark green in color, rather fine grained, and have well-developed slaty cleavage. They contain many small faults and probably some larger ones, which escaped detection because faulting brought like rocks into juxtaposition. However, even with due allowance for reduplication through faulting, a thickness of several thousand feet must be assigned to this division.

MESOZOIC AND TERTIARY ROCKS.

It is highly probable that some members which might on more detailed study be placed elsewhere have here been included in the Paleozoic. In fact, it is by no means certain that there was a decided stratigraphic break at the top of the Paleozoic, and therefore correlations based mainly on long-range observations and general stratigraphic sequence would fail to note faunal breaks unassociated with marked lithologic or structural discordances. Although some younger sediments may have been inadvertently included in the Paleozoic, the main representatives of the Mesozoic to which attention will be directed in this section are the Cretaceous sandstones and associated sediments, recognized in the region under discussion only on the lower part of Alatna River.

These rocks are entirely unmetamorphosed, although compact, well indurated, and so deformed that dips of 45° or more are common. A few thin conglomerates appear in the section, but the series as a whole consists of dark greenish-gray sandstones, with thin shaly beds.

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[1] Collier, A. J., Geology and coal resources of the Cape Lisburne region, Alaska: Bull. U. S. Geol. Survey No. 278, 1906.

The conglomerate phase becomes more pronounced toward the border of the basin, and Mendenhall notes that about the mouth of Helpmejack Creek, near the former Cretaceous shore line, the basal portion of the formation consists almost exclusively of conglomerate containing pebbles of the older formations to the north.

Although this series of rocks has been classified as Mesozoic by Mendenhall and as Cretaceous(?) by Schrader, both of whom called it the Bergman series, its age was not determined on paleontologic evidence. Mendenhall[1] states that it contains indistinct plant remains, but it has yielded no determinable fossils. The rocks are certainly younger than the Paleozoic rocks to the north and their greater induration shows that they are probably older than the Tertiary deposits of Dall River. Their lithologic similarity to the rocks extending from Nulato to Seward Peninsula, specimens of which, collected by the writer in 1909, yielded Cretaceous fossils, indicates that they are of Mesozoic age.

UNCONSOLIDATED DEPOSITS.

The purpose of the present paper is not so much to describe all the different deposits examined as to point out the general types recognized. Three main types of unconsolidated deposits were distinguished—marine, glacial, and stream gravels. All three are shown in one pattern on the map (Pl. XV).

MARINE GRAVELS.

The recognized marine deposits occur mainly along the Arctic seacoast and the lower portion of the Noatak. These deposits are only in part marine, for in places there were alternations of marine and fluviatile action, such as are now seen in the delta of the Noatak. The deposits at such places therefore present features characteristic of both agencies. None of the marine deposits have been prospected and consequently the history of the gravels has not been made out, but they have probably accumulated in the same manner as the coastal plain gravels in parts of Seward Peninsula.

No sections of the typical marine gravels along this part of the Arctic coast have been examined, and it is not definitely known whether or not the deposits are permanently frozen. From analogy with similar deposits elsewhere it is believed that the more recent marine gravels are not frozen, but that the older ones, which occur at some elevation above the sea, are probably permanently frozen. The presence or absence of permanent frost in the ground has a decided influence on the cost and method of mining, so that a determination of the physical character of the gravels is economically important.

[1] Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska, by way of Dall, Kanuti, Allen, and Kowak rivers: Prof. Paper U. S. Geol. Survey No. 10, 1902, p. 40.

GLACIAL DEPOSITS.

The glacial deposits may be roughly divided into two main classes—those of distinct ice-laid origin and those which have been in part handled by glaciers but whose dominant features were determined by running water. Deposits of the first class are relatively uncommon and even the most distinctive may merge into the second class, so that no sharp line of demarcation between them can be drawn.

The distinctly ice-laid deposits are most notable in the mountain valleys near the heads of the Alatna and Noatak. Even at the present time there are small glaciers in the highlands in this part of the region, and they are transporting and depositing débris and forming glacial moraines. In the past, however, these glaciers were much more extensive and formed deposits that may still be recognized. It is not yet possible to state the limit of these ancient glaciers because their deposits merge into deposits of glacio-fluviatile origin and, furthermore, in the time that has elapsed since the glaciers reached their maximum extent their deposits have been so much modified by later processes that their character or origin has been obscured.

Glacio-fluviatile gravels are widespread throughout both the Alatna and Noatak valleys. In the Alatna Valley ice-transported blocks have been found on divides 2,000 feet above the present valleys and at least 5 miles from their nearest outcrop. Washed gravels up to an elevation of 2,300 feet above the Alatna were noted on the hillsides below Lake Takahoola. Not only are there high-level glacio-fluviatile deposits but numerous outwash deposits, lying not more than 100 to 200 feet above the river, formed by the same agency, were also found. The glaciation in the Alatna Valley, however, was distinctly of the valley glacier type. No evidence of regional glaciation was observed and the known facts preclude the probability of such glaciation.

In the Noatak Valley glacio-fluviatile deposits are even more conspicuous and widespread. Although it was not possible to determine the elevation of the upper limit of outwash deposits at many places, gravel was observed to an elevation of 900 feet above the river near Midas Creek, to an elevation of 800 feet above the river at the canyon, and to at least 600 feet above the river west of camp August 23. These high-level deposits, however, are relatively thin and have but slight topographic expression. The lower outwash deposits, on the other hand, form large areas and are prominent features. They rise from 100 to 200 feet above the river and the river flows through them in narrow gorges, exposing good sections. Much of the material thus exposed exhibits water rounding and many of the sections show stratification. That these deposits are not merely gravels of the former Noatak is shown by the occurrence in them of many large angular blocks of rock derived from regions relatively remote from the places where they now occur. Some of these bowlders are 10 feet or more in longest dimension. These large bowlders are washed out from the gravel deposits through which the river flows and they form rapids, so that they are particularly conspicuous.

The surface of these outwash deposits is not smooth and even but is marked by depressions, some of which are occupied by lakes of irregular form and extent, which do not simulate abandoned river channels or other normal river features. Evidence of drainage modifications, such as is seen in the neighborhood of the canyon, show that blocking of the normal discharge must have been effected by an agent that has subsequently disappeared—probably ice. This obstruction may have formed lakes in which deposits were laid down. In other words, the late Pleistocene history of the region shows that a complex series of deposits was formed under a variety of conditions and by different processes. The material of all these deposits, however, was acquired mainly by the action of ice, and, although handled by ice or water, or both, it was not so much disintegrated, decomposed, and sorted as if it had been carried to its present position by running water alone.

STREAM GRAVELS.

Little need be said here of the gravels that are distinctly stream deposits. The stream gravels merge, on the one hand, into the marine gravels and, on the other, into glacio-fluviatile deposits. The deposits that are solely of stream origin show by the form, size, arrangement, and lithology of the pebbles their difference from the glacio-fluviatile deposits. The stream-laid gravels, however, are found chiefly in the smaller streams and, except where they are preserved beneath outwash material in protected places, are relatively uncommon in the valleys of the larger streams.

Many of the present streams have been developed in and are eroding the unconsolidated deposits of the preceding geologic period and are therefore really forming typical stream deposits. To the placer miner, however, these do not represent the ordinary single-cycle streams or even streams reworking former stream deposits or benches, for the distribution of the valuable minerals would be far different had they been deposited by one process. It is therefore believed that deposits formed solely by streams are to be sought only in the smaller valleys or in the larger ones where other erosion has been least active. In either class the deposits are likely to be small or discontinuous.

IGNEOUS ROCKS.

GRANITES.

For the purpose of this report the igneous rocks of the region may be divided into two main groups, the granitic and the basaltic. Igneous rocks of the granitic type were recognized in place only in the central part of the Alatna Valley and 20 to 30 miles westward, at the head of the Noatak. There are probably large areas of granite in the unexplored hills between the Kobuk and the Noatak on the south and, possibly, between the Noatak and Colville on the north. The granitic rocks show many phases, ranging from massive, even-grained, moderately fine textured granite to porphyritic gneissoid rocks. The granites cut the limestone of the central Alatna Valley, but contacts were not examined in detail. Granite pebbles found in the basal Cretaceous conglomerate indicate the upper age limit of the granitic intrusives, and if analogy with Seward Peninsula granite intrusives that cut fossiliferous limestones may be accepted, the lower limit of the intrusive period is Carboniferous. The determination thus reached roughly fixes the period of the intrusion between Carboniferous and Cretaceous time.

Topographically the granites form high, rugged peaks having strong relief, which is in a measure due to the character of the rock but is also produced by the glacial sculpturing that centered in the high ranges where the granites occur. The granites have not been closely studied petrographically, so that their mineral composition and lithologic character have not been determined. It is significant, however, that they contain few sulphides and that the surrounding rocks show no pronounced mineralization which was coincident with their intrusion.

BASALTIC ROCKS.

Basaltic igneous rocks were seen at several places in the Alatna-Noatak region. These rocks may be divided into two main groups—an older and a more recent one. The rocks of the older group can not yet be described mineralogically for the lack of microscopic study but are greenstones of medium fine texture, dark-green color, and relatively weak resistance to weathering. It is highly probable that there was more than one period of greenstone intrusion, as certain dikes appear to have been much metamorphosed and others are practically unaffected. This difference, however, may be explained by assuming that the metamorphism affected only rocks near to planes or zones of movement and that the unmetamorphosed greenstones were remote from such planes.

Most of the exposures of greenstone show a compact, rather dense rock. Here and there an amygdaloidal phase was seen which seems to correspond to the igneous greenstone schists which Schrader found in the Totsen group on John River and interpreted as old basaltic flows. Although some of these greenstones may have been of extrusive origin the evidence tends to show that the greenstones occur mainly as intrusive dikes and sills.

The later basic igneous rocks were seen in place mainly in the vicinity of the canyon of the Noatak. They occur as large stocklike intrusions from which apophyses extend into the adjacent sedimentary rocks. In the immediate contact the igneous rocks have locally metamorphosed the other rocks, but the effect does not seem to be widespread. Near the lower end of the canyon some ellipsoidal basalt appears to mark a special phase of this intrusion. The only minerals recognized in hand specimens were plagioclase feldspar and ferromagnesian minerals.

Topographically the later basic igneous rocks weather into numerous pinnacles. They are irregularly distributed and lack the definite trend usual in stratified rocks. Their color is dark, but at a distance is not distinctive enough to differentiate them from the other rocks of the region, except the limestone.

The age of the intrusion of these rocks was not definitely determined. They cut the Carboniferous rocks and are therefore younger than that series, but the absence of later rocks in the neighborhood of the intrusions prevents closer correlation. From analogy with other regions it is believed that they are earlier than the Upper Cretaceous, but final statement of their age must await fuller investigation. The later basic igneous rocks are apparently in no way connected with the recent basaltic flows of Seward Peninsula and parts of the Yukon drainage basin but are much older and are essentially intrusive rather than effusive.

In addition to the two types of basaltic igneous rock that were seen in place, float of a coarsely granular hornblendic rock was found in the stream and bench gravels at several points along Noatak River. Some of the hornblende needles are over an inch long and form nearly three-fourths of the entire rock. Float of this sort was found near Aneyuk River and at the canyon, so that in the hills away from the river there are undoubtedly other intrusives, the extent and relations of which are not yet determined.

VEINS.

The veins of the region may be roughly divided into two main types—quartz and calcite veins. The quartz veins are the most abundant and are economically the most important. They are further divisible into many smaller groups, based on differences in age or in mineralogic composition. How many periods of quartz vein formations there were is not known, but at least two have been recognized. The older veins appear to have been formed before the metamorphism of the lower schists and to have been afterwards deformed and sheared. As a result, they are much distorted and form discontinuous strings and lenses. These veins lack almost any other visible filling than quartz. Assays of similar veins in Seward Peninsula suggest that at least some of the veins in the Alatna-Noatak region carry gold. Although the gold tenor and the discontinuity of these veins preclude their being mined, they were probably the main sources of the placer gold in the streams.

These deformed and shattered quartz veins appear to be limited to the older schists, and if they are so restricted this fact will help to indicate where placers may be found.

The quartz veins that were formed after the main period of metamorphism are widespread. They occur in all the groups studied in this field, but are seldom found in the limestone, except near its contact with other rocks. The later quartz veins are mostly gash veins, formed by the fracturing of the rocks through deformation. The quartz in these veins seems to have migrated from the adjacent rocks, under such conditions that the chances of finding any economically valuable minerals in them are not good. None of these veins have been sampled, so their presumptive value is based mainly on the theoretical interpretation of the mode of filling. Sulphides or metallic minerals have not been recognized in veins of this type.

There are, however, other later quartz veins which seem to have had a deep-seated source and probably contain minerals of economic importance. Although these veins have not been so thoroughly metamorphosed as the older veins, they are more or less faulted and discontinuous. Many, however, show the typical comb structure usual in veins which have not been completely recrystallized. Some of these veins contain sulphides in small amounts, and if the evidence afforded by veins of similar type in Seward Peninsula is applicable to veins in this region, they may carry free gold. These veins were not large enough to warrant exploitation as lodes, but where processes of concentration have been effective they undoubtedly contribute some gold to placers.

Although veins of this type have been found at many places throughout the Alatna-Noatak region, they are more abundant in the schistose rocks than in the overlying limestones. In fact, it is relatively unusual to find quartz veins extending far into the limestones. Their absence is probably due not to the fact that the higher rocks were deposited after the formation of the veins but rather to the fact that extensive fissures could not be maintained in a rock that flows so easily under pressure as a limestone.

Calcite veins are confined almost exclusively to the limestone areas and rarely extend into the schists for more than a short distance from the contact. As a rule, they are similar to the quartz veins of the gash type and, like those veins, are believed to have been formed by the filling of fissures produced during the deformation of the region, their material being derived from the rock in their immediate vicinity. Calcite is practically the only mineral filling these veins. A few contain also a small amount of quartz but no sulphides. One calcite vein in Seward Peninsula carries free gold, but it is the only one of its kind known in the region. It is believed, therefore, that the calcite veins in the Alatna-Noatak region not only do not warrant exploitation as lodes but also did not afford material for productive placers.

So far no connection has been traced between any of the veins of these types and the igneous intrusions. The absence of definite proof, however, does not preclude the possibility of such a relation, but this can be determined only by more detailed investigation. The source of the vein filling in the two types of veins known to carry minerals of commercial value—the metamorphic quartz veins and the younger quartz fissure veins—is yet undetermined. The greenstones and associated schists show some sulphide mineralization of a disseminated type that may have been brought in during or immediately after the intrusion of this rock. The amount of mineralization from this source, however, seems to have been relatively slight. Sulphides are found also in the gabbro at the Noatak Canyon but only in grains scattered throughout the rock, and their mineralizing effect does not seem to have extended far beyond the contact. In the regions occupied by granite a very little disseminated sulphide mineralization was observed, but it was so slight that the rocks show practically no iron stains on weathered surfaces.

ECONOMIC GEOLOGY.

The region covered by this report is practically unprospected for metalliferous resources. A few prospectors have passed rapidly through certain parts, but have done no permanent development work. Probably not more than a hundred prospectors have traversed the 10,000 square miles covered by the Survey party in 1911, and it is doubtful whether at present there are half a dozen white men even intermittently engaged in prospecting in the region. Prospecting has been done in two main regions, the Alatna Valley and the Noatak Valley.

ALATNA RIVER REGION.

During the excitement of 1898 many prospectors reached the Kobuk and Koyukuk valleys and some disappointed ones essayed the Alatna. They found little of value, however, and some strikes elsewhere caused them to abandon their holdings and leave for more promising camps. In the Alatna Valley, where the schists form the bedrock, a little placer gold was found, and some sulphide-bearing veins were staked and held for many years awaiting a boom. Practically no work was done to open up the leads, and when the place was visited in 1911 a few insignificant pits driven on quartz stringers were the only visible traces of this early work.

In this same general belt of rocks, but farther east, on a small tributary of Malemute River called Mecklenburg Creek, a prospector reports having found colors of gold in the creek gravels. This locality was not visited, and nothing of importance was learned of the occurrence and no workable deposits have been developed. The gold is in small particles, rarely flaky, and is of a reddish color. No black or rusty gold was reported. In the concentrates magnetite is very abundant, but garnets are only sparingly found.

Some prospecting has also been carried on north of the larger limestone belt, where the dark slates form the country rock. Two prospectors have found sufficient prospects on the Kutuk to cause them to continue exploration, but they have uncovered no gravels of workable value. Work at this place has been carried on only in the shallow gravels of the present stream. It is believed that the gold has been derived from quartz stringers and veins in the slate. Magnetite is abundant in the concentrates, but garnets are practically absent.

Schrader notes that in 1902–3 prospectors reported lode deposits carrying gold and copper in the divide between the Alatna and Noatak. The veins were said to consist essentially of quartz with pyrite and chalcopyrite, but some specimens contained stibnite also. The location of the veins was given very indefinitely and they were not seen in 1911. The fact, however, that the highest assays made by the Survey of the specimens brought out by the prospectors carried less than $2 a ton in gold, as well as the fact that no work has been done recently in the region, shows that the tenor was not sufficient to warrant development under the high costs prevailing in the upper Alatna Valley.

NOATAK RIVER REGION.

Within the Noatak basin gold has been found mainly in the headwater region. Even there, however, only two small areas have been reported to afford placer ground and of these only one, that near Lucky Six Creek, has produced as much as a hundred dollars worth of gold.

INDEFINITELY LOCATED PROSPECTS.

In this region, as in others, reports of lost prospectors finding enormously rich deposits are common. Unfortunately, however, these "finds" can not be located when subsequently sought and the less that is known about them the more their reported value tends to increase. An instance of this sort was the reported discovery of rich gold quartz in the vicinity of Mount Kelley, a hill about 40 miles north of the southward bend of the Noatak, west of the canyon. On attempting to learn about this gold quartz it was found that the locality was stated in an extremely indefinite way, varying from the Igichuk Hills, near the mouth of the river, to the region beyond the Noatak drainage. Gold-bearing quartz may have been found in the Noatak basin, but when its location is given so indefinitely it is not possible to discuss the significance of the reported discovery.

Gold quartz has also been reported in the hills south of the river. a short distance east of the canyon. A prospector from Squirrel River, of the Kobuk basin, with pack horses, spent part of the fall and winter of 1910 in the hills north of Squirrel and Salmon rivers and returned with numerous specimens of quartz, some showing free gold. It was not possible to obtain a description of this trip at first hand and consequently most of the information is indefinite. That the prospector was satisfied with the indication of mineralization is shown by the report that he intends to return and carry on further exploration during the winter of 1911–12. Presumably the country rocks in this region are schists and metamorphic limestones, a ground that has elsewhere generally proved auriferous.

A short distance below the canyon a prospector's cabin, which evidently had been occupied during the previous winter, was visited. A well-worn trail led to a near-by creek, and there were indications that placer prospecting had been in progress. No information concerning the results of this work could be obtained. The geology in the neighborhood does not indicate a near-by source of gold, and the abandonment of the claims suggests that the returns were probably small.

In addition to gold, veins carrying copper and silver ores are also reported in the Noatak region. The silver ore is said to occur on the north side of the Kobuk-Noatak divide, between the Reed and Mauneluk River portages. Nothing was learned of the geology or of the mode of occurrence. The same prospector[1] reports that farther west, on the Noatak side of the pass from Kogoluktuk River, there is a considerable deposit of copper ore, and float of native copper is found in some of the streams. This place is probably in the headwaters of Ipmilouik River, a tributary of the Noatak above Midas Creek. Assays are stated[1] to have shown 9.81 per cent copper and 27.73 per cent lead, but the samples were not representative, being selected specimens. This ore is said to carry also some gold and silver. An assay of ore from what is supposed to be a continuation of the same vein on the Kobuk side of the divide is reported to have

[1] Lloyd, L., unpublished letter.

yielded gold and silver to the value of $1.24 a ton. No work has been done at this place; in fact, it was only discovered and a few samples taken during a hurried trip from the Kobuk to Lucky Six Creek.

LUCKY SIX REGION.

The only place where placer gold has been produced in the Noatak basin is on Lucky Six Creek, a stream joining the Noatak from the east about 12 miles in an air line south of the mouth of the stream heading in the mapped pass to Alatna River. Gold was discovered on this stream in 1898 and from time to time since that date small parties of prospectors have visited the region. This place is so inaccessible, however, that men have spent only a few days there. Not only is the region inaccessible, but it is also difficult to prospect, for lack of timber. It is reported that the planks used for making sluice boxes were whipsawed by hand on Reed River (a tributary of the Kobuk) nearly 30 miles away and hauled by dogs and men to Lucky Six. There were no logs for cabins and consequently the prospectors lived in tents. Although it is now known that spruce can be obtained in the Alatna Valley not more than 12 miles in an air line from the mouth of the creek, yet the labor of transporting lumber even this distance and over a divide at least 1,000 feet high is a great tax on time and energy. Even wood for fuel is scarce and is mainly green alder and willow.

The Lucky Six basin was not surveyed by the Geological Survey party, but the general geology was learned from a study of the stream to the north. This creek, known as Twelvemile Creek, is not more than 10 to 12 miles long. For about half a mile above its mouth the stream meanders on the outwash gravel plain of the main Noatak. Farther up in the hills the stream flows in a narrow, precipitous gorge incised in bedrock and early glacial deposits. In this stretch it is not more than 50 feet wide, even during times of high water, but it is a roaring torrent and its bed is full of huge bowlders that make crossing difficult. Still farther upstream the gradient of the valley decreases, but in the headwater region it again increases.

The Lucky Six region presents many geologic problems, for it contains various groups and kinds of rocks in intricate relations. The larger part of bedrock appears to have been originally a sediment that was subsequently metamorphosed. No large masses of granite were seen in place, though they are reported by prospectors and may exist in the more remote parts of the valley, which were not explored. Limestones form a considerable part of the divide north of Twelvemile Creek and appear to have a general east-west trend. The direction of the structure in the schists, however, is not constant, though it, too, appears to strike east and west and to dip north.

Gravel and partly rounded morainic material extend to an elevation of 1,500 feet above the creek, or 4,000 feet above the sea. It is reported that the gold was found not in this material but in the cracks and crevices of the bedrock in the creek or in the very shallow present-day creek gravels. All the gold is said to be notably coarse, fine flaky pieces being extremely rare. It is described as shaped like "pumpkin seeds," has a reddish color, and assays about $19.20 an ounce.[1]

While the members of the Survey party were in this region in 1911 they met three prospectors who intended spending the winter there. These prospectors had started up Alatna River in a light-draft steamboat with supplies for two years, but about 40 miles above the mouth their boat had been stopped by low water. They therefore decided to make a rapid reconnaissance of the region and await the freeze up before moving their supplies to the Noatak. Consequently the men, with supplies for a month, visited the headwater region and did a little prospecting. Their work was decidedly surficial, and it is understood that the returns were not sufficient to induce the men to hold to their original plan of wintering at this place.

MIDAS CREEK REGION.

From these same prospectors, one of whom had been in the headwater region of the Noatak in 1904, it was learned that placer gold had been obtained on Midas Creek, a tributary from the north joining the main stream near camp August 2. The gold found was reported to be in small particles, all of which were rather well worn. In 1911 the Midas Creek region was again visited by these prospectors and, although their work was superficial, they obtained certain significant results in connection with the geologic observations made by the survey party. It seems that disseminated gold in fine particles was found in the creek and ancient gravels of the Noatak, both north and south of the river, but the gravels of the tributaries of Midas Creek that are derived entirely from the hills north of camp August 2 are not auriferous. The geologic study of the rocks forming these hills indicates that they differ from the metamorphic schists in that they are younger and belong to the group described as the Paleozoic sediments. (See p. 13.) The older rocks that are more likely to be mineralized apparently form the bedrock to the south and underlie those forming the hills in which Midas Creek rises. It is therefore believed that the gold reported to have come from Midas Creek was derived either from the older rocks forming the southern part of the basin or may have come from outwash gravels that have been transported for long distances. These ancient gravels have been recognized up to an elevation of 1,000 feet above the

[1] Lloyd, L., unpublished letter.

mouth of Midas Creek and are believed to have been mainly of glacial origin.

Some prospecting has also been done on the south side of the Noatak opposite Midas Creek. Although it is reported that small colors of gold were found at many places, the abundance of large bowlders in the streams makes prospecting difficult without numerous appliances not easily procurable in this remote region. The bedrock south of the Noatak appears similar to that usually present in gold-bearing regions, although where the limestones form the hills the probability of productive placers seems slight.

CONCLUSIONS REGARDING FUTURE MINING DEVELOPMENT.

The foregoing account of the meager amount of prospecting done in the Alatna-Noatak region shows that conclusions regarding the economic resources of the region must be little more than tentative. It has seemed worth while, however, to state certain observations and the deductions made from them, in order that the available information and theory concerning this little-known region may be at the disposal of the prospector and of the investor.

From what has been said of the general geography it is evident that in a region so remote and so difficult of access, and having a climate so severe the costs of transportation, supplies, and labor are necessarily high and will not materially decrease in the near future. Fish and game may be sufficient for the needs of the prospector for short periods, but there is no adequate local food supply. Even wood for fuel is absent throughout a large part of the region, and timber for use in mining can be procured only in a very restricted area.

Although the commercial conditions will in large measure determine the future development of the Alatna-Noatak region, the present paper deals primarily with geologic facts and emphasis has here been placed upon these. The basis of the first mining development in the region will probably be gold-placer deposits rather than gold lodes or veins of the other metals. It is believed, therefore, that the regions most worthy of prospecting are those in which the metamorphic schists form the country rocks. From the geologic map it may be seen that these rocks are most widely distributed in the country between the Noatak and Kobuk and are almost absent north of the Noatak. The intricate structure of the region and the small scale of the map preclude the representation of all the details, so that the map should be regarded as indicating only the larger geologic features rather than detailed facts having but local significance.

Another geologic fact of importance that requires study is the history of the mineralized region. In the past much of the highland area of the Alatna-Noatak region was covered with snow and ice and many of the valleys were occupied by glaciers, producing conditions under which effective sorting ceased, and whatever detritus existed was swept away by the ice. This material was so mixed with glacially eroded material that there was little or no gravitative separation. On reaching the limits of glaciation the heterogeneous débris was deposited as the ice melted and was distributed by streams. This condition was dominant in the Noatak Valley. In the region where deposition was taking place, however, concentration was not pronounced, for the dominant process was aggradation. As a consequence, although a large amount of material was being dumped by the ice and spread out by the streams, deposits were building up. It should also be noted that the ends of the glaciers were not stationary, but almost continually advanced and retreated, so whatever processes of concentration took place at the front were weakened by being dissipated over a considerable area.

It is therefore believed that in the distinctly glacial deposits extensive rock placers are but little to be expected or would be so irregularly distributed that they would be difficult to mine systematically. Here and there, even in the glaciated areas, possibly some auriferous preglacial material may not have been eroded. Such auriferous deposits, however, would be distinctly local. Some areas of this sort may also be preserved in protected places under the mantle of outwash material. These may be of value, but would be difficult to find and to mine.

With the close of the period of greatest glaciation and accompanying outwash the streams intrenched their courses in the earlier gravels and now flow at many places in rather narrow trenches a hundred or more feet below the surface of these deposits. In this process concentration of these glacio-fluviatile deposits has been effected, but whether it has formed placers can be determined only by prospecting. From the assumed distribution and amount of gold in the outwash deposits it is probable that except under particularly favorable conditions this secondary concentration would not produce very rich placers. The places to be examined by prospectors are those where this later sorting has affected deposits formed by a long-continued stand of the ice in one place or where reconcentration of material from deposits subsequently buried by outwash is actively in progress.

In spite of the difficulties that handicap immediate development and forbid large enterprises dependent on quick returns on their investment, it is believed that there is a large area of unknown country between the Noatak and the Kobuk that warrants investigation by observant prospectors equipped with inexpensive outfits.

NOTES ON MINING IN SEWARD PENINSULA.

By Philip S. Smith.

INTRODUCTION.

No party from the Geological Survey was detailed to carry on investigations in Seward Peninsula during 1911. On returning from the Alatna-Noatak region, however, the writer spent several days in Nome waiting for the steamer. During that time he obtained some notes on the mining industry, and these, supplemented by reports in the technical journals and local papers, and by official correspondence on file in this office, have furnished the basis for the following statements.

PRODUCTION.

The gold production of the peninsula during 1911 was approximately $3,100,000, a decrease of about $400,000 from that of 1910. This falling off is attributable to three main causes—first, a decrease in the amount of winter mining; second, a general decrease in the number of mining operations except dredging; and, third, the handling of low-grade material. All of these causes may be referred more or less directly to the exhaustion of the known rich bonanzas before enterprises capable of handling a large amount of low-grade material cheaply have been established. Practically all placer camps have had a similar history.

In the early years of the development of the ancient beaches at Nome winter mining was important, for labor was cheap, the physical condition of the ground was favorable, and there were many rich areas. Gradually the working out of the richer parts left material of too low a tenor to pay the cost of hoisting and subsequent sluicing in the summer, and consequently this form of mining has decreased. It is estimated that the winter production for 1909–10 was approximately $1,000,000, but during the winter of 1910–11 it dropped to probably about $200,000. That this decrease was more than the decrease in the total of the year was due to the increase in certain of the summer operations, namely, dredging.

In general summer mining work, with the exceptions already noted, fell off considerably, owing to the working out of the known productive areas and the absence of discoveries of new placers that could be mined cheaply by methods not requiring elaborate equipment. No important new strikes were recorded. An attempt to create interest in placers in the extreme eastern part of the peninsula, in the Koyuk basin, was made. Reports from that place, however, do not tend to modify the opinion previously formed—that this region is not particularly promising[1] for extensive placers, though "one-man camps" may be developed there. Dredging, however, became more firmly established and was perhaps the most important feature in the development of the region. Several new dredges were built during the summer, and some of those constructed late in the fall of 1910 first began active work in 1911. The fact that with a lessened production from the winter and other summer mining the total output of gold did not decrease more than $400,000 from that of the previous year is entirely attributable to the increased number of dredges in operation.

The distribution of the gold production among the different Seward Peninsula camps was, in general, similar to that of former years. The Nome region still has the greatest annual output and is far ahead of its nearest competitors, Council and Solomon. Considerable activity in dredge building, however, has been shown by the latter camps, and their production is beginning to show an increase over that of a few years ago, when the bonanza days were past. Owing to a rather wet season, mining was done on several claims in the Kougarok and Fairhaven precincts that have been idle for the last few years. The production from these claims, however, was approximately the same as during previous years. Placer mining was in progress at several other places, but the gold production from these places was relatively small, and was won from previously known deposits that present no unusual features.

TIN DEPOSITS.

Although, as in the past, practically all the mineral production has been derived fom gold placers, interest has been renewed in the tin deposits, and a production of nearly 100 tons of concentrates, worth about $50,000, is reported from tin placers on Buck Creek. This output was obtained by the use of a dredge constructed last summer, so that only a short part of the season was available for mining. It is reported that the dredge commenced running on September 6 and closed by the middle of October. With a full season it should be possible at least to double the production stated above. A general

[1] Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato Inlet region, Alaska: Bull. U. S. Geol. Survey No. 449, 1911, pp. 110, 113.

description of the dredge and a brief account of mining at this place has recently been published by H. G. Peake,[1] who states that 2.85 tons of tin concentrates are obtained each day.

Not only has dredging for placer tin been carried on, but certain lode tin mines near York have been reopened under the superintendence of a competent mining engineer. Although the production was practically negligible, the examination is reported to have shown promising deposits, so that the company proposes to continue development work energetically during next season. No important new features of these lodes are said to have been disclosed by the prospecting. It is understood that it is the company's intention to ship the tin concentrates to Seattle, where they will be smelted.

DREDGING.

As has already been noted, there has been a gradual increase in mining with dredges throughout Seward Peninsula, and a still further growth of this industry is expected. Many of the dredges have been used for prospecting instead of for mining and some have been mishandled, so that nowhere near the theoretical efficiency has been obtained. Experience, however, is being gained and it is a hopeful sign that the big dredge-building firms are sending experienced engineers into the country to study the obstacles that must be overcome. One of the most promising features of this expert investigation was the refusal of a dredge-building company to put a machine on an unsuitable property. If this policy is continued one of the causes of past failures will be removed.

Several articles have recently been published on the dredging industry on Seward Peninsula. The most important of these are by T. M. Gibson[2] and Charles Janin.[3] From these publications and from statements by W. E. Thorpe, a construction engineer of the Yuba Construction Co., and from personal familiarity with the region, the following table, giving certain statistics concerning the dredges in operation during 1911, have been compiled. A few minor discrepancies appear between reports received from different sources, but so far as possible these have been adjusted.

[1] Peake, H. G., Tin dredging in Alaska: Min. and Sci. Press, vol. 103, 1911, p. 652.
[2] Gibson, T. M., Gold dredging industry on Seward Peninsula: Min. and Sci. Press, vol. 104, pp. 45–48.
[3] Janin, Charles, Gold dredging in Alaska and the Yukon: Min. Mag., vol. 6, pp. 45–48.

Dredges in operation on Seward Peninsula in 1911.

Company.	Region.	Creek.	Built.	Type or builder.	Size of buckets (cu. ft.).	Bucket line.	Source of power.	Fuel used a day.	Remarks.
Gold Beach Dredging Co	Nome	Osborn	1905	I. B. Hammond	5	Open	Crude oil	18 bbls	
Nome Consolidated Dredging Co.	do	Bourbon	1908	E. L. Smith-Lidgerwood	9	Close	Electricity	(?)	Power generated from oil.
Do	do	Wonder	1908	do	7	do	do	(?)	Do.
Plein Mining & Dredging Co.	do	Otter	1910	Risdon	3½	Open	Crude oil	13 bbls	
Saunders Dredging Co	do	Saunders	1910	(?)	3½	Close	Distillate	200 galls	
Arctic Gold Dredging Co	do	do	1910	Union Iron Works	2½	Open	do	160 galls	
Sioux-Alaska Mining Co	do	Moss	1910	do	2½	do	do	do	
Julien Dredging Co	do	Osborn	1911	Union Construction Co	2¾	do	do	190 galls	
Nome Consolidated Dredging Co.	do	Wonder			10		Electricity		Still under construction.
Seward Dredging Co	Solomon	Solomon	1905	Bucyrus	5	Close	Coal	12–15 tons.	Formerly the Three Friends.
Sievertsen	do	do		(?)	(?) 1	Open	Distillate	(?)	Built before 1906.
Mulligan	do	West		(?)	(?) 1		do	(?)	Built before 1906; runs on track.
Nome-Montana & New Mexico.	do	Solomon	1908	Risdon	5	Open	Coal	5 tons	Previously at Hope, Alaska.
Solomon Dredging Co	do	do	1910	Bucyrus	3½	Close	do	7 tons	
Flodin Mining & Dredging Co.	do	Big Hurrah	1910	Risdon	2½	Open	do	3 tons	
Sievertsen & Johnson	do	Solomon	1910	do	2½	do	do	do	
Kimball	do	Shovel	1911	Sluice-box type	2½	do	Distillate	150 galls	Similar to Kimball-Saupe dredge on Melsing Creek.
Blue Goose Mining Co	Council	Ophir		I. B. Hammond	5	do	Wood	12 cords	Built before 1905.
Alaska Gold Dredging Co	do	Warm	1909	Byron Jackson	2½	do	Distillate	160 galls	
Do	do	Goldbottom	1909	do	2¾	do	do	do	
Wild Goose Mining & Trading Co.	do	Ophir	1910	Yuba Construction Co	3½	Close	do	300 galls	
Goose Creek dredge	do	Goose	1910						Not in operation.
Alaska Gold Dredging Co	do	Willow	1910	Union Iron Works	2½	Open	Distillate	160 galls	
Kimball & Saupe	do	Melsing	1910	Empire Iron Works	2½	do	do	150 galls	Sluice-box type.
Lubbe	do	Mystery	1911	Union Iron Works	2½	do	do	do	
York Dredging Co	Port Clarence	Buck	1911	Union Construction Co	2¾	do	do	190 galls	
Cripple River Dredging Co	Southwest Seward Peninsular.	Cripple		E. L. Smith-Lidgerwood	(?) 5	(?)	do	(?)	Reported under construction.
Kelliher	Kougarok	Taylor		Union Iron Works	2¾	(?)	do	(?)	To be hauled to Taylor Creek during winter of 1911–12.

It has not been possible to compute accurately the number of cubic yards of auriferous gravel handled by the dredges or the value of the production. Brooks has stated that in 1910 from 1,200,000 to 1,500,000 yards [1] of gravel were dredged, having an aggregate value of $800,000, or an average value between 50 cents and 66 cents a cubic yard. Janin [2] estimated that the dredges in 1911 produced about $1,400,000 in gold. If this estimate is correct and the value per yard remained the same as that given by Brooks for 1910, it follows that between 2,000,000 and 2,800,000 cubic yards were mined by dredges in 1911. To find approximately the number of yards mined, a computation based on the length of the working season and the size of the dredges may also be made. According to Janin most of the dredges started work on or before June 24 and closed about October 24, thus working during a season of 126 days. From the table given above it may be determined that the average size of bucket used on the 23 dredges that were in operation in 1911 was about 3½ cubic feet. On the authority of W. E. Thorpe it may be assumed that the average 3½-foot dredge will handle about 1,200 cubic yards of gravel a day. Using these various factors and allowing for time lost not only in operation, but at both ends of the working season, it follows that over 2,000,000 cubic yards were probably handled by dredges in 1911.

This is by no means the theoretical capacity of even the machines now on the ground, and new ones are being installed every season. There is no reason why a dredging season of 120 days should not be assumed, and many experienced dredge men predict that dredges can be operated through November, so that possibly a season of 150 or more days may be counted on for the larger dredges. When it is realized that even with the present dredge equipment over a quarter of a million cubic yards can be handled each 10 days, the importance of the length of the working season becomes evident.

During 1911 four new dredges, as is shown by the table, page 7, in as many different parts of the peninsula were built and operated. Three new dredges were in the region in various stages of completion and should be in running order by the middle of the open season of 1912. Of these new dredges perhaps the most important is to be installed on Wonder Creek, near Nome. The hull has already been built, and the digging ladder, spuds, and other parts "are being put together in the company's shops [at Nome] this winter, thus occupying the mechanical force which it is necessary to retain under yearly contracts and cheapening cost of construction, together with material freight reductions." [3] This dredge will be equipped with 10-foot buckets, which are larger than any now used in Seward Peninsula. The motive power will be electricity, generated from oil.

[1] Brooks, A. H., The mining industry in 1910: Bull. U. S. Geol. Survey No. 480, 1911, p. 41.
[2] Janin, Charles, Gold dredging in Alaska and the Yukon: Min. Mag., vol. 6, pp. 45–48.
[3] Perkins, W. T., unpublished letter.

LODE DEVELOPMENTS.

Little has been done during the year in developing lodes outside of the tin region. (See p. 341.) None of the prospects except the one on Manila Creek has been exploited, but that general interest in lodes seems to have increased is indicated by the fact that a two-stamp custom quartz mill has been erected near Nome with the object of giving opportunity for testing commercial samples of ore. The mill has been in operation too short a time to show its value, but it is believed that it will prove to be of great service, not only in indicating workable ores, but also in pointing out the leads that are not worth further exploitation. That there are valuable vein deposits in Seward Peninsula is not doubted, and their discovery and development may be greatly facilitated by a commercial test such as the new mill should afford.

The mine on Manila Creek, noted above, is the only one that is reported to have shipped ore during 1911. At this place the ore is mainly stibnite (the sulphide of antimony), carrying accessory values in gold. Specimens from this place have shown native gold in crystalline aggregates associated with the stibnite. Fifteen tons of this ore are said by the local newspapers to have been shipped to the Tacoma smelter and to have yielded $125 a ton. This ore was probably hand sorted before shipping, so that the above returns do not represent the average run of the material. Nevertheless the presence of visible free gold in many of the specimens indicates a high gold tenor and a deposit worthy of full investigation.

Some graphite was sorted and sacked for shipment from near Imuruk Basin. It is understood, however, that the high transportation and treatment charges levied against former shipments have dissuaded the owners from sending out graphite at the present time.

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R.

S.

Y.

RECENT SURVEY PUBLICATIONS ON ALASKA.

[Arranged geographically. A complete list can be had on application.]

All these publications can be obtained or consulted in the following ways:

1. A limited number are delivered to the Director of the Survey, from whom they can be obtained free of charge (except certain maps) on application.

2. A certain number are delivered to Senators and Representatives in Congress for distribution.

3. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they can be had at prices slightly above cost. The publications marked with an asterisk (*) in this list are out of stock at the Survey, but can be purchased from the Superintendent of Documents at the prices stated.

4. Copies of all Government publications are furnished to the principal public libraries throughout the United States, where they can be consulted by those interested.

GENERAL.

*The geography and geology of Alaska, a summary of existing knowledge, by A. H. Brooks, with a section on climate, by Cleveland Abbe, jr., and a topographic map and description thereof, by R. U. Goode. Professional Paper 45, 1906, 327 pp. $1.

Placer mining in Alaska in 1904, by A. H. Brooks. In Bulletin 259, 1905, pp. 18–31.

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The mining industry in 1906, by A. H. Brooks. In Bulletin 314, 1907, pp. 19–39.

*The mining industry in 1907, by A. H. Brooks. In Bulletin 345, pp. 30–53. 45 cents.

The mining industry in 1908, by A. H. Brooks. In Bulletin 379, 1909, pp. 21–62.

The mining industry in 1909, by A. H. Brooks. In Bulletin 442, 1910, pp. 20–46.

The mining industry in 1910, by A. H. Brooks. In Bulletin 480, 1911, pp. 21–42.

The mining industry in 1911, by A. H. Brooks. In Bulletin 520, 1912, pp. 19–44.

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Railway routes from the Pacific seaboard to Fairbanks, Alaska, by A. H. Brooks. In Bulletin 520, 1912, pp. 45–88.

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The preparation and use of peat as a fuel, by C. A. Davis. In Bulletin 442, 1910, pp. 101–132.

*The distribution of mineral resources in Alaska, by A. H. Brooks. In Bulletin 345, pp. 18–29. 45 cents.
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*Methods and costs of gravel and placer mining in Alaska, by C. W. Purington. Bulletin 263, 1905, 362 pp. 35 cents. Abstract in Bulletin 259, 1905, pp. 32–46.
*Prospecting and mining gold placers in Alaska, by J. P. Hutchins. In Bulletin 345, 1908, pp. 54–77. 45 cents.
Geographic dictionary of Alaska, by Marcus Baker; second edition by James McCormick. Bulletin 299, 1906, 690 pp.
*Water-supply investigations in Alaska in 1906–7, by F. F. Henshaw and C. C. Covert. Water-Supply Paper 218, 1908, 156 pp. 25 cents.

Maps.

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*Preliminary report on the Ketchikan mining district, Alaska, with an introductory sketch of the geology of southeastern Alaska, by Alfred H. Brooks. Professional Paper 1, 1902, 120 pp. 25 cents.
*The Porcupine placer district, Alaska, by C. W. Wright. Bulletin 236, 1904, 35 pp. 15 cents.
The Treadwell ore deposits, by A. C. Spencer. In Bulletin 259, 1905, pp. 69–87.
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The Juneau gold belt, Alaska, by A. C. Spencer, pp. 1–137, and A reconnaissance of Admiralty Island, Alaska, by C. W. Wright, pp. 138–154. Bulletin 287, 1906, 161 pp.
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The Eagle River region, by Adolph Knopf. In Bulletin 480, 1911, pp. 103–111.
The Eagle River region, southeastern Alaska, by Adolph Knopf, including detailed geologic and topographic maps. Bulletin 502, 1912, 61 pp.
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The Yakutat Bay earthquake of September, 1899, by R. S. Tarr and Lawrence Martin. Professional Paper 69, 1912, 135 pp.

Topographic maps.

Juneau special map; No. 581A; scale, 1:62,500; by W. J. Peters. Price 5 cents each or $3 per hundred.
Berners Bay special map; No. 581B; scale, 1:62,500; by R. B. Oliver. Price 5 cents each or $3 per hundred.
Topographic map of the Juneau gold belt, Alaska. Contained in Bulletin 287, Plate XXXVI, 1906. Not issued separately.
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Copper Mountain and vicinity, Prince of Wales Island; No. 540B; scale, 1:62,500; by R. H. Sargent. Price 5 cents each or $3 per hundred.

CONTROLLER BAY, PRINCE WILLIAM SOUND, AND COPPER RIVER REGIONS.

*The mineral resources of the Mount Wrangell district, Alaska, by W. C. Mendenhall. Professional Paper 15, 1903, 71 pp. Contains map of Prince William Sound and Copper River region; scale, 12 miles=1 inch. 30 cents.
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Topographic maps.

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Preliminary report on the mineral resources of the southern part of Kenai Peninsula, by U. S. Grant and D. F. Higgins. In Bulletin 442, 1910, pp. 166–178.

Outline of the geology and mineral resources of the Iliamna and Clark lakes region, by G. C. Martin and F. J. Katz. In Bulletin 442, 1910, pp. 179–200.

Gold placers of the Mulchatna, by F. J. Katz. In Bulletin 442, 1910, pp. 201–202.

The Mount McKinley region, by A. H. Brooks, with descriptions of the igneous rocks and of the Bonnifield and Kantishna districts, by L. M. Prindle. Professional Paper 70, 1911, 234 pp.

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Reconnaissance from Circle to Fort Hamlin, by R. W. Stone. In Bulletin 284, 1906, pp. 128–131.

The Yukon-Tanana region, Alaska; description of the Circle quadrangle, by L. M. Prindle. Bulletin 295, 1906, 27 pp.

The Bonnifield and Kantishna regions, by L. M. Prindle. In Bulletin 314, 1907, pp. 205–226.

The Circle precinct, Alaska, by A. H. Brooks. In Bulletin 314, 1907, pp. 187–204.

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Placer mining in the Fortymile and Seventymile river districts, by E. A. Porter. In Bulletin 520, 1912, pp. 211-218.
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The Rampart and Hot Springs regions, by H. M. Eakin. In Bulletin 520, 1912, pp. 271-286.
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The Bonnifield region, Alaska, by S. R. Capps; including geologic and topographic reconnaissance maps. Bulletin 501, 1912, 162 pp.
Geologic reconnaissance of a part of the Rampart quadrangle, by H. M. Eakin. Bulletin —. (In preparation.)
Geologic reconnaissance of the Circle quadrangle, by L. M. Prindle. Bulletin —. (In preparation.)
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Fairbanks quadrangle; No. 642; scale, 1:250,000; by T. G. Gerdine, D. C. Witherspoon, and R. B. Oliver. Price 10 cents a copy or $6 per hundred.
Rampart quadrangle; No. 643; scale, 1:250,000; by D. C. Witherspoon and R. B. Oliver. Price 10 cents a copy or $6 per hundred.
Fairbanks district; No. 642A; scale, 1:62,500; by T. G. Gerdine and R. H. Sargent. Price 10 cents a copy or $6 per hundred.

Yukon-Tanana region, reconnaissance map of; scale, 1 : 625,000; by T. G. Gerdine. Contained in Bulletin 251, 1905. Not published separately.

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Circle quadrangle, Yukon-Tanana region; No. 641; scale, 1:250,000; by D. C. Witherspoon. Contained in Bulletin 295. Price 25 cents a copy.

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Gold fields of the Solomon and Niukluk river basins, by P. S. Smith. In Bulletin 314, 1907, pp. 146–156.

Geology and mineral resources of Iron Creek, by P. S. Smith. In Bulletin 314, 1907, pp. 157–163.

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*Investigation of the mineral deposits of Seward Peninsula, by P. S. Smith. In Bulletin 345, 1908, pp. 206–250. 45 cents.

*The Seward Peninsula tin deposits, by Adolph Knopf. In Bulletin 345, 1908, pp. 251–267. 45 cents.

*Mineral deposits of the Lost River and Brooks Mountain regions, Seward Peninsula, by Adolph Knopf. In Bulletin 345, 1908, pp. 268–271. 45 cents.

*Water supply of the Nome and Kougarok regions, Seward Peninsula, in 1906–7, by F. F. Henshaw. In Bulletin 345, 1908, pp. 272–285. 45 cents.

Water-supply investigations in Alaska, 1906 and 1907, by F. F. Henshaw and C. C. Covert. Water-Supply Paper 218, 1908, 156 pp.

Geology of the Seward Peninsula tin deposits, by Adolph Knopf. Bulletin 358, 1908, 72 pp.

Recent developments in southern Seward Peninsula, by P. S. Smith. In Bulletin 379, 1909, pp. 267–301.

The Iron Creek region, by P. S. Smith. In Bulletin 379, 1909, pp. 302–354.

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Mineral resources of the Nulato-Council region, by P. S. Smith and H. M. Eakin. In Bulletin 442, 1910, pp. 316–352.

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A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, by P. S. Smith and H. M. Eakin. Bulletin 449, 1911, 146 pp.

Notes on mining in Seward Peninsula, by P. S. Smith. In Bulletin 520, 1912, pp. 339–344.

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The surface water supply of Seward Peninsula, by F. F. Henshaw and G. L. Parker; with sketch of geography and geology, by P. S. Smith, and report on placer mining, by Alfred H. Brooks; including topographic reconnaissance map. Water-Supply Paper —. (In preparation.)

Topographic maps.

The following maps are for sale at 5 cents a copy or $3 per hundred:

Casadepaga quadrangle, Seward Peninsula; No. 646C; scale, 1:62,500; by T. G. Gerdine.

Grand Central quadrangle, Seward Peninsula; No. 646A; scale, 1:62,500; by T. G. Gerdine.

Nome quadrangle, Seward Peninsula; No. 646B; scale, 1:62,500; by T. G. Gerdine.

Solomon quadrangle, Seward Peninsula; No. 646D; scale, 1:62,500; by T. G. Gerdine.

The following maps are for sale at 25 cents a copy or $15 per hundred:

Seward Peninsula, northeastern portion of, topographic reconnaissance of; No. 655; scale, 1:250,000; by T. G. Gerdine.

Seward Peninsula, northwestern portion of, topographic reconnaissance of; No. 657; scale, 1:250,000; by T. G. Gerdine.

Seward Peninsula, southern portion of, topographic reconnaissance of; No. 656; scale, 1:250,000; by T. G. Gerdine.

Seward Peninsula, southeastern portion of, topographic reconnaissance of; scale, 1:250,000. Contained in Bulletin 449. Not published separately.

NORTHERN ALASKA.

A reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska, by way of Dall, Kanuti, Allen, and Kowak rivers, by W. C. Mendenhall. Professional Paper 10, 1902, 68 pp.

*A reconnaissance in northern Alaska across the Rocky Mountains, along the Koyukuk, John, Anaktuvuk, and Colville rivers, and the Arctic coast to Cape Lisburne, in 1901, by F. C. Schrader and W. J. Peters. Professional Paper 20, 1904, 139 pp.

Coal fields of the Cape Lisburne region, by A. J. Collier. In Bulletin 259, 1905, pp. 172–185.

Geology and coal resources of Cape Lisburne region, Alaska, by A. J. Collier. Bulletin 278, 1906, 54 pp.

The Shungnak region, Kobuk Valley, by P. S. Smith and H. M. Eakin. In Bulletin 480, 1911, p. 305.

The Squirrel River placers, by P. S. Smith. In Bulletin 480, 1911, p. 319.

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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

BULLETIN 521

THE COMMERCIAL MARBLES OF WESTERN VERMONT

BY

T. NELSON DALE

WASHINGTON
GOVERNMENT PRINTING OFFICE
1912

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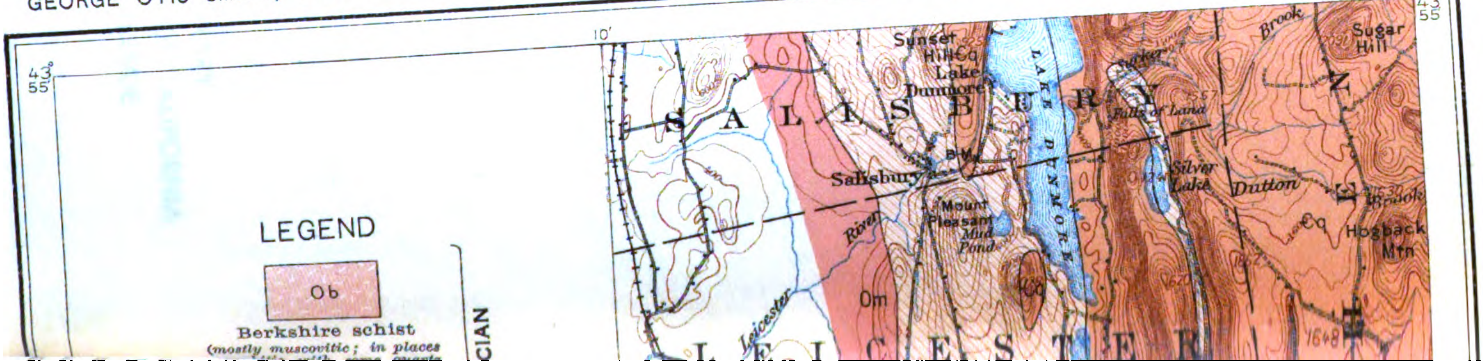
LEGEND
Ob
Berkshire schist
(mostly muscovitic; in places
CIAN
SALISBURY
LEICESTER
Sunset Hill
Lake Dunmore
LAKE DUNMORE
Salisbury
Mount Pleasant
Mud Pond
River
Leicester
Om
Falls of Lana
Silver Lake
Dutton
Brook
Sugar Hill
Hogback Mtn
73°00'
43°55'
10'

THE COMMERCIAL MARBLES OF WESTERN VERMONT.

By T. Nelson Dale.

INTRODUCTION.

This publication has a twofold object—to bring the science of geology to bear upon the problems of the marble industry in western Vermont and briefly to make known the more important scientific results obtained in the course of the mapping of the marble belts of that part of the State and in the study of its marbles.

The marble district specially considered lies west of the Green Mountain Range in Bennington, Rutland, and Addison counties, but the reddish dolomite marble quarried at Swanton, in Franklin County, and the black calcite marble quarried on Isle la Motte, in Grand Isle County, are also described. The green serpentine of Roxbury, nearly in the center of the State, in Washington County, and the chrome mica schist of Shrewsbury, in Rutland County, have also been included. The bulletin covers all the quarries of commercial marble that were in operation in the State in 1910. The marble deposits on the east side of the Green Mountain axis, including the small disused quarries in Orange County, are not here considered.

The field work was done by the writer in parts of the summers of 1888, 1899, 1900, 1903, and 1904. Mr. F. H. Moffit spent the summers of 1899 and 1900 and a month in 1902 on the areal and structural geology of the marble belt and adjacent schist masses in Arlington, Sandgate, Manchester, Dorset, Danby, and Tinmouth. His maps, notes, sections, and specimens have been used in the preparation of this bulletin. Mr. N. C. Dale assisted the writer in the summer of 1903. The writer also spent most of the summer of 1910 in visiting all the active marble quarries of the State and in otherwise completing the work begun in 1888.

The notes on the texture of marble (pp. 51–54) are based on the study of 200 thin sections.

Mr. George Steiger, of the Geological Survey, has contributed a quantitative determination of the graphite in the gray marble of West Rutland. Mr. W. T. Schaller, also of the Survey, has made a qualitative examination of a dolomitic bed near Brandon, and he and Mr.

J. S. Diller have made an examination of the chrome mica schist marble of Shrewsbury. Mr. E. S. Larsen has also made a few petrographic determinations.

The marble companies have materially aided the work by placing their core-drill records at the writer's service, by facilitating his investigations, and by furnishing sawed cubes for thin sections and polished specimens.

The elementary geologic principles which should guide the quarryman and the prospector in the marble belts of western Vermont are outlined on pages 77–85.

In order to render the bulletin more widely serviceable as few technical terms as possible have been used, even in the more scientific parts. A glossary of such technical terms as have unavoidably been used will be found on pages 162–164.

It is proposed to supplement this bulletin by one on the marbles of eastern Vermont.

THE WORK OF VERMONT GEOLOGISTS.

Much work has been done by geologists of Vermont on the geology of its marbles.

The State report of Hitchcock and Hager, published in 1861, laid the foundation for all future work. Next in importance were the discoveries of Rev. Augustus Wing, published by James D. Dana in 1877, determining the geologic age and structural relation of various parts of the marble and limestone areas. Then came the general summary of the geologic features of the marble belt by President Ezra Brainerd, in 1885, and in connection with it the interesting economic papers published the same year by Prof. Henry M. Seely on the marble industry of western New England and its early beginnings in Vermont. These were followed, in 1898 to 1908, by several annual reports by Prof. George H. Perkins, State geologist, in which the location and characteristics of the quarries were given, the marble firms and plants noted, and the colors and shades of all the marbles carefully described. The report for 1908 also contains two important papers by Prof. Perkins on the geology of Franklin and Chittenden counties and the formation to which the "Champlain marbles" belong. The same report also includes a paper by George E. Edson on the geology of Swanton. Finally, the State geologist's report for 1910 contains a brief reference to the marble industry and some photographs of unusual folds in the great marble belt in Leicester.

The design of this bulletin is not to supplant or duplicate, but to complement the work of the geologists of the State. It is expected that this will be accomplished not only by means of the geologic maps and sections and the results of the microscopic study of the marbles but also by furnishing those engaged in the marble industry a brief key to the structural geology of the marble beds.

The reader will be frequently referred to the reports of the State geologists for information on special points. A bibliography of Vermont marbles will be found on pages 59–60.

MARBLE IN GENERAL.

LIMESTONE AND MARBLE.

If a chemical precipitate of carbonate of lime is examined microscopically, it will be found to consist of irregular, infinitesimal granules of uncrystalline matter. When analyzed, this material will be found to have essentially the composition of what is technically known as marble or crystalline limestone. A thin section of marble, when placed under a microscope, is seen to be an aggregate of translucent to transparent crystalline plates, generally of irregular outline, of calcite or dolomite, with the rhombohedral cleavage characteristic of these minerals, and also generally crossed by twinning planes. These twinning planes, which are so conspicuous in thin sections of marble, are due to the growth of two crystals in such juxtaposition (but not parallel) that there is a uniform mathematical relation between the axes of the two crystals. The twinning plane seen in the crystalline grain of a thin section of marble is the plane along which the two crystals meet. But as this twinning process generally repeats itself in the same crystalline mass or particle, a single microscopic grain may contain several such planes. The difference between a collection of individual crystals of calcite and a piece of calcite marble is that the former, like granulated sugar, consists of complete crystals, whereas in calcite marble the crystals have been formed so close to one another that no one crystal has been able to complete itself. There has been no space for the formation of the faces of individual crystals.

Many so-called granular limestones when examined microscopically are found to consist of exceedingly minute, irregular plates of polarizing but untwinned calcite. Such limestones are really part-way marbles.

A few specimens of limestones were examined microscopically to throw light on the relation of limestone and marble:

A very fine-grained limestone, Chickamauga (201), collected by Dr. C. W. Hayes near Attalla, Ala., with flintlike fracture, brownish-gray color, and strong effervescence with HCl, consists of irregular polarizing particles 0.0028 to 0.006 millimeter in diameter, with sparse polarizing plates, some of them of rhombic form (dolomite), 0.008 to 0.02 millimeter in diameter, and sections of fossils.

Another limestone, Chickamauga (202), collected also by Dr. Hayes near White Cliff Springs, near Starrs Mountain, in Tennessee, has a very fine texture, is dark brown in color, effervesces strongly, is finely veined and fossiliferous. In thin section this rock shows irregular nodules of very fine polarizing granules of irregular form in a matrix of polarizing calcite particles. Nodules and matrix are crossed by fine veins of calcite. The fossil sections polarize.

An oolitic limestone from Short Creek, Galena, Kans., with a light-brownish cement and strong effervescence, consists of slightly flattened spherules, 0.02 to 0.05 millimeter in diameter, of polarizing irregular grains (0.006 to 0.014 millimeter) lying in a matrix of polarizing and twinned calcite plates.

It is usually assumed that natural chalk is uncrystalline, but the crystalline nature of chalk has been determined by Kauffmann and verified by Renard.[1]

The difference between one of these semigranular limestones and a true marble appears in polishing. The marble alone yields a brilliant surface, which is due to the effect of light upon its uniformly crystalline particles.[2]

DEFINITIONS OF MARBLE

The distinctions indicated lead to the following definitions:

Marble in the technical sense is a rock consisting mainly of crystalline particles of calcite or dolomite or of both. But marble in the commercial sense includes a wide variety of stones and even some of very different composition and history. A Vermont serpentine is described on page 49 and a chrome mica schist on page 50. Both are commercial "marbles."

CHEMICAL COMPOSITION.

The chemical composition of marble varies primarily according as it consists of calcite or of dolomite or of an admixture of both. White calcite marble is almost entirely carbonate of lime. In white dolomite marble carbonate of magnesia takes the place of part of the carbonate of lime. As the colored marbles of these two sorts contain small percentages of other minerals (graphite, quartz, hematite, limonite, magnetite, pyrite, muscovite, actinolite, tremolite, etc.), their analyses differ slightly from those of the white marbles.

A few reliable analyses of typical American and European marbles follow.

Analysis of white calcite marble from West Rutland, Vt.[3]

Insoluble	8.00
Alumina (Al_2O_3)	.39
Ferrous oxide (FeO)	.14
Magnesia (MgO)	Trace.
Lime (CaO)	50.79
Water (H_2O) at and above 105°	1.01
Carbon dioxide (CO_2)	39.80
	100.13

[1] Renard, A. F., Des caractères distinctifs de la dolomite et de la calcite dans les roches calcaires et dolomitiques du calcaire carbonifère de Belgique: Bull. Acad. roy. Belgique, vol. 47, 1879, p. 555.

[2] See, for a discussion of the effect of light on polished stone surfaces, Seipp, H., Italienische Materialstudien, Stuttgart, 1911, pp. 76–105.

[3] By L. G. Eakins, Bull. U. S. Geol. Survey No. 419, 1910, record No. 1213, p. 189.

Analysis of white calcite marble, slightly mottled with gray, from the Columbian quarry, Proctor, Vt.[1]

Calcium carbonate ($CaCO_3$)	98.37
Magnesium carbonate ($MgCO_3$)	.77
Iron carbonate ($FeCO_3$)	.034
Manganese and aluminum oxides	.005
Siliceous matter insoluble in acid	.63
Organic matter	.08
	99.889

As is shown on page 40, these clouded marbles contain minute lenses and beds of dolomite, which account for the $MgCO_3$

Analysis of white dolomite marble from Lee, Mass.[2]

Insoluble	0.19
Alumina (Al_2O_3) Ferric oxide (Fe_2O_3)	.24
Calcium carbonate[3] ($CaCO_3$)	55.14
Magnesium carbonate[4] ($MgCO_3$)	43.88
	99.45

Analyses of Norwegian dolomite marbles.[a]

	1	2
Insoluble	0.106	0.46
Calcium carbonate ($CaCO_3$)	54.05	54.16
Magnesium carbonate ($MgCO_3$)	45.93	45.09
Iron carbonate ($FeCO_3$)	.086	.32
Manganese carbonate ($MnCO_3$)	.032	....
	100.204	100.03

[a] Vogt, J. H. L., Norsk Marmor, 1897, p. 20. 1, Cream colored, from Hammarfald, Røsvik; 2, white, from Hemnæs Seljeli.

The following are two analyses of calcite marbles from the quarries worked by the ancient Greeks:

Analyses of Greek marbles.[a]

	1	2
Calcium carbonate ($CaCO_3$)	100.002	100.09
Ferric oxide (Fe_2O_3)	.122	....
	100.124	100.09

[a] Lepsius, G. R., Griechische Marmorstudien, Berlin, 1890, pp. 18, 29. 1, "Lower white Pentelicon" marble from Mount Pentelicon, northeast of Athens, milk-white color; 2, "Lower white Attic marble" from Agrilesa Valley, 2½ miles north of Cape Sunium or 25 miles southeast of Athens, light bluish gray tint.

Lepsius states that the Pentelicon marble contains a few grains of quartz and scales of muscovite and chlorite, some pyrite with a zone

[1] By S. L. Penfield, Yale University, Twentieth Ann. Rept. U. S. Geol. Survey, pt. 6, continued, 1899, p. 447.

[2] By E. A. Schneider, Bull. U. S. Geol. Survey No. 419, 1910, record No. 1279, p. 189.

[3] Recalculated from CaO and CO_2 of original.

[4] Recalculated from MgO and CO_2 of original.

of limonite stains, and more rarely very minute grains of magnetite. The golden-brownish film noticeable on the Parthenon and other Greek structures made of this marble is attributed to this content of $Fe_4O_9H_6$. In contrast with this he finds that the marble of the Agrilesa Valley, which is chemically pure calcium carbonate, forms no such crust in ancient sculptures.

Analysis of white Norwegian calcite marble from Velfjorden, Troviken.[1]

Calcium carbonate ($CaCO_3$)	99.27
Iron carbonate ($FeCO_3$)	.137
Manganese carbonate ($MnCO_3$)	.0026
Magnesium carbonate ($MgCO_3$)	.68
Insoluble	.77
	100.86

Analysis of Carrara marble.[2]

Calcium carbonate ($CaCO_3$)	99.77
Magnesium carbonate ($MgCO_3$)	.90
Silica (SiO_2)	.16
Alumina and iron sesquioxide (Al_2O_3, Fe_2O_3)	.08
	99.91

Giampaoli[3] gives for Carrara marble: Calcium carbonate ($CaCO_3$), extremes 98 to 99 per cent; magnesium carbonate ($MgCO_3$), maximum 0.9 per cent; silica (SiO_2), maximum 1.0 per cent.

Analyses of Carrara and Tyrolese marbles.[a]

	Carrara, white mottled.	Schlanders, Tyrol.	
		Mottled, coarse.	White to grayish, very hard.
Calcium carbonate ($CaCO_3$)	99.236	99.010	97.040
Magnesium carbonate ($MgCO_3$)	.284	.521	2.109
Iron oxides (FeO, Fe_2O_3) and phosphoric oxide (P_2O_5)	.251	.062	.360
Silica (SiO_2)	....	....	Trace.
	99.771	99.593	99.509
Specific gravity at 16.25° C	2.732	2.700	2.566

[a] Wittstein, G. C., Untersuchungen einiger weissen Marmorarten, 1851.

It will be noticed that the calcite marbles in all the analyses show a range of 99.04 to 100 per cent of calcium carbonate.

A composite analysis by H. N. Stokes of 498 constructional limestones is given for comparison. The principal difference is in its high percentage of silica (14.09) and its small percentage of calcium carbonate (72.50).

[1] Vogt, J. H. L., Norsk Marmor, 1897, p. 19.
[2] Rosenbusch, H., Elemente der Gesteinslehre, 3d ed., 1910, p. 521.
[3] Giampaoli, A., I marmi di Carrara, Pisa, 1897.

Composite analysis of 498 constructional limestones.[1]

Silica (SiO_2)	14.09
Titanium dioxide (TiO_2)	.08
Alumina (Al_2O_3)	1.75
Iron oxides (Fe_2O_3, FeO)	.77
Manganese oxide (MnO)	.03
Calcium carbonate ($CaCO_3$)	72.50
Magnesia (MgO)	4.49
Potash (K_2O)	.58
Soda (Na_2O)	.62
Lithia (Li_2O)	Trace.
Water combined (H_2O)	.30
Water uncombined and organic matter	.88
Phosphorus oxide (P_2O_5)	.42
Carbon dioxide (CO_2)	3.68
Sulphur (S)	.07
Sulphur trioxide (SO_3)	.07
Chlorine (Cl)	.01
	100.34

The dolomite marbles in the analyses show a range of 30.27 to 30.88 per cent of lime and of 21.42 to 21.87 of magnesia, but a pure dolomite contains 30.4 per cent of lime and 21.9 of magnesia.[2]

Dieulafait [3] determined the presence of diffused manganese in the marbles of Carrara, Paros, and the Pyrenees. Many of the exceedingly minute black particles present in all the white marbles examined by the writer may be an oxide of manganese. Two analyses of rose-colored calcite marble from eastern Vermont made by George Steiger, of the Survey, for another bulletin by the writer show 0.23 and 0.49 per cent of manganese oxide.

Lepsius [4] notes that several of the Greek marbles (Paros, Naxos, Pentelicon, Hymettos, etc.) yield a marked bituminous odor when struck, which he attributes to the presence of a small amount of hydrocarbon.

Egenter [5] calls attention to the odor of the contact-metamorphic marble of Carinthia, in Austria, which he attributes to sulphureted hydrogen.

Lindenmann[6] reports that the Bardiglio marble of Carrara and the marble of Sterzing, in the Tyrol, both emit a very strong odor when struck.

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[1] Clarke, F. W., The data of geochemistry, 2d ed.: Bull. U. S. Geol. Survey No. 491, 1911, p. 533, analysis H. In copying the analysis part of the CO_2 of the original has been combined with the CaO to show the percentage of $CaCO_3$.

[2] Clarke, F. W., op. cit., p. 544, analysis F.

[3] Existence du manganèse à l'état de diffusion complète dans les marbres bleus de Carrare, de Paros et des Pyrénées: Compt. Rend., vol. 98, 1884, pp. 589–591.

[4] Lepsius, G. R., Griechische Marmorstudien: Anhang Abhandl. K. Akad. Wiss. Berlin, 1890.

[5] Egenter, Paul, Die Marmorlagerstätten Kärntens: Zeitschr. prakt. Geologie, vol. 17, 1909, pp. 419–439

[6] Lindenmann, Bernhard, Ueber einige wichtige Vorkommnisse von körnigen Carbonatgesteinen mit besonderer Berücksichtigung ihrer Entstehung und Structur: Neues Jahrb., Beilage Band 19, 1904, pp. 197–317.

Further chemical details as to the marbles will be given in the descriptions of the different marbles.

PHYSICAL PROPERTIES.

Marble, besides possessing the qualities of hardness, cohesiveness, compressive strength, porosity, expansiveness under heat, thermal conductivity, sonorousness, translucence, and flexibility, is polishable and can be deformed in confinement under powerful compression. Its color, texture, specific gravity, hardness, and porosity will be considered under other heads.

Tests made at the Watertown Arsenal give the white dolomite marble of Lee, Mass., an ultimate compressive strength of 18,047 pounds to the square inch;[1] the calcite marbles of West Rutland and Proctor a compressive strength of 11,525 to 14,397 pounds to the square inch;[2] and the coarse calcite marbles of South Dorset an ultimate compressive strength averaging 11,300 pounds when placed on bed and 9,100 pounds when placed on edge.

Tests of the dolomite marble of Lee give it a shearing strength of 2,052 pounds to the square inch and a maximum fiber strength of 1,585 pounds to the square inch.[1]

Vogt [3] gives the compressive strength of a Norwegian dolomite marble as 24,891 to the square inch, of Carrara marble as 6,329 pounds, and of Tyrolese statuary marble (Laas) as 16,036 pounds.

Geikie [4] in an interesting petrographic study of Edinburgh gravestones describes some slabs of white marble, presumably from Italy, firmly set into sandstone monuments, which in consequence either of their porousness and the freezing of interstitial water or else of their greater expansiveness than sandstone, or from both causes, had bulged out 2½ inches from their original vertical position and showed a series of rents along the crest of the bulge.

The Watertown Arsenal tests referred to above give the coefficient of expansion of dolomite marble from Lee as only 0.00000562 under a difference of temperature of 156° F. Bartlett [5] found the expansion of marble to be 0.000005668 inch to the foot for each degree Fahrenheit.

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[1] Twentieth Ann. Rept. U. S. Geol. Survey, pt. 6, continued, 1899, pp. 405, 406.

[2] Tests Nos. 9059, 9060, 9063, made for the Vermont Marble Co., April, 1893, at the Watertown Arsenal. See p. 121.

[3] Vogt, J. H. L., Norsk Marmor: Norges geologiske Undersøgelse, No. 22, Christiania, 1897, p. 355.

[4] Geikie, Archibald, Rock weathering as illustrated in Edinburgh churchyards: Proc. Roy. Soc. Edinburgh, vol. 10, 1880, pp. 518–532; fig. 1, Thin sections of fresh and weathered marble after 87 years exposure; Pl. XVI, *A*, Bowed marble slab in frame of sandstone; *B*, Marble slab, cracked diagonally, in frame of sandstone. See also Geikie's Geological sketches at home and abroad, London, 1882, Chapter VIII, Rock weathering measured by the decay of tombstones, pp. 162–174.

[5] Bartlett, W. C., Experiments on the expansion and contraction of building stones by variation of temperature: Am. Jour. Sci., 1st ser., vol. 22, 1832, pp. 136–140.

Yamagawa[1] determined the thermal conductivity of marble as averaging 0.00728 centimeter a second. A previous determination by Depretz was 0.0077 centimeter.

Thin slabs of ordinary Carrara marble have a marked sonorousness when struck with a hammer. The Vermont calcite marbles are only feebly sonorous, but on the other hand the dolomite marbles of Lake Champlain possess more sonorousness than the Carrara marble.

White marbles become transparent or nearly so in thin sections prepared for the microscope, but differ considerably in translucence on the rough or polished face. Some have a waxy look, which is probably attributable to the greater transparence of their grains; others are milk-white and opaque. Lepsius [2] in connection with his study of Greek marbles determined that the best Pentelicon marble admits light to a depth of 0.59 inch, and the Parian to 1.37 inches. Upon this feature largely rested the reputation of Parian marble. Lindenmann [3] gives the translucence of Carrara statuary marble as from 1.18 to 1.57 inches. The coarse calcite marble formerly quarried at Adams, Mass., referred to on page 54, is unusually translucent.

The flexibility of marble has long been known. It probably depends largely on the shape and cohesion of its grains.[4]

The important experiments of Adams, Nicholson, and Coker [5] show that marble when tightly inclosed can be deformed—that is, it flows. They fitted cylinders of Carrara and Vermont marble tightly into steel tubes and applied great pressure to the ends of the cylinders, which caused them to bulge out on the sides, distending the inclosing tube. When the deformed marble was sliced and examined microscopically it was found to be solid, but many molecular changes had taken place in the individual crystalline plates, such as slippage and twinning. They also found that the marble if deformed at ordinary temperature was stronger under slow than under rapid deformation, that the deformed marble was stronger when the experiment was tried at a higher temperature than at ordinary temperature, and that when deformed in the presence of moisture (water gas) and a high temperature the deformed marble was actually stronger than

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[1] Yamagawa, Kenjiro, Determination of the thermal conductivity of marble: Jour. Coll. Sci., Imp. Univ. Japan, vol. 2, 1888. Review in Neues Jahrb., 1892, vol. 2, p. 43.

[2] Lepsius, G. R., Griechische Marmorstudien: Anhang Abhandl. K. Akad. Wiss. Berlin, 1890, p. 47.

[3] Lindenmann, Bernhard, Ueber einige wichtige Vorkommnisse von körnigen Carbonatgesteinen mit besonderer Berücksichtigung ihrer Entstehung und Structur: Neues Jahrb., Beilage Band 19, 1904, p. 273.

[4] See Dewey, Chester, Notice of the flexible or elastic marble of Berkshire County: Am. Jour. Sci., 1st ser., vol. 9, 1825, p. 241. Julien, A. A., The durability of building stones: Tenth Census, vol. 10, 1884 (on the flexibility of marble, pp. 366, 367; describes the curvature of a marble slab in the Alhambra). Winslow, A., An illustration of the flexibility of limestone [white crystalline]: Am. Jour. Sci., 3d ser., vol. 43, 1892, pp. 133, 134.

[5] Adams, F. D., assisted by Coker, E. G., An experimental investigation into the flow of rocks—The flow of marble: Am. Jour. Sci., 4th ser., vol. 29, 1910, pp. 465–487; Pl. III, *A*, Thin section of Carrara marble magnified 40 diameters; *B*, The same caused to flow under pressure of 296 to 725 pounds to the square inch, showing schistosity, magnified 60 diameters. See Mr. Adams's other papers in bibliography, p. 55.

the original marble. These experiments are very instructive, for they throw light on the causes of the remarkable folds in the marble beds of Vermont and similar regions and the conditions under which they were formed.

GENERAL TEXTURE.

The difference between a limestone and a marble has been stated (p. 11). In marble the grains are all crystalline, with rhombohedral cleavage, mostly twinned, and more or less interlocked but never in such an intricate way as they are in granite. To this fact and the marked cleavage of calcite and dolomite the generally lower cohesiveness of marble than of granite is largely due. Hirschwald [1] figures two kinds of grain form in calcite marble—the denticulate and the smooth—and this distinction appears to be generally valid, although the grains in most of the Vermont calcite marble are not denticulate. In some dolomite marbles the grains do not interlock and some of the grains even have a rhombohedral form so that the texture under the microscope appears less cohesive than that of the other marbles. In both calcite and dolomite marbles the cleavage and twinning of each grain is independent of that of other grains.

Although the form of their grains is generally irregular, in some marbles one or two axes of the grains are much longer than the others and the longer axes of different grains are parallel, giving to the rock a certain schistosity which is usually parallel to the bedding. (See figs. 6, 22.) A thin section of such a marble from the St. Gotthard is figured by Rosenbusch.[2] This elongation, however, may be confined to but a part of the grains and these may not be arranged. A marble at Leicester Junction (p. 147 and fig. 25) exhibits alternate tiers of large and small grains. As the marble is intensely folded this arrangement may be due to granulation or it may be the result of the interbedding of dolomite and calcite, the smaller grains being dolomite.

Lepsius [3] in his study of Greek marbles found that those of Pentelicon, Hymettos, and the vicinity of Cape Sunium and of Doliana, in Arcadia, consist of irregularly bounded grains of twinned calcite, lying in a matrix of much more minute calcite grains without cleavage or twinning planes, and that the proportionate amount of the matrix varies in different beds and localities. He regards the matrix in these marbles as a remnant of the limestone out of which the twinned grains were formed under metamorphism.

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[1] Hirschwald, J., Die Prüfung der natürlichen Bausteine auf ihre Wetterbeständigkeit, Berlin, 1908, Pl. XVI, figs. 1, 2.

[2] Rosenbusch, H., Elemente der Gesteinslehre, 3d ed., 1910, fig. 78.

[3] Lepsius, G. R., Griechische Marmorstudien: Anhang Abhandl. K. Akad. Wiss. Berlin, 1890.

Vogt[1] figures a Norwegian marble in which interlocking grains of calcite alternate irregularly with angular ones of dolomite.

In some Vermont marbles minute beds and lenses of dolomite are intercalated in the calcite mass and other interesting combinations of calcite and dolomite occur. (See p. 131, fig. 20.) Vogt[2] figures a marble in which the calcite plates, owing to secondary compression, due to contact metamorphism, have suffered granulation and had their twinning planes bent. Hirschwald[3] also figures thin sections of marble with bent twinning planes. One of the marble beds of West Rutland shows this also.

A thin section of calcite marble with flexed twinning planes is shown in figure 1.

FIGURE 1.—Thin section of white calcite marble from the Goodale or Girard College quarry in Sheffield, Mass., with flexed twinning planes due to secondary compression. Texture very coarse and irregular. Dotted particles are quartz. Enlarged 20 diameters. This quarry supplied columns for Girard College, in Philadelphia. The curvature of the calcite plates can be detected, even in a hand specimen.

In a brecciated marble each fragment has its texture more or less differently oriented and the texture of the fragment differs from that of the secondary cement. The same is also true of the pebbles in a marble conglomerate, except that more or less parallelism in the texture of the smaller pebbles may be expected.

There is also a variation in the grade of texture. The grains may be large, medium, or small and a further variation may be traceable to the regularity or irregularity in the size of the grains in the same marble.

The presence of sericite (fibrous potash mica), tremolite, actinolite (varieties of hornblende), or other fibrous minerals complicates the texture of marble. (See pp. 41, 43.)

The texture is indirectly affected by the character of the bedding, which may be even or plicated or elongated. This is more apparent in the graphitic and micaceous marbles. In some Vermont marbles

[1] Vogt, J. H. L., Der Marmor in Bezug auf seine Geologie, Structur und seine mechanische Eigenschaften: Zeitschr. prakt. Geologie, January, 1898, p. 14, fig. 10.

[2] Op. cit., p. 14, fig. 12; also Norsk Marmor, 1897, p. 59, fig. 8.

[3] Hirschwald, J., Die Prüfung der natürlichen Bausteine auf ihre Wetterbeständigkeit, Berlin, 1908, Pl. XVI, figs. 4, 5.

sharply plicated planes of bedding are intersected at intervals by slightly undulating planes of slip cleavage and both sets of planes are laden with graphite. (See p. 124 and Pls. V, *A*, and VIII, *B*, *b*.)

The texture of marble thus depends on the form, size, evenness, and arrangement of its grains and on the nature and size of the grains of other minerals in it and is affected by the amount of plication or elongation of the bedding, by the relative abundance of the planes of slip cleavage which cross it, and by any secondary compression that the marble may have suffered.

COLORS.

It would require very elaborate methods to determine the precise causes of the more delicate tints of marble, such as the bluish, ivory, and smoky. The causes of other tints are not far to seek.

The black and grayish marbles owe their shade to the presence of carbon, usually in the form of graphite in infinitesimal scales and powdery particles disseminated throughout the plates of calcite or dolomite.

The reddish, pinkish, and reddish-brown marbles contain minute particles of a compound with manganese oxide (MnO) or of hematite (Fe_2O_3) or of both.

The brownish, yellowish, and cream-colored marbles owe their color to limonite or hydrous iron sesquioxide (ferric oxide) ($2Fe_2O_3.3H_2O$) in varying amounts. In thin sections of some marbles this limonite stain can be seen emanating from oxidized particles and crystals of pyrite.

The greenish marbles (of course exclusive of the serpentines), of Vermont at least, owe their color mainly to fibrous muscovite (sericite), with which in the brighter marbles chlorite and epidote are associated.

A purplish tint in one of the dolomites of Lake Champlain (p. 143) appears to be due to the combination of hematite and magnetite.

The more uncommon colors of marble are purplish, as in the Pavonazzo and Seravezza breccias, imported from Italy, bright yellow, as in the "Giallo Antico" from North Africa, and orange-yellow, as in some marbles from Norway. Among the uncommon combinations of colors is that of rose-pink and deep green in the "Leifset Gloire" from Norway.

Vogt [1] is inclined to attribute the sky-blue, bright-red, and orange tints of some Norwegian marbles to organic compounds. He states that the blue disappears on heating for a short time to 100° C., or after five years exposure to the light, and that the red changes after heating for a short time to 300° or for a longer time to 150° to 200° but returns on cooling.

[1] Vogt, J. H. L., Norsk Marmor, 1897, p. 354.

ORIGIN OF LIMESTONE AND MARBLE.

The origin of marble can not well be considered without considering that of the limestone from which it has been formed. The origin of dolomite marble will be considered after describing the relations of dolomite and calcite marble.

Some of the simplest illustrations of the formation of calcareous deposits are to be found at no great distance from the Vermont marble belt. About 4 miles nearly north of Fair Haven, in Rutland County, Vt. (see topographic map of Whitehall quadrangle, U. S. Geol. Survey), is Inman Pond, which is about half a mile long. When the pond is low a snow-white calcareous deposit, which consists mainly of fragments of fresh-water snail shells (Limnæa and Planorbis), is exposed on the shore. The pond is surrounded by hillocks of slightly calcareous slate and the glacial gravels probably contain some limestone from the limestone areas to the north and west. The brooks, supplied with carbonic acid by the rain, have taken up calcium carbonate from the slates and the gravel and furnished the pond with slightly calcareous water, which the snails have taken into their systems and out of which they have secreted shells of calcium carbonate. The death of generations of snails has formed the white marl.

Queechy Lake, also half a mile long, lies in a minor limestone valley within the Taconic Range in Canaan, Columbia County, N. Y. (See topographic map of Pittsfield quadrangle, U. S. Geol. Survey.) The bottom of the east side of the lake is covered with certain foliaceous algæ, the leaves of which are incrusted with calcium carbonate. As generations of these plants die a calcareous sediment forms. It is supposed that the chemical precipitation of lime by water in such a case is accelerated by the exhalation of oxygen by the plants and the consequent decomposition of the calcium bicarbonate.

As most limestones are seen by the character of their fossils to be of marine origin, we must consider processes like those illustrated to have taken place in the sea—that is, calcium carbonate has been either deposited through the agency of life or chemically precipitated. An ordinary limestone would result from any great accumulation of such organic or chemical calcareous sediments compressed under their own weight. The formation of organic calcareous sediments is going on to-day in the ocean on a large scale about coral reefs and shell beds and wherever the minute calcareous shells of rhizopods rain down on the ocean floor, also wherever lime-secreting algæ abound.

Two places are cited, one in the Mediterranean and another on the west coast of Florida, where river water charged with calcium bicarbonate forms crystalline calcareous sediments as it enters the sea. The Florida deposit is of two sorts—a calcareous mud and a crystalline calcium carbonate that is essentially a calcite marble.[1] But it is generally assumed by geologists that such deposits are exceptional, that most limestones have been formed through the medium of marine organisms, and that those limestones which abound in fossil crinoids, corals, brachiopods, gastropods, or rhizopods convey to us what is probably the most correct conception not only of the origin of limestone but also of the original condition of most calcite marbles.

Some fossiliferous limestones that have not been subjected to a crustal movement great enough to destroy the outline of their fossils are yet crystalline and therefore marble. It may be uncertain whether the crystallization of such limestones took place before or after their emergence. In either case where the fossils have become crystalline we have to assume the percolation of acid waters dissolving the calcareous shells, etc., and then redepositing the lime thus taken up as crystalline calcite. This process has taken place in the black and gray marbles of Isle la Motte (see p. 47) and in all the crinoid or shell marbles of commerce, such as the Tennessee marbles.

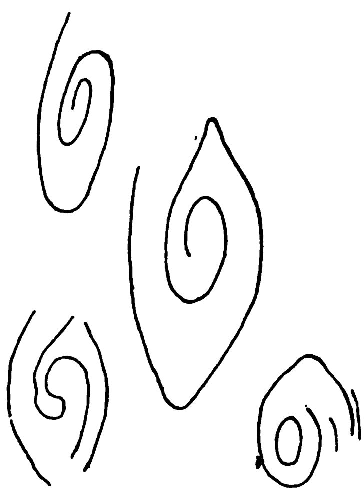

FIGURE 2.—Sections of marine snail shells in light marble on dumps at West Rutland in 1890. A little less than one-half natural size.

That the calcite marbles of western Vermont were partly if not wholly of organic origin is shown by the fossils they still contain. One of the beds of bluish-gray marble at West Rutland abounds in sections of Maclureas (large marine snails), as may be seen by examining the slabs coming from the sawing sheds. A photograph of one of these slabs polished, taken by the State geologist, has been reproduced in one of his reports.[2] Figure 2 is taken from drawings made by the writer. Some of the grayish marble beds above the quarries at West Rutland are very fossiliferous, as is a ledge beside a brook about one-fourth mile south of the Eastman quarry. (See Pl. IV.) The bluish marble at Day's quarry, in Ira, long worked for lime, contains sections of large gastropods, probably

[1] Lyell, Charles, Principles of geology, 9th ed., 1853, pp. 260, 279. Dall, W. H., and Harris, G. D., Correlation papers—Neocene: Bull. U. S. Geol. Survey No. 84, 1892, pp. 99–101, 154. Willis, Bailey, Conditions of sedimentary deposition: Jour. Geology, vol. 1, 1899, pp. 512–514.

[2] Perkins, G. H., Report of the State geologist on the mineral industries and geology of certain areas of Vermont: Report for 1907–1908, Pl. V.

Maclureas also.[1] Most of the Vermont calcite marbles, however, have no traces of fossils.

It is assumed that the general absence of fossil forms from calcite marble is due to their having been obliterated in the process of dynamic crystallization. This process has been reproduced experimentally, uncrystalline calcium carbonate having been changed to calcite marble by pressure alone, heat alone, or both together.[2]

The simplest of all these experiments consisted in exposing limestone and chalk in a closed gun barrel to great heat,[3] which resulted in transforming them into marble.

That the horizontal massive strata which now constitute the marble beds of western Vermont were subjected to very great compression is evident from the folding they have undergone. This is shown in the general and detailed sections (Pls. II and III; figs. 10, 11, 14, and 18, pp. 78, 79, 103, and 125). Such folding can be produced only by powerful lateral compression, and such compression would generate heat. Furthermore, the micaceous marbles that are interbedded with the others and the small beds of mica schist that are interbedded with the clear marbles owe their fibrous mica to the micasization of particles of clayey sediment, and the process of micasization, as reproduced experimentally, has been found to require heat as well as pressure.[4]

For these reasons the calcite marbles of western Vermont and of regions of like geologic character are regarded as limestones of marine and mostly of organic origin, which have been metamorphosed under great pressure accompanied by heat.

In view of what has been stated as to the origin of limestone and calcite marble we should distinguish between (*a*) a fine-grained limestone in which the particles are exceedingly minute and of irregular form and polarize but are without twinning planes; (*b*) a fossiliferous limestone in which percolating waters have dissolved calcareous fossils and deposited crystalline calcite; and (*c*) a fully crystalline calcite marble, the product of metamorphism, in which the calcite plates, larger than those in the matrix of *b*, are mostly twinned. Hirschwald,[5] in his exhaustive work on the testing of the weathering qualities of building stones, divides the finer-grained limestones

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[1] Letter from C. D. Walcott.

[2] See Clarke, F. W., The data of geochemistry, 2d ed.: Bull. U. S. Geol. Survey No. 491, 1911, pp. 531, 532.

[3] See Hall, James, Trans. Royal Soc. Edinburgh, vol. 6, 1812, pp. 71-185; Becker, Arthur, Min. pet. Mitt., vol. 7, 1886, pp. 122-145; and Le Chatelier, H., Compt. Rend., vol. 115, 1892, pp. 817-820, 1009-1011.

[4] A. Daubrée (Études synthétiques de géologie expérimentale, 1879, pp. 176, 177; Smithsonian Rept. 1861. p. 285), by exposing moist clay in a closed steel tube to the heat of a gas furnace for several days, succeeded in manufacturing minute crystals of a uniaxial mica or a chlorite. On the subject of micasization or sericitization see Clarke, F. W., The data of geochemistry, 2d ed.: Bull. U. S. Geol. Survey No. 491, 1911, pp. 566-568.

[5] Hirschwald, J., Die Prüfung der natürlichen Bausteine auf ihre Wetterbeständigkeit Berlin, 1908, p. 382.

(excluding marbles) into two groups--cryptocrystalline, in which the interlocking ill-defined crystalloids polarize light, and pelitomorphic, which consist of roundish granules 0.003 to 0.005 millimeter in diameter, that feebly but clearly operate upon polarized light.[1]

The metamorphism by which a bed of limestone is changed to marble is not always traceable entirely to lateral compression of the strata. It may also be caused in part by the heat proceeding from an igneous intrusive.

Renwick[2] mentions an interesting occurrence at Middleton, near Wirksworth, in Derbyshire, where beds of limestone have been traversed by a dike at a very low angle. The limestone below the dike has been changed to marble, and is quarried for marble uses, but the limestone above the dike is unaltered and is used for lime burning, etc.

Conybeare[3] described the conversion of chalk into marble in the north of Ireland, in these words: "Here within the distance of 90 feet three [basalt] dikes may be seen traversing the chalk, which is converted into a finely granular marble where contiguous to the two outer dikes and through the whole of the masses included between these and the central one."

Finally, the metamorphism by which a bed of limestone passes into marble may be of any geologic age. Naturally we look for marbles in the strata formed after marine life became abundant and in those places where organic deposits have been subjected to powerful crustal movements or exposed to igneous intrusion.

CALCITE MARBLE.

If calcite marble contained nothing but calcite its chemical composition and properties and many of its physical properties would be identical with those of calcite. Calcite ($CaCO_3$), or calcium carbonate, contains 56 per cent of CaO (lime) and 44 per cent of CO_2 (carbon dioxide). It effervesces strongly with cold dilute hydrochloric acid and is entirely soluble in cold dilute acetic acid. When burned it loses CO_2 and becomes CaO (quicklime). It has a specific gravity of 2.72 and a hardness of 3, being a little harder than gypsum, which is 2, and softer than dolomite, which is 3.5 to 4. It has a marked rhombohedral cleavage and a white or grayish streak when scratched.

Calcite marble when perfectly pure and therefore white consists entirely of crystalline plates of calcite with rhombohedral cleavage,

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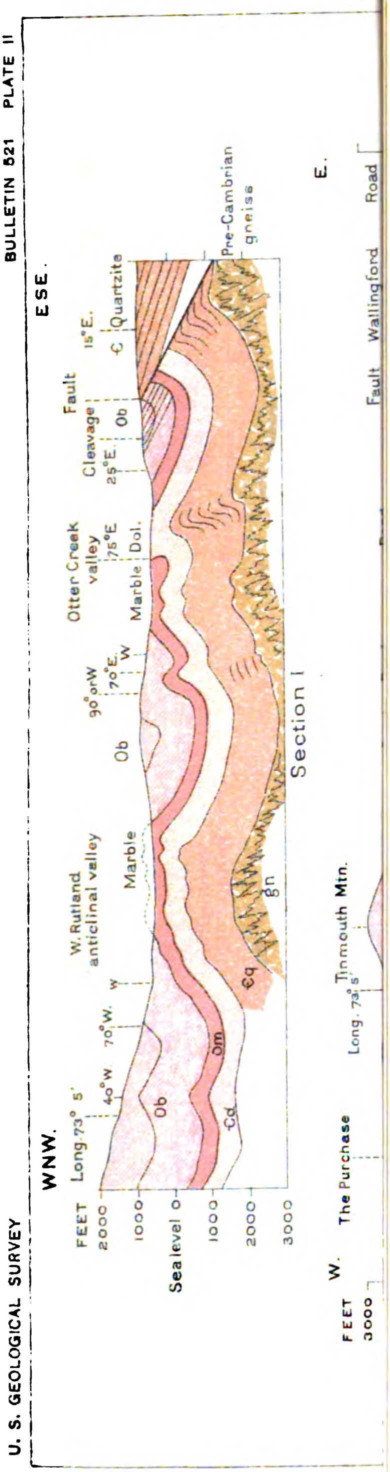
[1] Hirschwald, J., Die Prüfung der natürlichen Bausteine auf ihre Wetterbeständigkeit, Berlin, 1908, pp. 443, 444; sec. 532; Pl. XVII, figs. 10, 11, 12.

[2] Renwick, W. G., Marble and marble working, London, 1909, p. 4, fig. 1.

[3] Conybeare, W. [Descriptive notes referring to the outline of sections presented by a part of the coasts of Antrim and Derby, from the joint observations of Rev. W. Buckland and himself during a tour in the summer of 1813]: Trans. Geol. Soc. London, vol. 3, 1816, p. 210.



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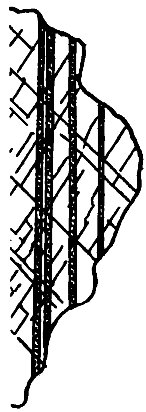

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[1] Hirschwald,
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[2] Renwick, W
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many of which are twinned. These twinning planes are parallel to either set of the sides of the cleavage rhomb or else bisect more or less exactly its acute angle, never its obtuse angle.

A typical microscopic grain of calcite with cleavage and twinning as it appears in a thin section of marble is shown in figure 3. Calcite marble always takes a high polish, but the presence of minute particles of quartz, dolomite, or mica detracts from the polish, the quartz and dolomite from their greater hardness forming minute protuberances on the face, and the mica causing minute cavities from the dropping out of scales in the process of sawing and polishing. Typical thin sections of white calcite marble are shown in figures 16 and 24, pages 119 and 140.

The commonest accessory minerals in the pure-white calcite marbles of Vermont are quartz, muscovite, and pyrite. Exceedingly minute opaque particles are not uncommon. Their nature is uncertain. They are probably magnetite or pyrolusite (manganese dioxide) or both.

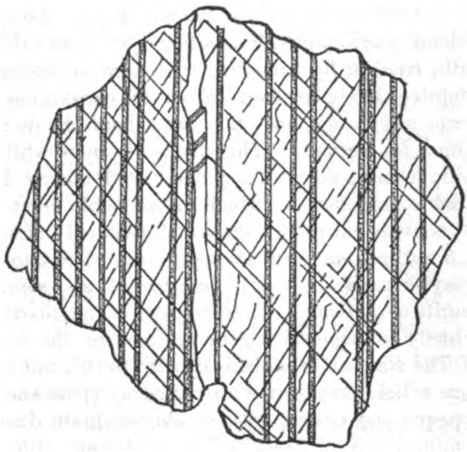

FIGURE 3.—Thin section of a grain of white calcite marble, "Mahogany bed," Freedley quarries, showing typical calcite twinning bisecting acute angle of cleavage rhomb. Enlarged 55 diameters.

The graphitic, muscovitic, and brecciated calcite marbles of Vermont are discussed on pages 39, 41, 48. The other minor varieties are described in connection with the quarries and all are summarized and classified in the table on pages 150–154. The grades of texture of calcite marbles are specially considered on page 54.

In connection with this part of the subject descriptions of three thin sections of Italian (Carrara) and one of Greek (Pentelicon) marble, examined by the writer, are given here for comparison.

"Carrara ordinary," white marble with slight bluish tinge and undefined light-gray mottling. Texture even; outlines of some grains slightly toothed; twinning parallel to sides of cleavage rhomb or bisecting its acute angle; minute opaque specks throughout; a few grains of pyrite; quartz rare; grain diameter 0.05 to 0.5 but mostly 0.12 to 0.3 millimeter.

"Pentelicon," modern commercial, white, less bluish than marble above described. Texture somewhat irregular, less regular than that of Carrara marble; outlines of grains not toothed; twinning parallel to sides of cleavage rhomb or bisecting its acute angle; minute opaque specks throughout; a few grains of pyrite; quartz sparse; muscovite scales very rare; grain diameter 0.05 to 0.75, but mostly 0.12 to 0.37 millimeter, more of 0.12 than in Carrara marble.

The interesting study of Greek marbles by Lepsius [1] already referred to (p. 18) was based on the examination of thin sections obtained from outcrops at the chief quarries worked by the ancient Greeks, at some of which unfinished columns or statues still remained, and on a comparison of such sections with others obtained from chips of similar marbles in ancient Greek buildings and sculptures. These quarries were on the islands of Paros and Naxos, in the archipelago; on Mounts Pentelicon and Hymettos, about northeast of Athens; in the Agrilesa Valley, 2½ miles north of Cape Sunium and 25 miles southeast of Athens; and at Doliana, in Arcadia, southwest of Corinth. As Lepsius's book is one of the most thorough works on the texture of marble yet published but is inaccessible in translation, a brief summary of its conclusions is here given:

"Lichnites Lithos" of Paros, "Parian statuary," from the northwest side of the island, was obtained from a bed 6½ to 13 feet thick with an average dip of 30° into the hill, reached by tunneling from a point 656 feet above sea level along the bed to a depth of 195 to 260 feet. From this excavation at least 1,000,000 cubic feet of marble, from which, of course, the waste should be deducted, had been excavated in ancient times for statuary. This marble is snow white, with a faint bluish-gray tint. It is very translucent and was also noted among Roman stonecutters for its hardness—that is, its cohesion—which was probably due to its being quarried so far underground. It consists entirely of cleft and twinned calcite grains with diameter mostly of 1 to 1.5 millimeters, many grains 1.5 to 2, some 2 to 3, and a few 3 to 5. It contains some grayish particles, mostly translucent, also some extremely minute black ones (magnetite or carbon?). In some parts of the quarry the marble has dark-gray streaks due chiefly to magnetite, as determined by the form of the crystals.[2]

The Naxos marble beds dip 25° to 70°, but were quarried diagonally. The marble has a light-gray tint with dark-gray spots and streaks and some gray grains. It is opaque and coarse, with an average grain diameter of 2 to 3 millimeters and many grains 3 to 5 millimeters, here and there with some fine interstitial grains. Many of the grains contain minute gray, black, or colored particles to which the marble owes its tint. In places the dark particles are so plentiful as to cloud the otherwise clear calcite.[3]

The "lower white Pentelicon marble" is somewhat milk white with a faint yellowish tint and rare light-gray streaks. The grain diameter is mostly 0.5 to 1 millimeter, never over 2 millimeters. The grains lie in an opaque milk-white groundmass of fine grains, without cleavage or twinning planes. Both large and small grains contain very minute and indeterminable inclusions. Muscovite, chlorite, a reddish-violet potash mica, pyrite with a zone of limonite, more rarely magnetite, and rare grains of quartz occur in it. The decay of parts of the great frieze of the Parthenon, which was cut from this marble, is due to the presence of mica streaks along the bedding plane.[4] (See further, p. 37.)

"Hymettic marble," from the upper blue-gray beds of the northwest and north slopes of Mount Hymettos, consists of cleft and twinned calcite grains up to 0.5 or rarely 0.8 millimeter in diameter, thus smaller than in the Pentelicon marble, in a dense, slightly translucent groundmass of fine calcite grains without cleavage or twinning, the groundmass predominating over the larger calcite grains. The accessory

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[1] Lepsius, G. R., Griechische Marmorstudien: Anhang Abhandl. K. Akad. Wiss. Berlin, 1890.
[2] Idem, pp. 43–52.
[3] Idem, pp. 52–55.
[4] Idem, pp. 15–22.

minerals are muscovite, chlorite, and small black particles of iron, which rust on exposure. The gray shade is attributed to minute grains of carbon.[1]

The "lower white Attic marble" from the quarry near Cape Sunium has a light bluish-gray tint and gray banding. Its cleft and twinned larger calcite grains measure as much as 1 millimeter. The groundmass of smaller structureless grains is relatively small in amount. The marble does not form a yellowish crust in weathering. The minute black specks, visible in thin sections, are regarded as carbon.[2] (See p. 15.)

The marble of Doliana, in Arcadia, is faintly bluish gray and without streaks. The cleft and twinned calcite grains are denticular and elongate, with diameters of 0.5 to 1, rarely 2 to 4 millimeters, lying in a dense glassy light bluish-gray groundmass of minute structureless calcite grains. This marble contains 0.12 per cent of Fe_2O_3 and therefore in weathering forms a yellow and reddish brown film. In weathering the groundmass becomes milk white, the larger grains become more conspicuous, and the stone finally becomes "sandy." The thin sections show rare quartz grains and dark grains.[3]

Interesting descriptions of other European marbles will be found in the papers of Vogt, Lindenmann, Weinschenk, and Steinhäuser, cited in the bibliography on pages 56, 58.

Of the Tyrolese marbles less is known in this country than of the Italian. They occur near Laas Peak, about 22 miles west-southwest of the city of Meran, in Vintschgau, in the Austrian Tyrol. They include a coarse marble with grain diameter of 5 millimeters (Sterzing) which takes a high polish, and also a finer marble, "Laas statuary," with a maximum grain diameter of 1 millimeter. The latter is quarried at a point 7,535 feet above the valley floor. It is clear white and very sonorous. It is almost as translucent as Carrara statuary marble, but is somewhat harder and coarser and has been found to be more durable under outdoor exposure in the climate of central Europe. It has been used for the statues of Mozart and Haydn in Vienna and Von Moltke in Berlin and is regarded as equal to Parian marble for statuary.

The purplish and white brecciated "pavonazzo" of Carrara contains a little micaceous hematite and some biotite. The "cipolino" of the same region has calcite grains with flexed twinning planes. It contains biotite passing into chlorite, epidote, klinozoisite, titanite, tourmaline, and green hornblende. The "bianco P" of Carrara has veinlets of untwinned dolomite.

DOLOMITE MARBLE.

A pure dolomite marble would have the chemical and many of the physical properties of dolomite. It has greater compressive strength than calcite marble, as is shown by the tests recorded on page 16.

Dolomite ($CaMgC_2O_6$), a carbonate of lime and magnesia, contains 54.35 per cent of $CaCO_3$ (calcium carbonate) and 46.65 per cent of $MgCO_3$ (magnesium carbonate). It effervesces less readily with cold

[1] Lepsius, G. R., Griechische Marmorstudien: Anhang Abhandl. K. Akad. Wiss. Berlin, 1890, pp. 22-24.
[2] Idem, p. 27.
[3] Idem, pp. 31-33.

dilute hydrochloric acid than calcite and is next to insoluble in cold dilute acetic acid. It burns like calcite. It has a specific gravity of 2.83 and a hardness of 3.5 to 4, being thus a little heavier and harder than calcite. It has a marked rhombohedral cleavage and crystallizes in rhombohedra, the faces of which are usually curved.

Dolomite marble is of two kinds. One is like that of Lee, Mass., which consists of crystalline plates of dolomite of irregular outline, with rhombohedral cleavage and twinning planes that are either parallel to a side of the cleavage rhomb or bisect its obtuse angle, as in figure 4. Rarely it bisects the acute angle. In a section of dolomite from Plymouth, Vt., a grain was found in which twinning planes bisect both acute and obtuse angles. In calcite the twinning plane never bisects the obtuse angle, being either parallel to one of the sides of the rhomb or bisecting its acute angle. This distinction between dolomite and calcite is based on the difference in the rhombohedra of the two minerals and affords a simple means of distinguishing the two marbles in thin sections.[1] When both minerals occur in the same thin sections without twinning and the dolomite is not in rhombs, the microchemical test may be used.[2] In the dolomite marble of Lee the grains are as much interlocked as they are in many calcite marbles, but in some dolomite marbles of this class the texture is somewhat granular, resembling that of loaf sugar, in which the grains simply cohere. In such a marble the cohesion is less than that of a calcite marble or of the dolomite marble of Lee, although the material is harder than calcite.

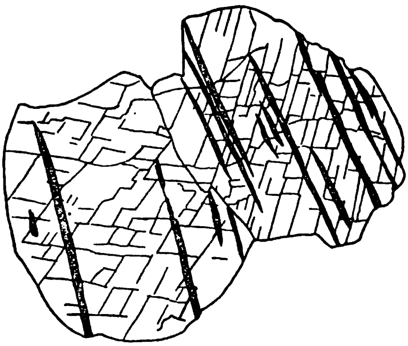


FIGURE 4.—Thin section of white twinned dolomite marble from Gross quarry, Lee, Mass., showing two grains of dolomite with typical dolomite twinning bisecting obtuse angle of cleavage rhomb. Enlarged 77 diameters.

In the other variety of dolomite marble the texture is finer and more granular or mixed coarse and fine, and a larger or smaller percentage of the grains have a rhombic outline but are not twinned. (See fig. 8, p. 44.) Exceptionally, however, a lens or veinlet with twinned plates of dolomite occurs in these marbles. To this variety belong the marbles of Lake Champlain fully described beyond.

[1] See Rosenbusch, H., Elemente der Gesteinslehre, 3d ed., 1910, p. 523; also Vogt, J. H. L., Der Marmor in Bezug auf seine Geologie, Structur, und seine mechanische Eigenschaften: Zeitschr. prakt. Geologie, Berlin, 1898, p. 11.

[2] See Lemberg, J., Zur mikroskopischen Untersuchung von Calcit, Dolomit und Predazit: Zeitschr. Deutsch. geol. Gesell., vol. 40, 1888, pp. 357-359.

Dolomite marbles of both kinds take a high polish but of course are harder to polish than calcite marble. Some dolomite marble becomes minutely pitted in polishing from the dropping out of powdery magnesia as a result of the decomposition of some of the dolomite grains.

The commoner accessory minerals of white dolomite marble are quartz, pyrite, muscovite, and tremolite.

The colored dolomite marbles of Vermont, containing hematite or graphite, are described on pages 43–46, and are summarized and classified in the table on pages 152–153. Their grades of texture are specially considered on pages 142–143.

Descriptions of a few thin sections of dolomite marble from Massachusetts, Connecticut, and Norway, studied by the writer, are added for reference and comparison.

White dolomite marble, Gross quarry, Lee, Mass. Pale bluish white without tremolite, which, however, abounds in certain beds. Texture, even; grain outlines but slightly toothed; twinning bisects obtuse angle of cleavage rhomb. (See fig. 4.) Grain diameter 0.07 to 1, mostly 0.02 to 0.5 millimeter.[1]

Bluish dolomite marble, Ashley Falls Marble Co.'s quarry, Ashley Falls, Mass. Light bluish gray, rarely with prisms of tremolite and minute pyrite. Texture even; grain outlines somewhat toothed; twinning planes bisect obtuse angle of cleavage rhomb; minute opaque specks throughout; a few muscovite scales; quartz rare and small; no pyrite or tremolite in sections. Grain diameter 0.02 to 0.75, mostly 0.05 to 0.5, average 0.27 millimeter.

Light bluish gray, very fine grained dolomite (not commercial marble) from a drill core 35 feet below rock surface at Agricultural National Bank, Pittsfield, Mass. Texture uneven; grain outline roundish or angular, not rhombic and without twinning. Some muscovite scales; quartz and plagioclase feldspar grains; pyrite crystals. Diameter of grains 0.02 to 0.17 but mostly 0.05 to 0.12, average 0.08 millimeter. Some lenses or veins of coarse particles abounding in minute opaque specks, diameter 0.12 to 1.25 millimeters, with twinning bisecting obtuse angle of cleavage rhomb.

White dolomite marble from near Amenia, N. Y., but in Connecticut. White to cream color, granular appearance. Texture even; grain outlines straight or roundish; twinning bisects obtuse angle of cleavage rhomb; one bisecting acute angle. (See p. 28.) Grain diameter 0.05 to 0.62, mostly 0.12 to 0.25, average 0.18 millimeter.

White dolomite marble from Norway. Milk-white with parallel grayish streaks. Texture very irregular; grain outlines not toothed; twinning planes parallel to sides of cleavage rhomb or bisecting its obtuse angles. Minute opaque specks throughout. Several large muscovite flakes; pyrite minute, sparse. In finer parts grain diameter 0.05 to 0.25, average 0.15 millimeter; in coarser parts 0.12 to 1.37, many 0.25 to 0.62 millimeter.

RELATION OF CALCITE MARBLE TO DOLOMITE IN VERMONT.

As will be seen from the geologic map (Pl. I) and the discussion of the geologic formations on page 64, the lower 650 feet, approximately, of the Vermont calcareous belt consist mainly of dolomite, described in detail on page 66, and the marble is confined almost entirely to the

[1] This marble has been described by J. S. Diller in Bull. U. S. Geol. Survey No. 150, 1898, pp. 299, 300.

upper half of the formation. The most productive quarries appear to be in the upper part of this upper half, although some occur also in the lower part. But, as appears from the detailed sections and the stratigraphic succession on page 66, the marble beds themselves are interbedded with dolomite.

At the now disused Sutherland Falls or Proctor quarry (see Pl. I) the calcite marble beds, roughly estimated at 170 feet thick but in part doubled over so as to measure apparently 200 feet, are overlain on the west by dolomite and also underlain on the east by another dolomite. The dolomite on the west side, which is followed farther west by calcite marble, consists of dolomite granules, rarely rhombs, having an average grain diameter of 0.04 millimeter and some dolomite plates reaching 0.25 millimeter, with twinning planes bisecting the obtuse angle; also sparse quartz grains, muscovite flakes, and pyrite oxidizing to limonite. The whitish dolomite on the east side consists of dolomite plates, some of them twinned, all crowded with dark granules, having diameters mostly 0.12 to 0.45 millimeter, lying in a matrix of smaller untwinned clear dolomite grains. The outlines of the larger plates, being governed by those of the small ones, appear denticulate.

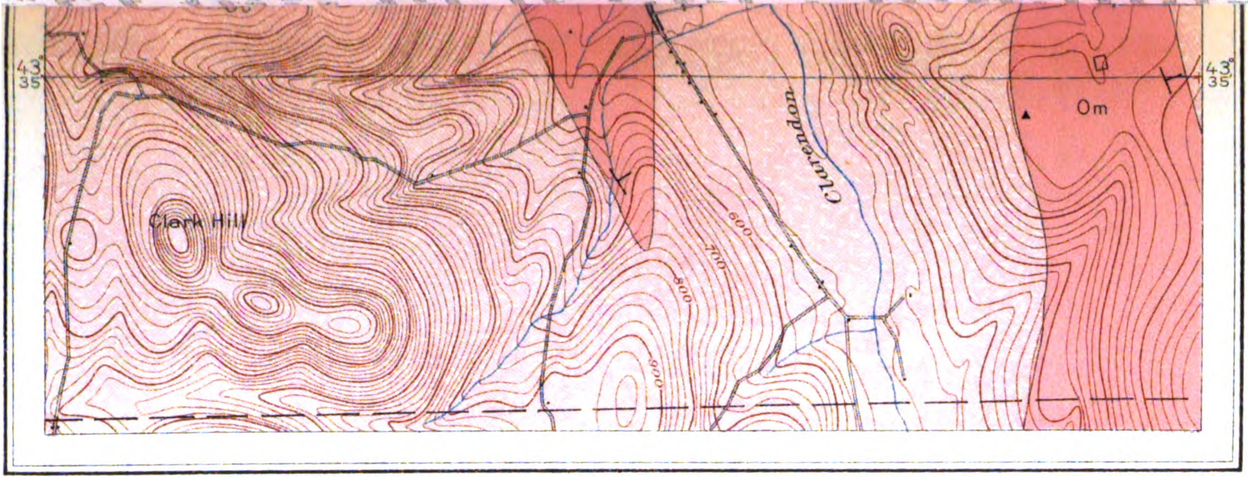
At the True Blue quarry (see Pl. XV, *A*, and fig. 18, p. 125) there is a 15-foot bed of dolomite with calcite marble on both sides of it. A drill core at West Rutland shows nine dolomite beds from 1.8 inches to 16 feet thick, alternating with beds of calcite marble. The whole series measures 250 feet 7 inches, out of which the dolomite beds measure 73 feet 9 inches.

A drill core at the Albertson quarry shows three or four dolomite beds from 4 to 22 feet thick alternating with beds of calcite marble, the whole series measuring 94 feet 4 inches.

At the Florentine quarry in Pittsford the bluish-gray calcite marble contains nodules of very dark gray dolomite. The nodules are brecciated and veined with calcite and quartz. In thin section they are seen to consist of graphitic dolomite.

At the Valley quarry of the Norcross-West Marble Co. at South Dorset there is a 10-foot bed of dolomite at the northeast end of the quarry in contact with the marble. This consists of dolomite grains tending to rhombic outline, averaging about 0.1 millimeter in diameter. The larger particles are cloudy and full of minute dark specks, sparse quartz, a little vein quartz, and pyrite (?).

At the Eastman quarry in West Rutland (see Pls. I, IV) there is a dove-colored dolomite on the east side of the marble beds, which is finely veined with quartz and weathers a delicate pale brown. It consists of grains of dolomite, rarely rhombs, averaging 0.028 millimeter in diameter, with sparse small quartz particles and intersecting quartz veins, some of these with large dolomite plates; also



14. Umbrella
15. Rutland-Florence
16. Albertson
17. True Blue
18. Riverside

MAP OF WEST RUTLAND BELT OF MARBLES

Showing quarries and probable distribution of the marbles

Scale $\frac{1}{31,250}$

0 ½ 1 Mile

1912

a few flakes of muscovite and dark particles, probably pyrite, accounting for the discoloration of the surface.

Coarse-grained white calcite marble and fine-grained white dolomite are interbedded in one of the old quarries near the Owls Head, as shown in figure 5. This was described by the writer in 1902.[1] The dolomite consists of irregular dolomite grains, rarely tending to rhombic form, averaging about 0 06 millimeter in diameter, sparse

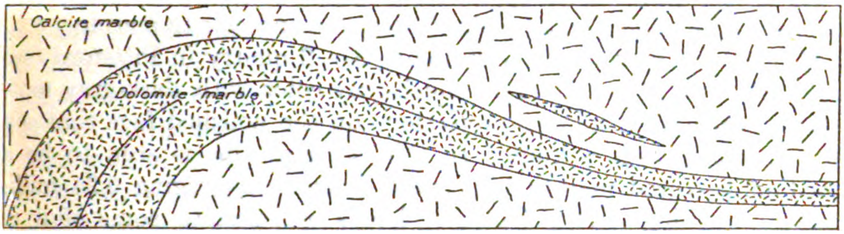


FIGURE 5.—Interbedded calcite marble and dolomite. Length, 40 feet. Old quarry three-fifths mile west of the Owls Head, Dorset, Vt.

quartz grains up to 0.12 millimeter, rare muscovite plates and feldspar grains, and minute opaque particles. An analysis of it by George Steiger, of the Survey, first published in the paper just cited, is as follows:

Analysis of whitish dolomite from quarry in Dorset, Vt.

Silica (SiO_2)	8. 36
Alumina (Al_2O_3)	1. 77
Iron sesquioxide (Fe_2O_3)	. 22
Iron oxide (FeO)	1. 08
Magnesia (MgO)	16. 68
Lime (CaO)	29. 03
Soda (Na_2O)	. 06
Potash (K_2O)	1. 08
Water uncombined (H_2O-)	. 03
Water combined (H_2O+)	. 42
Carbon dioxide (CO_2)	41. 66
	100. 39

Between the dolomite and the calcite is a small quartzose bed, which contains sparse quartz grains, stringers of sericite, pyrite, quartz lenses, and calcite plates. As shown in figure 5, there is also a lens of dolomite in the marble and near the dolomite bed.

On the west side of Pine Hill, in the upper part of the marble series close to its contact with the overlying schist, 1½ miles south-southeast of Proctor (see Pls. I and IV), is a bed of gray and white

[1] Dale, T. N., Structural details in the Green Mountain region and in eastern New York: Bull. U. S. Geol. Survey No. 195, 1902, pp. 13–15.

mottled calcite marble containing angular and roundish fragments of dolomite,[1] which, being less soluble by atmospheric acid than the rest of the rock, project on the weathered surface. The marble shows calcite with grain diameter of 0.05 to 0.37 millimeter; the dolomite consists of large irregular plates 0.25 to 1.5 and small grains averaging roughly 0.07 millimeter. The dolomite fragments range from an inch or over down to 0.1 inch in diameter. This association of dolomite and calcite appears to be due to the brecciation of a series of alternating small beds of dolomite and calcite marble.

The calcite marble of the Florence No. 2 quarry in Pittsford (see map, Pl. I) is of a very light bluish-gray color with dark-gray mottlings, which form minute projections on the polished face that can be scratched with a knife. In thin sections this is seen to be a medium-textured marble, with grain diameter averaging 0.24 millimeter, inclosing minute bands or lenses of dolomite, some of it in rhombs, with a grain diameter averaging, roughly, 0.15 millimeter, and a few quartz grains and muscovite scales. The mottled calcite marble of the Turner quarry, "Pittsfield Italian," has similar minute beds of dolomite. A sketch of one of these in natural size is shown in figure 20, page 131. The marble of the Landon quarry has similar little dolomite beds. (See p. 135.)

The slightly bluish-white, gray-streaked calcite marble near the base of the marble beds, quarried near Clarendon village (see p. 110), has calcite grains mostly from 0.12 to 0.5 millimeter in diameter, and contains bands of dolomite of irregular and rhombic grains averaging roughly 0.06 millimeter.

A banded calcite marble at a disused quarry three-fourths of a mile southwest of the top of Boardman Hill, in Clarendon, belonging near the top of the marble beds, consists of black, dark-gray, and whitish parallel bands from 0.02 to 0.5 inch thick. In thin section some of these little beds are seen to consist of calcite grains from 0.12 to 0.75 millimeter in diameter, some of them full of graphite; others have calcite with a grain diameter from 0.07 to 0.25 millimeter. But some of the beds are dolomite with an average grain diameter of 0.06 millimeter and with some large dolomite plates of 0.09 millimeter. Some of the calcite bands also contain small lenses of dolomite.

The most interesting combination of calcite and dolomite is the black marble of Isle la Motte. (See p. 47 and fig. 9.) The dark bluish-gray weathered surface of this black marble, which effervesces freely with acid, shows little irregular beds of brownish-gray color which effervesce less freely and form a network about and between the fossil fragments. In thin section this rock is seen to consist of irregular alternations of dolomite in rhombs 0.02 to 0.1

[1] This bed was referred to by Hitchcock and Hager (Geology of Vermont, vol. 1, 1861, p. 399).

millimeter in diameter and of fossiliferous calcite bands. In the gray crinoid marble bed of the same quarry (p. 48) some of the crinoid columns are of calcite with twinning planes bisecting the acute angle of the cleavage rhomb, but the matrix contains rhombs of dolomite.

The black unmetamorphosed marble of Isle la Motte, with its large Maclureas and other Chazy fossils, may be safely regarded as a close approximation to the condition of the Chazy limestone in the metamorphic marble belt of Vermont before metamorphism took place; and the association of dolomite and calcite in the one throws light on their association in the other, particularly in those parts of the rock where the dolomite forms minute lenses or bands in the calcite marble. These bands were there prior to regional metamorphism.

Exploration of the marbles in eastern Vermont, the results of which will appear in a later bulletin, brings out the fact that the calcite marbles there are also interbedded with dolomite, but generally in beds from a fraction of an inch to several inches thick, and that this dolomite, although fine grained, is almost everywhere twinned, whereas in western Vermont it is mostly untwinned, "granular."

THE ORIGIN OF DOLOMITE.

Much has been written on the origin of dolomite, and some facts have been definitely established.

Dolomite may be formed in the ocean by the chemical action of sea water substituting magnesium for part of the calcium in a deposit of calcium carbonate or in a coral. The best evidence of this is the drill core obtained by a boring made on the coral island of Funafuti under the direction of the Royal Society.[1] The bore hole was 1,114 feet deep and penetrated a rock of organic origin, consisting of various alternations of calcitic and dolomitic rock. The percentage of $MgCO_3$ (magnesium carbonate) was inconsiderable down to 640 feet, where it was 26.33 per cent. From 698 feet down to 1,114 feet it ranged from about 39 to 41 per cent. As the percentage of magnesium carbonate in living coral and in the calcareous parts of other marine organisms is insignificant, and as the salts of the sea, which make up 3.737 per cent of the water, contain 1.676 per cent of CaO (lime), or 1.196 per cent of Ca (calcium), and 6.209 per cent of MgO (magnesia), or 3.769 per cent of Mg (magnesium), it is thought that the magnesium in the dolomitic beds of this organic rock may have been supplied by the sea through a process of dolomitization.[2]

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[1] The atoll of Funafuti, Royal Soc. London, 1904.

[2] Instructive papers on this subject are those of Skeats, E. W., The chemical composition of limestones from upraised coral islands, with notes on their microscopic structures: Bull. Mus. Comp. Zool. Harvard Coll., vol. 42, 1903, p. 53; On the chemical and mineralogical evidence as to the origin of the dolomites of southern Tyrol: Quart. Jour. Geol. Soc. London, vol. 61, 1905, p. 97.

Dolomite has also been formed by the dolomitization of a limestone after its emergence from the sea. Unmistakable evidences of this process have been found in Ireland and other places.[1]

In these localities dolomitization was brought about after emergence by percolating waters carrying magnesium carbonate in solution, which was substituted for part of the calcium carbonate in the limestone. Whether these magnesian waters came indirectly from the sea or directly during a second submergence is not clear.

Dolomite has also, it is asserted by some geologists but disputed by others, been formed by chemical precipitation in the sea. Archibald Geikie[2] says that dolomite "occurs sometimes in beds of original deposit, associated with gypsum, rock salt, and other results of the evaporation of saturated saline waters; it is also found replacing what was once ordinary limestone." Zirkel[3] maintains that the direct precipitation of dolomite is just as possible as that of calcite. Strahan[3] describes a 4-foot seam of coal in one of the English collieries which in a space of 750 feet passes into a 3-foot bed of pure dolomite and the origin of which is attributed to direct deposition.[4]

Loretz[5] described certain fine foliaceous dolomites, the texture of which in his opinion points strongly to direct deposition. Gümbel[6] regards the interbedding of dolomite and limestone, the occurrence of lenses of dolomite in limestone, the strict separation of dolomite from overlying limestone, and the distinct bedding of the dolomite as all pointing to the original sedimentation of dolomite.

On the other hand, Doelter and Hoernes regard the greater part of dolomite as due to the calcareous secretions of marine organisms dolomitized probably by magnesium chloride in sea water.[7]

Klement[8] regards it as formed by concentrated sea water in solarly superheated closed basins acting upon aragonite deposited by marine organisms. Aragonite is that form of $CaCO_3$ which constitutes corals, shells, etc.

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[1] See Wyley, Andrews, On the character and mode of occurrence of the dolomitic rocks of Kilkenny: Jour. Geol. Soc. Dublin, vol. 6, 1856, pp. 114-119, figs. 1-3, showing a vertical "dike" of dolomite 1 to 2 feet thick crossing horizontal beds of limestone, also dolomite replacing the upper part of a series of horizontal and undulating beds of limestone, the boundary between the two rocks zigzagging most irregularly across the bedding planes. See also Harkness, Robert, On the jointings in the Carboniferous and Devonian rocks in the district around Cork; and on the dolomites of the same district: Quart. Jour. Geol. Soc. London, vol. 15, 1859, p. 100. Dolomitization has operated along the joints of the limestone.

[2] Textbook of geology, vol. 2, p. 193.

[3] Zirkel, F., Lehrbuch der Petrographie, 2d ed., vol. 3, 1894, p. 502.

[4] Strahan, A., On the passage of a seam of coal into a seam of dolomite: Quart. Jour. Geol. Soc. London, vol. 57, 1901, pp. 297-306.

[5] Loretz, H., Untersuchungen über Kalk und Dolomit: Zeitschr. Deutsch. geol. Gesell., vol. 30, 1878, pp. 387-414, Pls. XVII, XVIII; vol. 31, 1879, pp. 756-774.

[6] Gümbel, C. W., Die geognostischen Verhältnisse des Ulmer Cementmergels, seine Beziehungen zu den lithographischen Schiefer und seine Foraminiferen Fauna: Sitzungsb. K. b. Akad. München, 1871, pp. 38-62.

[7] Doelter, C., and Hoernes, K., Chemisch-genetische Betrachtungen über Dolomit: Jahrb. K.-k. geol. Reichsanstalt, vol. 25, 1875, pp. 297-332.

[8] Klement, C., Sur l'origine de la dolomie dans les formations sédimentaires: Mém. Soc. belge géol., pal. et hydrol., vol. 9, 1895, pp. 3-23; abstract in Geol. Mag., London, new ser., dec. 4, vol. 2, 1895, p. 329.

Pfaff[1] attributes dolomite to the dolomitization of $CaCO_3$ (either as chemical precipitate or of organic origin) during or after its deposition.

Hunt's early experiments[2] demonstrated that precipitations of a mixture of calcium carbonate and hydrated magnesium when heated above 120° pass into dolomite.

Van Hise[3] and Clarke[4] do not consider the chemical precipitation of dolomite as probable under any conditions.

Linck[5] attributes the origin of dolomite largely to ammonium salts arising from organic decomposition, basing this theory on certain laboratory experiments.

In connection with the question of the origin of dolomite, attention should be called to the alternation of dolomitic and calcitic beds observed in many places besides those described in the previous pages. Vogt[6] gives a section at Furuli, in Fauske, Norway, showing a series of beds 146 feet thick consisting of 48 feet of slate overlying 57 feet of plicated fine-grained limestone, which overlies a series made up of two beds of yellow calcite marble alternating with two of dolomite marble, each bed about 12 feet thick and all plicated and without any transition from the dolomite to calcite marble. It is evident that such repeated alternations of dolomite and calcite can not be explained by dolomitization after emergence, nor can the kindred occurrences in the Vermont marble belt at West Rutland and in Dorset (described on pp. 30–32) be explained in that way.

The interbedding of dolomite and limestone is very characteristic of the limestone belt in Lehigh County, Pa., particularly in the town of South Whitehall. At a quarry visited by the writer in 1892, on the south side of Jordan Creek near Jordan Bridge (see map of Slatington quadrangle, U. S. Geol. Survey), three beds of dolomite, each 18 inches to 2 feet thick, alternate with four beds of limestone averaging about 15 feet thick. The whole series is intricately folded, there being three anticlines and three synclines in a length of 100 feet; and the limbs of these folds measure from 12 to 35 feet in length. The limestone emits a fetid odor when struck with the hammer. In thin sections the limestone is seen to consist of finely stratified irregular plates of polarizing calcite, 0.004 to 0.02 millimeter in diameter, crossed by irregular beds or veinlets of black carbonaceous matter, with lenses of calcite and rhombs reaching 0.2 millimeter, and a little pyrite. The dolomite consists of grains,

1 Pfaff, F., Ueber Dolomit und seine Entstehung: Neues Jahrb., Beilage Band 23, 1907, pp. 529–580.

2 Hunt, T. S., Am. Jour. Sci., 2d ser., vol. 28, 1859, pp. 170, 365; vol. 42, 1866, p. 49.

3 Van Hise, C. R., A treatise on metamorphism: Mon. U. S. Geol. Survey, vol. 47, 1904, pp. 798–808.

4 Clarke, F. W., The data of geochemistry, 2d ed.: Bull. U. S. Geol. Survey No. 491, 1911, pp. 534–543, particularly p. 540.

5 Linck, G., Monatsh. Deutsch. geol. Gesell., 1909, p. 230. See also Clarke, F. W., The data of geochemistry, 2d ed.: Bull. U. S. Geol. Survey No. 491, 1911, p. 536.

6 Vogt, J. H. L., Der Marmor: Zeitschr. prakt. Geologie, 1898, p. 9, fig. 5.

mostly rhombs, of dolomite, from 0.05 to 0.15 millimeter in diameter, averaging about 0.1 millimeter, in a slight very dark matrix.

Chemical analyses of both rocks made for the writer's study of this subject in 1903 by W. F. Hillebrand follow. The limestone was taken immediately under one of the dolomite beds.

Analyses of limestone and dolomite, near Jordan Bridge, South Whitehall, Pa.[a]

	Limestone.	Dolomite.
Silica (SiO_2)	3.72	2.80
Alumina (Al_2O_3)		
Ferrous oxide (Fe_2O_3)		
Ferric oxide (FeO)	.81	.84
Phosphoric acid (P_2O_5)		
Titanium dioxide (TiO_2)		
Magnesia (MgO)	3.17	17.87
Lime (CaO)	48.95	31.68
Carbon dioxide (CO_2)	41.58	43.62
Manganese oxide (MnO)	....	Faint trace.
Water, alkali (?), and carbonaceous matter	1.77	3.19
	100.00	100.00

[a] Bull. U. S. Geol. Survey No. 419, 1910, p. 190 (slightly abbreviated from original).

The carbonates in these analyses figure out as follows: Magnesium carbonate ($MgCo_3$), 37.52; calcium carbonate ($CaCO_3$), 55.65. These analyses show that both rocks contain quartz and carbonaceous matter and that the dolomite contains 10 per cent more $CaCO_3$ and about 7 per cent less $MgCO_3$ than a normal dolomite.

In the dolomites of Green Peak, Vt. (p. 31), the percentage of SiO_2 (silica) is 8.36, most of which, according to the sections, occurs as quartz and the rest in mica and feldspar. The statuary-marble bed of the Goodell quarry, near Brandon (p. 137), is in contact with a graphitic quartzose dolomitic calcitic rock. The presence of more silica in the dolomite beds of the Vermont marble belt than in the adjacent calcite marble beds points to conditions of sedimentation different from those which prevailed when the calcite beds were being deposited.

How shall these microscopic beds of dolomite in the black unmetamorphic marbles of Isle la Motte and in some of the finely banded metamorphic marbles of the Vermont valleys (p. 32) be explained? The same question may be asked as to the minute interbedding of dolomite and sericite schist, each a millimeter thick, in a plicated rock in the Alps, in which, of course, the schist was of mechanical sedimentary origin.[1] However the alternation of dolomitic and calcitic beds may be explained, the sharply defined and repeated alternations indicate great differences in the conditions of original sedimentation or in those conditions which brought about and arrested the process of submarine dolomitization.

[1] See Allenspach, G., Dünnschliffe von gefälteltem Röthidolomit-Quartenschiefer am Piz Urlaun: Vierteljahrsschr. Naturforsch. Gesell. Zürich, vol. 45, 1900, pp. 227-237.

WEATHERING OF MARBLE.

The weathering of marble is governed by four factors—the chemical composition of the marble, its texture, the general character of the climate to which it is exposed, and the local artificial conditions of the surrounding atmosphere.

Both calcite and dolomite marble are soluble in carbonic acid, which is brought down from the atmosphere in every drop of rain water; but as dolomite is less readily soluble in this acid than calcite a dolomite marble, the other factors being equal, will prove more durable than a calcite marble. (See p. 27.)

It has been thought that a fine-textured marble, by offering the rain water a greater length of grain boundary than a coarse-textured one, would weather more readily, but on the other hand a coarse-textured, loosely compacted marble will weather readily because acid water, once admitted between the grains, will travel more rapidly.[1] Marbles containing silicates in large flakes or crystals are more susceptible to weathering, for acid water gains free access along the boundaries of the silicates.

It is generally known that carvings in European marbles will stand exposure in the climate of southern Europe much better than in that of our Eastern States. Vogt states that in the dry atmosphere of Egypt, Greece, and Italy marble statues after an exposure of 1,000 years lose some of their fine lines but become coated with a fine protective crust. Lepsius found that this protecting film on ancient Greek monuments was ferruginous and that it was formed only on the marbles containing a small percentage of $Fe_4O_9H_6$. On the other hand Vogt refers to a number of Norwegian churches built partly or entirely of Norwegian calcite marble which have stood six or seven centuries exposed to the raw, windy, and cold climate of northern and western Norway with but very little if any weathering. In contrast with this Hirschwald[2] reproduces a thin section of marble, presumably Italian, which had been exposed in a monument in Berlin for 192 years and which shows the erosion of the grain surfaces, the loosening of their cohesion, and the deposition of an ocher-like substance between them.

The amount of weathering, other things being equal, is probably related to the degree of humidity of the atmosphere and the amount of rainfall. Though it is mainly due to carbon dioxide brought down by rain, it is probably due in part, as pointed out long ago by Joseph Henry, to nitric acid generated by lightning.[3]

[1] Vogt, J. H. L., Der Marmor: Zeitschr. prakt. Geologie, 1898, pp. 48, 49.

[2] Hirschwald, J., Die Prüfung der natürlichen Bausteine auf ihre Wetterbeständigkeit, 1908, Pl. XVIII, fig. 3.

[3] See Hall, James, Report on building stones: Thirty-ninth Ann. Rept. New York State Mus. Nat. Hist., 1886, p. 218.

The effect on white marble of such a climate as that of New England, outside of the cities, can be observed in many country churchyards and cemeteries. As the epitaphs on tombstones and monuments give the approximate date of their erection the amount of solution by weathering in a century can be calculated. The cemetery on Burial Hill, at Plymouth, Mass., offers some pertinent data. On a marble stone in horizontal position, dated 1825, the lettering is almost effaced, and one of the same year in vertical position is badly weathered. On a horizontal stone of 1854 the edges of the letters are rounded. But slate stones from England, Wales, and New England in the same cemetery, dated 1683, 1743, 1745, 1773, and 1828, have well-preserved lettering. The good state of preservation of epitaphs on slate dating back to the early settlement of New England is noticeable in many other cemeteries. The climatic conditions at Plymouth were doubtless aggravated by fogs and salt air. At the other extreme may be cited a block of white marble taken in 1910 from a building near South Dorset, Vt., and probably quarried there, inscribed "A. D. 1831," in which the edges of the letters and figures are fairly sharp, having stood 79 years without perceptible weathering. Generally in New England, however, the lettering on white marbles 75 to 100 years old is so far weathered that it will probably be completely effaced within 300 years of the date of the cutting. It is also a question how long the letters on the marble headstones in the national cemetery at Arlington, Va., will stand the humid atmosphere of that region.

Geikie [1] in his paper on the weathering of tombstones notes the relative durability of epitaphs on marble and slate at Peterhead, in northeast Scotland. Epitaphs 100 to 150 years old on marble were half effaced, but some 110 years old on slate had retained their sharpness.

In considering the weathering of marble in the smoke-laden atmosphere of great cities and industrial centers we must take into account, besides the action of atmospheric acids, that of sulphuric acid arising from the smoke of railroads, factories, foundries, and steam plants where soft coal is used.

Geikie [2] reproduces two thin sections of white marble, presumably Italian, one of the fresh stone obtained in an Edinburgh marble worker's yard, the other taken at right angles to the surface of an urn that had been exposed for 87 years in an Edinburgh cemetery. The second one shows that the acids have penetrated between the calcite grains and along the cleavage and twinning planes, widening them by solution, also that by a combination of sulphuric acid from

[1] Geikie, Archibald, Rock weathering as illustrated in Edinburgh churchyards: Proc. Royal Soc. Edinburgh, vol. 10, 1880, p. 531.

[2] Idem, fig. 1, p. 520.

the atmosphere with the lime of the calcite grains a crust of calcium sulphate (gypsum) has been formed in the openings and along the surface. Moreover this gypsum is full of dust and soot particles. From Geikie's examination of the marbles in that cemetery he estimates that weathering under the conditions at Edinburgh proceeds at the rate of 0.33 inch, or roughly 9 millimeters, a century. In other words lettering or designs cut 0.5 inch into marble would under such conditions be completely effaced in 150 years. In line with this conclusion is the fact stated by Goodchild[1] that dressed surfaces of limestone in the north of England lose an inch of surface in from 240 to 500 years.

In this connection attention should also be directed to the rapid blackening of all light marbles by soot wherever much soft coal is used and to the fact that the amount of this disfigurement increases with the elaborateness of the ornamentation, which prevents its removal by rain.

Renwick,[2] an English writer on marble, describes the effect of the London atmosphere on various marbles in these words:

> Generally speaking, it appears that while certain varieties of marble are available for exterior work, their general use is inadvisable, for the reason that discoloration and disintegration will ensue as a result of atmospheric impurities, generally sulphuric acid, generated by the action of rain water falling through a smoke-laden atmosphere on a soot-covered building, the effect sought to be produced by their use being thus speedily lost, even if nothing worse happens. The red marbles mostly contain clayey veins and patches, which disintegrate under the action of sun, rain, and frost. With the greens effervescence results; the violets lose their color; while with breccias the colors fade and a leaching out becomes apparent along the line of the cementing medium of the material. Laminated marbles waste in their softer layers, leaving the harder parts exposed, and these in course of time will break away.

Seipp[3] has recently published an interesting study of the weathering of various marbles in Italian buildings and monuments. With the aid of a botanist he found that the blackening which is so conspicuous in exposed marble statues and carvings in that climate is due to a coating of the lichens Verrucaria, Opegrapha, and probably also Lithoicea, to particles of dust and soot adhering to the lichens, and to the film of humus arising from their decomposition.

THE MARBLES OF WESTERN VERMONT.

GRAPHITIC CALCITE MARBLE.

One of the marked varieties of Vermont marble is the gray, which ranges in shade from light to very dark and is generally of bluish tinge. Some of it is finely banded, light and dark, with some bands almost or quite black, as in the specimens from a disused quarry on Board-

[1] Goodchild, J. G., Geol. Mag., 1890, p. 466.
[2] Renwick, W. G., Marble and marble working, London, 1910, pp. 58, 59.
[3] Seipp, H., Italienische Materialstudien, Stuttgart, 1911, pp. 23–35, 62–70, 117–153.

man Hill, in Clarendon (p. 32), and from the Clarendon Marble Co.'s quarry in the same township (p. 111). Some of this gray marble is in sharply plicated beds crossed by planes of slip cleavage, as shown in the slabs photographed in Plates V, *A*, and VIII, *B*, *b*, in both of which the two sets of planes are conspicuous for their blackness.

In thin section all these gray marbles are characterized by a greater or less abundance of minute black particles, rarely scales of carbon disseminated in the calcite grains. An analysis (No. 2534) made by George Steiger, of this Survey, shows that in a typical specimen of this marble, "West Rutland blue," this carbon is graphite and that its percentage in the marble amounts to 0.03. Mr. Steiger adds the following explanation to his analysis:

This determination of graphite was made by the method proposed by Brodie. One hundred grams of the marble were dissolved in dilute hydrochloric acid, filtered through asbestos, and the insoluble residue (which contained all the carbon), together with the asbestos used in filtering, treated for eight days with strong nitric acid and potassium chloride. The residue from this treatment was light colored and showed no indication of any carbon being left unattacked. According to Brodie, who is confirmed by others, by this treatment amorphous carbon is oxidized to CO_2, while graphite is oxidized to what is called graphitic acid, this compound being a light-yellow or brownish material. The solution was next filtered and the residue treated with a solution consisting of chromic and sulphuric acid, which oxidizes graphitic acid to CO_2; the latter was passed through barium hydrate solution and the precipitated barium determined as sulphate.

Some few recent authorities do not consider this formation of graphitic acid as an absolute proof of graphite, but it is the most reliable test that can be made by chemical means.

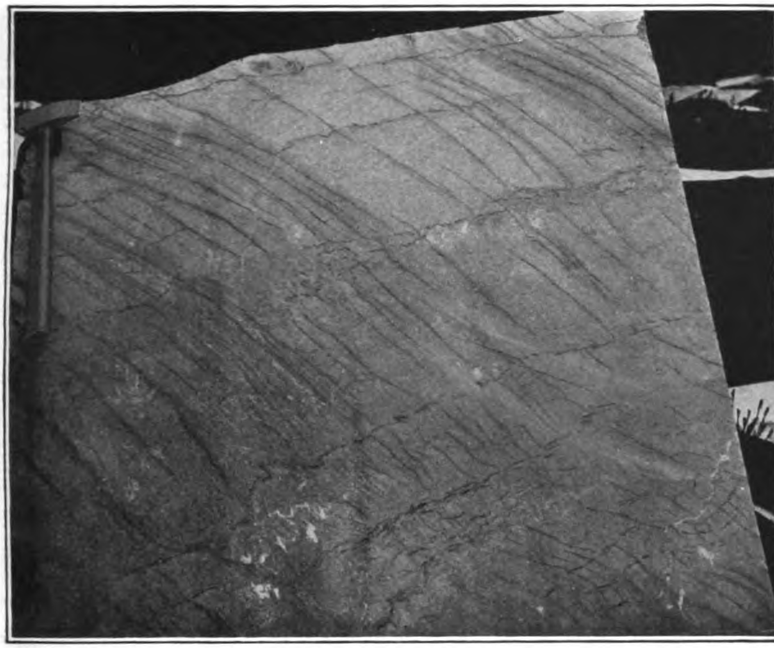
In some of these marbles that are a little darker the percentage of carbon would be very little higher. The thin sections show that besides carbon a little quartz and pyrite are generally present, and less commonly muscovite.

If the calcite in these marbles is attributed to the calcareous parts of crinoids, brachiopods, and mollusks, the graphite is probably to be regarded as derived from the decomposition of marine algæ, and the fine interbedding of more or less graphitic parts to be attributed to alternating periods of dominant plant or animal marine life, but the abundance of the graphite in the planes of slip cleavage would have to be explained by transfers of graphite from the adjacent calcite grains during metamorphism.

These gray marbles take a high polish and are very attractive.

CLOUDED CALCITE MARBLE.

In the clouded calcite marble of Vermont the "clouds" generally follow the bedding planes, which in places are sharply plicated. An examination of the polished surface of one of these marbles with a magnifying glass shows that the cloudy bands project an infinitesimal distance above the general surface, and are therefore harder than



A. SAWN SLAB OF GRAPHITIC CALCITE MARBLE FROM THE TRUE BLUE QUARRY, WEST RUTLAND.

Showing planes of bedding and of slip cleavage laden with graphite. The beds are inclined to the left and the cleavage to the right. Hammer 18 inches.

B. ROUGH BLOCK OF HEMATITIC DOLOMITE MARBLE FROM SWANTON.

Cut across the bed. The ground is bright reddish. Hammer 18 inches.

A. POLISHED SLAB OF PLICATED MUSCOVITIC CALCITE MARBLE FROM WEST RUTLAND.

Rule 2 feet.

B. POLISHED SLAB OF PLICATED CLOUDED CALCITE MARBLE FROM THE NEW HOLLISTER QUARRY, PITTSFORD.

The darker parts are graphitic and slightly dolomitic. Diameter 18 inches.

calcite. As they can be scratched with a knife, they are softer than quartz. This is corroborated by a microscopic examination of thin sections, which shows that the cloudy parts consist mainly of dolomite with a grain diameter ranging from 0.02 to 0.25 millimeter, averaging, roughly, 0.15 millimeter. Associated with the dolomite are plentiful minute particles of graphite, which account for the dark shade; also some quartz, pyrite, and rarely muscovite. A still further corroboration is furnished by Penfield's analysis (p. 13) of one of these clouded marbles from the Columbian quarry, at Proctor, which shows 0.77 per cent of $MgCO_3$ (magnesium carbonate). A sketch of one of these dolomite beds is shown in figure 20, page 131.

Where the small cloudy beds are plicated, a slab sawn in the general direction of the stripe will intersect the tops of minute meandering anticlines, but if sawn in the direction of the dip it will intersect several superposed series of such plications. In either case the marble will be clouded, but the distribution of the "clouds" or bands will differ. Where the plication has been extreme, the mottling will be very irregular on the slab. A polished slab of one of these clouded calcite marbles containing some slightly graphitic calcitic beds is shown in Plate VI, *B*.

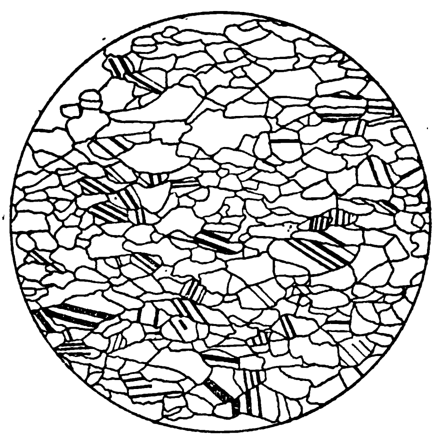


FIGURE 6.—Thin section of graphitic calcite marble showing elongate texture. From "17-foot bed," Eastman quarry, West Rutland. Enlarged 27 diameters.

MUSCOVITIC CALCITE MARBLE.

Many of the banded marbles of western Vermont owe their banding to fibers and scales of muscovite mingled in varying amounts with the calcite grains and forming little beds which alternate with beds of calcite grains alone. The marble has a grayish or greenish tint of varying intensity. The whole series of beds is generally more or less intricately plicated. Slabs showing cross sections of such a series are used for ornamental wainscoting and panels. (See Pls. VI, *A*, and XIV, *B*.)

In these marbles the long axes of the calcite grains are generally parallel to the bedding, as shown in figure 6, so that the marble has under compression acquired a certain schistosity. In thin section the fibrous muscovite is found associated with quartz grains, rarely one of plagioclase feldspar, also with epidote and chlorite, which emphasize the greenish tint proceeding from the muscovite. In some beds the muscovite, epidote, and chlorite are distributed so uniformly through the calcite as to produce a bright-greenish marble. Along with these minerals are usually found small dark lenses of uncertain character, minute opaque specks, and a little pyrite.

The fibrous muscovite of these marbles must have originated in clayey (feldspathic, quartzose) sediment, of which the few plagioclase grains are unaltered remnants and most of the quartz possibly also. The epidote and chlorite must have originated in minerals containing magnesia, silica, iron, and alumina, with which, to form the epidote, lime from the calcareous sediments became combined. These mechanical sediments, combined with calcareous sediments, presumably of organic origin, were metamorphosed, as already explained (p. 23), into muscovitic calcite marble containing small quantities of accessory minerals.

FIGURE 7.—Thin section of quartzose dolomitic and sericitic calcite marble from knoll near Brandon. Dotted particles are quartz; finer-grained area at upper left side is dolomite; the fibrous portions consist of sericite, which, where shaded, is graphitic; the black particles are pyrite; the larger clear particles and the banded particles are calcite. Enlarged 27 diameters.

About 1½ miles southwest of Brandon in the marble belt (see Pl. I) is a knoll rising 120 feet above the Otter Creek flood plain and consisting of rusty-weathering impure bluish marble that illustrates well the effect of metamorphism on a mass of calcareous sandy and clayey marine sediments. Part of a thin section of this rock is reproduced in figure 7. In some places the rock is a medium-grained calcite marble, containing some quartz. In others it is a fine-grained dolomite, including lenses of calcite and quartz. In still others it is a graphitic, pyritiferous sericite schist. The whole mass is intricately plicated and crossed by planes of slip cleavage. It combines some of the features of a marble with some of quartzite, some of dolomite, and some of a muscovite (sericite) schist. The muscovitic calcite marbles are the result of the same processes which produced this rock, but the sediments were more dominantly calcareous.

Owing to their considerable content of mica, the muscovitic calcite marbles do not take a perfect polish.

ACTINOLITIC CALCITE MARBLE.

Exceptional among the Vermont marbles are those quarried a mile northwest of South Dorset or 1¼ miles southwest of the Owls Head, in Dorset. (See Pl. I and p. 99.) They are coarse textured and range from faintly greenish or cream to smoke colored. Some beds are banded with fine dark-green to grayish-green beds, acutely plicated at intervals. Thin sections show that these little beds consist of fibrous actinolite and quartz with some pyrite and minute dark lenses of uncertain composition. The smoke-colored parts appear to owe their shade to thinly disseminated lenses of this kind.

This actinolite (a variety of hornblende, a silicate of lime, magnesia, and iron) must be attributed to the metamorphism of material of mechanical sedimentary origin containing magnesia, iron, and silica, combined with lime from the calcareous sediments.

Plate VII shows two pilasters of this actinolitic marble cut parallel to the strike, with some plication and a little brecciation along the strike.

DOLOMITE MARBLES OF LAKE CHAMPLAIN.

The marbles commercially known as "Champlain marbles" differ greatly in composition, texture, color, and physical qualities from the marbles that are extensively quarried along the Taconic Range. They owe their name to their occurrence in a strip along or near the east shore of the northern part of Lake Champlain. They include the marbles of Swanton, which are of Lower Cambrian age, and those of Monkton, along the foot of the Green Mountain range, which are probably areally continuous with and of the same geologic age as those of Swanton.

For the geology of these marbles the reader is referred to the writings of the Vermont and other geologists.[1]

SWANTON.

The marbles of Swanton are all quartzose dolomites, most of the quartz being in angular particles (0.02 to 0.15, generally under 0.07 millimeter across) and thus of mechanical sedimentary origin. The quartz grains have cavities with moving vacuoles. Rare grains of feldspar (orthoclase, microcline, and plagioclase) occur with them. The dolomite is in irregular untwinned plates and rhombs (0.02 to 0.3, averaging roughly 0.1 millimeter in diameter). The rock is more or less pinkish or reddish from minute particles of hematite (Fe_2O_3)

[1] See Perkins, G. H., The Winooski or Wakefield marble of Vermont: First Rept. State Geologist, 1898, pp. 30-37; Second Rept., 1900, pp. 55, 56; Sixth Rept., 1908, pp. 28-30, 224-245. Hitchcock, C. H., The Winooski marble of Colchester, Vt.: Proc. Am. Assoc. Adv. Sci., vol. 16, 1867, p. 119. Billings, E., Note on the discovery of fossils in the Winooski marble at Swanton, Vt.: Am. Jour. Sci., 3d ser., vol. 10, 1872, pp. 145-146. Edson, G. E., Geology of the town of Swanton: Sixth Rept. State Geologist, 1908, pp. 217-219.

disseminated in the dolomite grains and also as a matrix between them. This reddish matrix is not slaty, for in cross sections it fails to show aggregate polarization. As the marble has a marked argillaceous odor, kaolin may be present. The hematite in places is seen to arise from the oxidation of black metallic particles which also show on the polished face and easily cling to a common magnet when the rock is powdered, do not appear reddish on the edges, and have a blackish streak. The rock in which the magnetite abounds has a purplish color. A grayish to reddish variety near the base of the series and certain bluish-gray beds near the top, weathering yellow, show limonite stain proceeding from abundant minute grains of pyrite. The first variety shows magnetite also, rarely oxidized to hematite. Some of the sections of the "red" show a little mica (muscovite and biotite). Chlorite forms on some of the joints, also orange-colored calcite; and felty asbestos "mountain leather" is reported as occurring between the beds. A typical thin section of the reddish variety of dolomite at Swanton is shown in figure 8.

FIGURE 8.—Thin section of hematitic quartzose dolomite from Swanton. Dotted particles are quartz; black are magnetite; shaded areas are hematite stain; a black-banded particle is plagioclase, a long-streaked one, muscovite; the rest are dolomite. Enlarged 77 diameters.

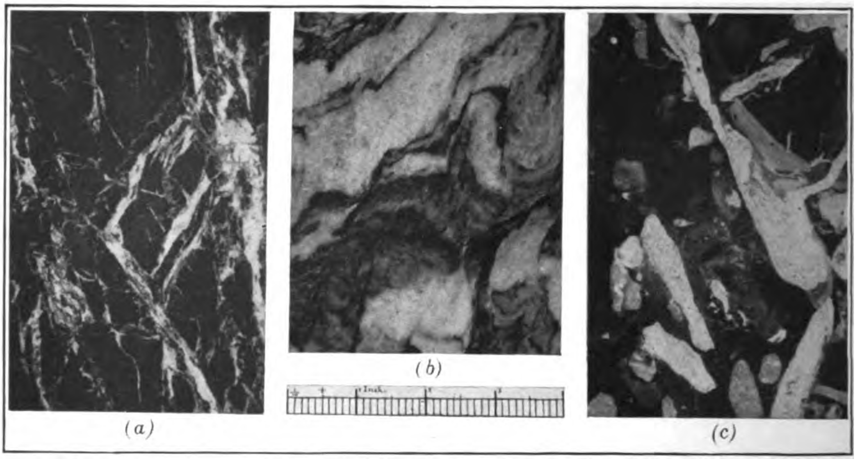
Some of the marble beds of Swanton are of a uniform dark reddish-brown color; others, however, are mottled with white, consisting of twinned dolomite associated here and there with vein quartz. Still others, and these are the more typical marbles of Swanton, have a reddish or pinkish matrix containing very irregular light-pink to white dolomitic lenses or beds 0.1 to 0.7 inch wide and up to 9 inches long, generally with their long axes parallel to the bedding but in some beds at all angles to it, even perpendicular. Some of these lenses consist of coarse twinned dolomite and calcite with a nucleus of vein quartz. These are regarded by Walcott[1] as Actinozoa (corals), Archæocyathinæ, originally more or less conical in form but now greatly distorted.

Perkins regards the present position of some of these lenses as due to brecciation, but however that may be the nucleated structure and

[1] Walcott, C. D., The fauna of the Lower Cambrian, or Olenellus zone: Tenth Ann. Rept. U. S. Geol. Survey, pt. 1, 1890, pp. 587, 588. In a letter of recent date Dr. Walcott adds: "As far as we know, this group of fossils on the North American continent, both on the coast of Labrador and in southwestern Nevada, is associated with the Lower Cambrian, and the same is true in northwestern Vermont."

POLISHED PILASTERS OF ACTINOLITIC CALCITE MARBLE FROM "GREEN BED," VALLEY QUARRY, SOUTH DORSET.

Showing some brecciation along the strike. Length 11 feet 3 inches, width 20 inches.



A.

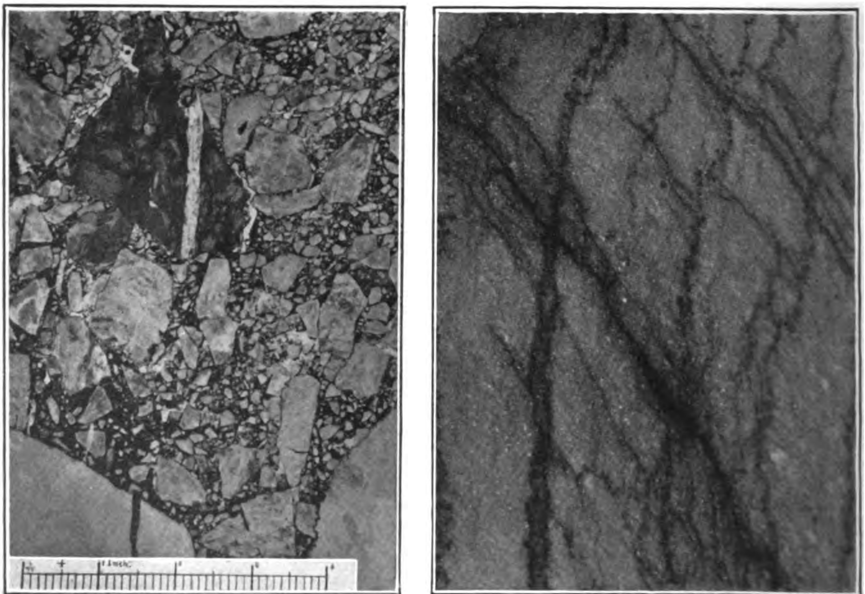
a, SERPENTINE FROM ROXBURY, SHOWING VEINING.

b, "KIEL'S GREEN MARBLE," FROM EASTMAN QUARRY, WEST RUTLAND.

Alternating beds of cream-colored calcite marble and dark-green muscovitic and chloritic marble, both plicated and crossed by slip cleavage.

c, "JASPER" MARBLE FROM SWANTON.

The ground is bright-reddish quartzose hematitic untwinned dolomite. The white objects are distorted and brecciated corals of twinned and untwinned dolomite and quartz.



(*a*) (*b*)

B.

a, POLISHED SPECIMEN OF BRECCIATED CALCITE AND DOLOMITE MARBLE FROM DYER QUARRY, MANCHESTER.

The cement is bright reddish and the fragments are bluish gray or cream-colored. The dark one with light vein is dull reddish brown.

b, SAWN SPECIMEN OF GRAPHITIC CALCITE MARBLE FROM ALBERTSON QUARRY, WEST RUTLAND.

Showing plicated bedding planes running lengthwise, crossed by planes of slip cleavage inclined to the right, both laden with graphite.

POLISHED MARBLE SPECIMENS.

general shape of some of them is good evidence of organic origin. Possibly some of the lenses were originally dolomite beds which alternated with ferruginous clayey beds but now lie brecciated in a hematitic argillaceous matrix, and only the nucleated lenses are distorted dolomitized corals, but some of these are also clearly brecciated. Perkins[1] reproduces a photograph of a slab of marble from Swanton filled with brachiopods (Salterella). A photograph of rough blocks of marble from Swanton is reproduced in Plate V, *B*, and one of a polished piece with corals in Plate VIII, *A*, *c*.

These marbles are thus mainly magnetitic quartzose dolomites partly of sedimentary and partly of organic origin. The magnetite may have been originally deposited as a carbonate. In most of the beds the magnetite has become more or less oxidized into hematite, giving the marbles their reddish color. The corals have evidently been largely dolomitized and the central cavities, partly original and partly made by solution, have become filled with quartz from siliceous solutions. Whether this dolomitization took place in the sea or after emergence is uncertain. The marbles are thus the result of an interesting series of processes—sedimentation, both mechanical and organic, if not chemical also; dolomitization; metamorphism, accompanied by siliceous infiltration; brecciation; and underground oxidation.

The marbles of Swanton are very sonorous and, of course, harder than calcite marbles or even twinned dolomite marbles.

MONKTON.

The dolomite marble of Monkton occurs along the west foot of the Green Mountain range from Bristol to East Monkton, where it is in contact with the quartzite that forms the west side of the range.[2] In its mottling this marble resembles slightly that of Swanton, but the ground is pink or pinkish and the blotches have a less regular form and are white or of a delicate rose color. On continued outdoor exposure these colors become more faint and on long weathering they disappear altogether and the rock either whitens or becomes dull greenish gray. In thin section the rock is seen to consist of dolomite plates and rhombs, mostly under 0.1 millimeter in diameter, and of more or less angular quartz grains up to 0.07 millimeter, with rarely one of feldspar (orthoclase and plagioclase), magnetite grains up to 0.005 millimeter, mostly altered to hematite, rare pyrite altered to limonite, a little sericite, and in places vein quartz.

The rock has fine beds or films of fibrous muscovite at short intervals. In thin section one of these, 1 to 2 millimeters thick, is seen to

[1] Perkins, G. H., Sixth Rept. State Geologist Vermont, 1908, Pl. XXXIX.
[2] See Seely, H. M., Seventh Rept. State Geologist Vermont, 1910, p. 298.

consist of minutely plicated sericite with many grains of magnetite; next and parallel to it runs a ¼-inch vein of quartz with calcite, dolomite, sericite, and magnetite.

The dolomite marble of Monkton is therefore also a hematitic quartzose dolomite, but with less hematite than the marble of Swanton, and is interbedded with fibrous muscovite. The hematite and the pinkish tint are derived by oxidation from the magnetite, as in the marbles of Swanton. The quartz and feldspar grains are of mechanical sedimentary origin, as was also the clay from which the fibrous muscovite was formed during metamorphism; vein quartz was deposited by siliceous waters at the same time.

The dolomite marble of Monkton is attractive on account of its very delicate color, but this color is not durable under outdoor exposure and the stone can be utilized only for indoor decoration.

DOLOMITE MARBLES OF PROCTOR AND PITTSFORD.

In the dolomite series which underlies the calcite marbles of the Otter Creek valley (see Pl. I and p. 66) a graphitic dolomite has recently been prospected for marble at a point about 1¾ miles southwest of Pittsford village, in the township of Proctor (see p. 128), and found to take a good polish. This dolomite marble (specimen D, XXXI, 53, b) is of bluish-black color and consists of greatly plicated, extremely fine black and white laminæ or beds not over 0.1 inch thick, suggesting a possible organic origin.[1] Thin sections show it to be a dolomite of irregular plates from 0.02 to 0.25 millimeter in diameter, some of them twinned, and rare quartz grains. The white beds, from 0.12 to 0.25 millimeter thick, in places widen to lenses with vein quartz and dolomite plates up to 0.75 millimeter. The graphitic beds are from 0.12 to 0.5 millimeter thick. A medium bluish-gray dolomite near the graphitic beds is of similar character, but the darker bands are less graphitic. None of the sections show any conclusively organic texture.

From the now disused Whelden quarry at the Florence crossroads, 2½ miles northwest of Pittsford village, in Pittsford Township (see Pl. I), dolomite was shipped in 1900 to Bellows Falls for its magnesia, which is said to have been used in the manufacture of paper. The quarry is in a series of pink and cream-colored dolomites 40 feet thick. Some of the beds are ivory colored, others delicate rose, and others cream, spotted or banded with pink. In thin section these beds are seen to be slightly quartzose dolomites, with a grain diameter of 0.009 to 0.17 millimeter, averaging from 0.04 to 0.09, with lenses of quartz and of twinned dolomite. They owe their tints to limonite or oxidized pyrite or to hematite from oxidized magnetite. There are

[1] See Perkins, G. H., Fourth Rept. State Geologist Vermont, 1904, Pl. LXXII (*Stromatocerium lamottense* Seely, which it somewhat resembles).

small intercalated beds of sericite schist, quartz, and dolomite. The dolomite beds can be followed from this point for 2 miles along the strike.

This whole set of dolomite beds contains a variety of attractively colored fine-grained dolomite marbles, which but for the thinness of the beds and a possible tendency to fracture along intersecting fine quartz veins would possess economic value. Even as they are and quite irrespective of their colors these dolomites would serve well for mosaic flooring and terrazzo.

These pinkish and cream-colored dolomites, generally weathering light brown, form hillocks northeast and north-northeast of Brandon village and occur also in Chittenden, on Mount Chaffee, and form the summit and west side of the 2,547-foot hill south-southeast of that mountain, as shown on the map.

UNMETAMORPHIC CALCITE MARBLE OF ISLE LA MOTTE.

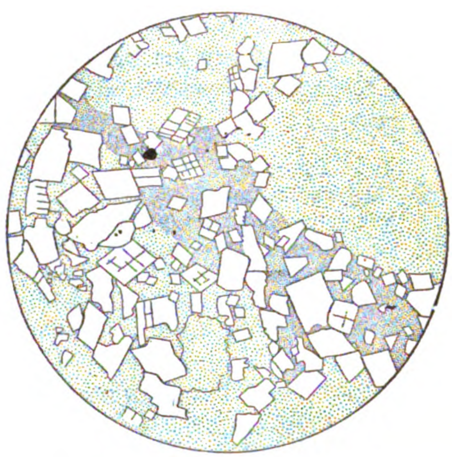


FIGURE 9.—Thin section of carbonaceous unmetamorphic calcite marble from Isle la Motte, showing dolomite crystals in groundmass of fine-grained, obscurely crystalline limestone. The darker parts are more carbonaceous; black particles are pyrite.

Although, as was explained on page 32, the black marble of Isle la Motte contains a little dolomite, it is essentially calcite marble and mainly of organic origin, as shown by its abundant fossils and its carbon, but its calcite has crystallized without the aid of great compression and mainly as a result of chemical processes. The crinoids, gastropods, etc., still retain their forms, but their calcareous parts have been dissolved and redeposited as crystalline calcite and their internal cavities have also been filled with it or with the original fine calcareous sediment which has also been redeposited in crystalline condition. The geology of this marble has been described by Vermont geologists.[1]

The fresh rock has an extremely dark gray ("black"), finely crystalline surface, but it weathers a dark bluish gray, in places with fine brownish-gray streaks parallel to the bedding. A typical thin section

[1] Hitchcock, Edward, and Hager, A. D., Geology of Vermont, vol. 2, 1861, pp. 776–778. Brainerd, Ezra, The Chazy formation in the Champlain Valley: Bull. Geol. Soc. America, vol. 2, 1891, pp. 297–298. Perkins, G. H., First Rept. State Geologist, 1898, pp. 40–42; Second Rept., 1900, p. 31; Sixth Rept., 1908, pp. 22–23, Pl. VI.

of it is shown in figure 9. In some thin sections it consists of small irregular, finely granular but crystalline masses in a matrix of coarse and crystalline particles of calcite throughout which dolomite rhombs are more or less thickly disseminated. In others it consists of irregular bands of dolomite in rhombs measuring from 0.025 to 0.1 millimeter, alternating with bands of fossiliferous granular limestone in which most of the grains are crystalline untwinned calcite. There are some dolomite rhombs, however, both in the fossils and in the granular calcite. Some dolomite rhombs occur in the central tubes of crinoid stems which are twinned dolomite or calcite, probably the latter. The rock contains a few grains of quartz, carbonaceous particles, and spherules of pyrite oxidizing to limonite.

A bed of very dark brownish crinoid limestone shows in thin section crinoids and other fossils changed to twinned calcite lying in a matrix of extremely fine grained, in places pyritiferous material containing dolomite rhombs. Some of the dolomite rhombs lie in meandering fractures and carbonaceous streaks within plates of calcite.

An analysis of the marble from Isle la Motte by Olmstead, published by Hager[1] in 1858, shows a small percentage of magnesium carbonate.

Analysis of "Isle la Motte black marble."

Calcium carbonate ($CaCO_3$)	87.94
Magnesium carbonate ($MgCO_3$)	4.56
Alumina and iron sesquioxide (Al_2O_3, Fe_2O_3)	2.60
Insoluble, mostly silica (SiO_2)	4.80
Water (H_2O) and loss	.10
Manganese oxide (MnO)	Trace.
	100.00

"MANCHESTER BRECCIA."

A "breccia" is a rock which has been more or less crushed by crustal movement but the particles of which have been recemented together by minerals deposited by percolating solutions. A breccia can always be distinguished from a rock made up of waterworn pebbles by the angularity of its particles. Breccias from the very mode of their origin are weak, and even when used for decorative purposes usually have to be fortified by cementing them at the back to slabs of solid marble or slate. Some of the most attractive imported marbles are breccias from Italy and North Africa.

Aside from the dolomite and calcite marble breccia on the west side of Pine Hill, in Proctor (p. 31), and an outcrop in Sudbury (p. 139), the only marble breccia yet known in Vermont is that in Manchester, 2 miles S. 10° E. from the top of Mount Equinox. (See p. 97 and Pl. I.)

[1] Hager, A. D., The marbles of Vermont, 1858, p. 6.

A photograph of a polished specimen of this marble breccia is reproduced in Plate VIII, *B*, *a*. The cement is brick-red and the fragments, of very unequal size, are of three sorts—(1) a light-pinkish or cream-colored calcite marble with a grain diameter from 0.05 to 0.37 millimeter and the long axes of the grains parallel, containing a little sericite and some quartz grains; (2) a deep-reddish hematitic dolomite marble, containing some calcite, with a grain diameter averaging roughly 0.09 millimeter, some of the particles veined with quartz; and (3) a light bluish-gray calcite marble with a grain diameter from 0.12 to 0.5 millimeter. The cement owes its bright-red color to hematite stain proceeding from particles of magnetite. It contains many very minute particles of the three kinds of marble in the breccia, and calcite plates, quartz grains, up to 0.2 millimeter, and rarely a feldspar grain (microcline). It owes its cementing property to calcite and hematite.

The rock takes a good polish but like other breccias needs to be fortified. Some of the fragments in it are so large as to deprive the rock of that degree of uniformity which would make it all of commercial value.

SERPENTINE OF ROXBURY.

The serpentine of Roxbury[1] is a marble only in a commercial sense. Roxbury is on the east side of the Green Mountain axis, in Washington County, 14 miles southwest of Montpelier. The quarry is about half a mile south of the station, on the east side of a north-south ridge. The serpentine there is 50 to 60 feet wide, dips 45°–65° roughly west, and is reported to continue for several miles in a north-northwest to south-southeast direction, with varying width but in places tapering out altogether. It is in contact on the east with a schist whose foliation strikes N. 15°–20° W. and dips from 65° N. 73° E. to vertical, and on the west with a similar schist whose foliation has about the same strike but dips 65°–70° W. These rocks, in thin sections, are found to be chlorite or chloritized biotite schist with epidote, calcite, and rarely muscovite, also tremolite schist with chlorite. The tremolite schist is on the west side. These schists may be altered eruptives. Their poverty in quartz is significant.

Dark-colored serpentine is a hydrous silicate of magnesia and iron. Some serpentines are of metamorphic sedimentary origin; others are metamorphosed eruptive rocks, and to this class that of Roxbury probably belongs. The nature of the original dike rock is uncertain. It may easily have been peridotite, which has a large content of

[1] See Hitchcock, Edward, and Hager, A. D., Geology of Vermont, 1861, vol. 1, p. 543; vol. 2, p. 780; also the following reports of the State geologist: First, 1898, pp. 37, 38; Second, 1900, p. 56; Third, 1902, pp. 89, 90; Fifth, 1906 (Marsters, Origin of serpentine), pp. 53–61; Sixth, 1908, p. 31; Seventh, 1910 (Richardson, Serpentine), pp. 318, 319.

magnesia and iron oxides. The serpentine in thin section shows a fibrous and radial texture with veinlets of magnesite and talc and with large particles of magnetite, which also appear on the polished face. The rock is of dark purplish or greenish color in the mass and is plentifully veined with white magnesite. Polished faces are almost black but crossed by a network of veins and veinlets of white and of light green wherever the magnesite is mingled with the serpentine. As many of these veins are faulted and sheared, the rock has evidently since its alteration to serpentine been subjected to compression. These sheared veins in thin sections show alternating blades of magnesite and foliated serpentine bent at right angles to the direction of the vein, forming "shear zones" like those in slates.

It is uncertain when the rocks on either side of the serpentine acquired their schistosity. Some of their minerals probably originated in emanations from the dike material, now serpentine, and are due to the heat accompanying the intrusion.

The serpentine of Roxbury takes a fairly good polish and its striking contrasts of shade and color and the irregularity of its veining make it a very attractive ornamental stone for interior work. (See Pl. VIII, *A*, *a*.)

CHROME MICA SCHIST OF SHREWSBURY.

The newly discovered green "marble" of Shrewsbury is a chrome mica schist and is included among marbles for commercial reasons only. It occurs in a small saddle on the north side of Round Hill, on the west flank of the Green Mountain range, 3¾ miles southeast of the Rutland station and about 900 feet above it, in the northwestern part of Shrewsbury Township. The schist, which is about 100 feet thick, strikes N. 15°–30° W., dips steeply east, and probably belongs in the Lower Cambrian schist. The discoverer and prospective operator is Edward H. Foley, 147 South Main Street, Rutland, Vt.

The schist (specimen D, XXXI, 87, a, rough; b, polished) in the rough has a bright verdigris-green to faintly greenish gray color. Its luster ranges from glistening to waxy and its texture is foliaceous and plicated. The polished stone has a brilliant dark emerald-green color varied with fine streaks, more or less plicated, of lighter green. It resembles talc in places but is considerably harder. J. S. Diller and W. T. Schaller, of this Survey, find that it consists largely of chrome mica (fuchsite) with some chlorite, quartz, and tourmaline, and the writer finds also magnetite present.[1]

[1] Fuchsite is briefly described in E. S. Dana's Descriptive mineralogy, 6th ed., 1892, p. 616. It was first described by Schafhäutl, who examined some from Schwarzenstein, in the Zillerthal, Tyrol, and gave its composition as follows: SiO_2, 47.95; Al_2O_3, 34.45; Fe_2O_3, 1.80; MgO, 0.72; K_2O, 10.75; F, 0.35; Cr_2O_3, 3.95; Na_2O, 0.37; Ca, 0.42; total, 100.76. Its content of chrome sesquioxide, to which it owes its brilliant color, is thus only 3.95 per cent. Schafhäutl, in 1843, described another chrome mica with 5.91 per cent of Cr_2O_3. For analysis of a fuchsite from Montgomery County, Md., by T. M. Chatard, see Bull. U. S. Geol. Survey No. 419, 1910, p. 286, analysis J. This specimen contained only 2.03 per cent of Cr_2O_3.

The brilliant green color and high polish of this stone make it very suitable for internal decoration. Its commercial value will depend on the size and soundness of the blocks obtainable.

The fuchsite schist is cut by a 5-foot dike of rhyolite porphyry, somewhat micasized and kaolinized, of light-grayish color at the surface and stained with limonite. On the west side of the schist is a quartz vein with a little pyrrhotite (magnetic iron pyrites).

MICROSCOPIC TEXTURE OF THE CALCITE MARBLES.

GRAIN FORM.

The grains of calcite in calcite marble never show crystallographic outlines. Their forms are altogether irregular, being bounded, as seen in cross section, by irregular curves or straight lines making reentrant or projecting angles which are usually obtuse. Only where calcite and dolomite grains are mixed do the calcite grains appear to have jagged or denticulate outlines. The grain form in some of the typical Vermont marbles is shown in figures 13, 15, 16, 21, and 24, pages 99, 108, 119, 134, 140.

In beds which have suffered much compression the grains are very perceptibly elongated in at least one direction and probably in two. This is shown in figures 6 and 22 (pp. 41 and 136). This grain elongation characterizes the muscovitic marbles on both sides of the West Rutland anticline. The effect is to give a degree of schistosity to the marble, so that it breaks more readily along the bedding plane.

As has already been explained (p. 32) the clouded marbles are marked by fine passages or lenses of untwinned grains of dolomite marble which are in general not only very much smaller in diameter than the calcite but of more regular outline and here and there of crystallographic (rhombic) form. The marbles of the Clarendon Valley, Landon, and Hollister quarries show this feature. (See pp. 110, 133, 135.)

GRAIN DIAMETER.

In measuring the diameters of the grains in thin sections for this bulletin the method followed has been first to measure the smallest and the largest particle, then to note the general maximum and minimum diameter. The actual minimum differs far less in most of the marbles than the maximum, so that an average based on it is misleading. In a few of the more even-grained marbles the average grain diameter has been obtained by the Rosiwal method. This average appears to be always less than the average of the general maximum and minimum estimated with the micrometer.

The most noticeable fact as to the grain diameter of Vermont marbles is the coarseness of some and the fineness of others. The

Danby and Dorset constructional marbles (Dorset Mountain and Green Peak types) have a grain diameter from 0.05 to 1.5 millimeters, mostly 0.12 to 0.5, and an average diameter from 0.20 to 0.24 millimeter, or 0.005 inch. At the other extreme the statuary marble of both sides of the West Rutland anticline and at the Goodell quarry, in Brandon, has a grain diameter of 0.02 to 0.5 millimeter, mostly 0.07 to 0.16, averaging 0.1 millimeter or about 0.0025 inch. Furthermore, about half a mile southeast of the village of Sudbury, about 5½ miles west of Brandon, is an outcrop of light bluish gray calcite marble, probably of no commercial value, in which the grain diameter ranges from 0.02 to 0.2 millimeter, mostly from 0.05 to 0.1, averaging probably about 0.05 millimeter, or 0.0013 inch—that is, about half the grain diameter of the statuary "Rutland."

The other marbles fall naturally into two intermediate groups—one of finer grain, comprising marbles like those of Middlebury and Brandon, the "second statuary" of West Rutland, and bed F (cream) of the Eastman quarry, having extremes of 0.02 to 0.75 millimeter, mostly 0.1 to 0.25, and averaging about 0.12 millimeter, or 0.003 inch; and one of coarser grain, comprising marbles like those of the True Blue, Shangrow, and several of the beds of the Eastman quarry, with grain diameters from 0.12 to 0.75 millimeter, mostly 0.12 to 0.37, and some of the beds of the Hollister quarry and the Pittsford and Brandon "Italian" marbles, with grain diameters of 0.05 to 1 millimeter, mostly 0.12 to 0.5. These coarser marbles together range mostly from 0.12 to 0.31 and average 0.15 millimeter, or 0.004 inch.

Another noticeable textural feature is the great variation in regularity or evenness. The "True Blue" and "statuary Rutland" are even textured, but the "mahogany bed" of the Freedley quarry on Dorset Mountain, the "Pittsford Italian," the "Brandon Italian," and the "Clarendon" are uneven. The most irregular in grain diameter is the fossiliferous graphitic marble of the Day lime quarry, in Ira, which has a range from 0.02 to 2 millimeters. This subject will be further considered under the next heading.

GRAIN ARRANGEMENT.

As shown in the drawings (figs. 13, 15, 16, 21, and 24, pp. 99, 108, 119, 134, and 140), many of the marbles show no arrangement of their particles. This absence of arrangement is as characteristic as the irregularity of grain form.

Where the grains are elongated there is generally a parallelism between the long axes of the different grains, and it is this arrangement which imparts a slight schistosity to the marble. This parallelism characterizes many of the muscovitic marble beds but is not confined to them. (See figs. 6 and 22, pp. 41 and 136.)

The marble quarried for lime at Leicester Junction consists of fine and coarse grains in alternate parallel bands averaging about 0.05 millimeter in width. The larger grains are from 0.04 to 0.09 millimeter long and the smaller ones 0.009 to 0.03 millimeter in diameter. (See fig. 25, p. 148.)

On the other hand, the marble of the "mahogany bed" at the Freedley quarry, on Dorset Mountain (p. 106), consists of large plates measuring 0.02 to 1.25 millimeters, mixed with small ones of 0.07 to 0.25 millimeter, without any arrangement whatever. The same irregularity of size but not of arrangement appears in the section of "Brandon Italian" shown in figure 22 (p. 136).

In the clouded marbles (Hollister, Landon, Florence No. 2, etc.), which contain lenses and little plicated beds of dolomite grains in a mass of calcite grains, and also in some of the banded graphitic marbles (Clarendon) the grain arrangement is chemical and stratigraphic.

The arrangement of grains is affected not only wherever the beds have been elongated in folding but also at the intersections of plicated beds and planes of slip cleavage, as in the marble of the Albertson quarry (Pl. VIII, *B*, *b*).

COMPARISON WITH EUROPEAN MARBLES.

Vogt [1] classifies Norwegian and European marbles in six textural groups, as follows:

1. Entirely compact (extra fine grained), with a grain diameter of mostly 0.02 to 0.03 millimeter (Värra, near Trondhjem), and almost entirely compact, 0.03 to 0.06 millimeter (Carrara "white P").
2. Very fine grained, 0.1 to 0.3 millimeter (Carrara, ordinary).
3. Moderately fine grained, 0.25 to 0.75 millimeter (Carrara, statuary).
4. Slightly coarse, 0.75 to 1 millimeter.
5. Moderately coarse, 1 to 3 millimeters (most of the Norwegian marbles).
6. Very coarse, 2 to 5 millimeters.

In comparing Vermont marbles with this classification the "statuary Rutland" and "second statuary Rutland" belong in group 2; the Florence No. 2, "light Rutland Italian," "brocadillo," "Pittsford Italian," and some of the beds of the Hollister quarry belong in group 3; and the "Dorset" and "Danby" marbles belong in group 5.

[1] Vogt, J. H. L., Der Marmor: Zeitschr. prakt. Geologie, 1898, p. 12.

The measurements of ancient Greek marbles made by Lepsius (pp. 26, 27) are here summarized and referred to Vogt's scale:

Classification of ancient Greek marbles according to grain diameter.

	Diameter in millimeters.		Scale No.
	Average.	Maximum.	
Hymettos (excluding fine grains of groundmass)	Under 0.5	0.8	3
Doliana, Sunium, white Pentelicon (groundmass excluded)	0.5-1	2-4	4
Parian (no groundmass)	1-1.5	5	5
Naxos (exclusive of fine-grained groundmass, small in amount)	2-4	8	6

GRADES OF TEXTURE.

In grading the marbles of western Vermont by texture alone the simplest system appears to be to divide them into five grades defined by the maximum grain diameter in connection with the average grain diameter, and to refer each grade to a well-known type or types. To these five grades a sixth has been added in the table below to cover a very coarse Massachusetts marble, which has also been found in eastern Vermont.

Classification of Vermont marbles by grades of texture.

Grade.	Grain diameter.				Grade types.
	Maximum (millimeter).	Average (millimeter).	General average.		
			Millimeter.	Inch.	
1. Extra fine	0.2	0.05-0.10	0.06	0.0023	Dolomite marbles of Swanton, Sudbury outcrop of calcite marble, dolomitic lenses in mottled calcite marbles.
2. Very fine	.5	.07- .16	.10	.0039	"Statuary Rutland," Goodell quarry, Brandon.
3. Fine	.75	.10- .25	.12	.0047	"Second statuary Rutland," bed IJ of Eastman quarry.
4. Medium	1.0	.12- .31	.15	.0059	"Brandon Italian," "True Blue," bed K of Hollister quarry, excluding dolomite streaks.
5. Coarse	1.5	.20- .60	.24	.0094	"Dorset A," "White Stone Brook," Dorset Mountain.
6. Extra coarse	2.54	.30-1.35	.50	.0196	Adams, Mass., and eastern Vermont.

In this scheme the Parian statuary (p. 26) would belong in grade 6, the modern commercial Pentelicon (p. 25) in grade 3, and the Carrara ordinary (p. 53), the Laas statuary (Tyrol), and the dolomite marbles of Lee and Ashley Falls, Mass., in grade 4.

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THE MARBLE BELTS OF WESTERN VERMONT.

PHYSIOGRAPHY.

Before considering the geologic relations of the marble beds of western Vermont it may be useful to recall the surface features of this part of the State, which are somewhat complex.

Beginning at latitude 44° 15′, or about 15 miles south of the latitude of Burlington, near the Addison-Chittenden county line, the west flank of the Green Mountain range lies near longitude 73° 5′ and extends thence southward with minor deviations for 36 miles to Coxe Mountain, a little north of Pittsford village, about latitude 43° 44′ and longitude 73° 3′. From this point the range curves eastward, forming an embayment that is 6 miles wide near Rutland, where it reaches longitude 72° 56′. This embayment extends 43 miles south from Coxe Mountain, gradually curving westward to the Manchester-Sunderland line, where the west flank is again at longitude 73° 5′. From that line it curves 3 miles farther west in a distance of 8½ miles and reaches longitude 73° 9′ near the Shaftsbury-Glastenbury line. The length of the flank of the range here considered is thus 87½ miles.

West of the Green Mountain range and 3 miles southwest of Brandon village, at about latitude 43° 46′ and near longitude 73° 7′, is the north end of the Taconic range, which extends with a course more or less parallel to that of the Green Mountain range to latitude 43°, the south limit of the area under consideration, near the Arlington-Shaftsbury line and beyond. The valley between these two ranges, known as the Vermont Valley, varies greatly in width, being 4 miles wide near Manchester, 2 miles near Brandon, but in places between East Dorset and Danby only one-fourth of a mile. This narrowing is due to the fact that for 6 miles, between the Manchester-Dorset line on the south and latitude 43° 20′ on the north, the Taconic range widens out eastward for 5 miles in the Dorset Mountain mass, which rises to an altitude of 3,000 feet above the valley bottoms. Opposite the Rutland embayment there is a minor range between the Taconic and Green Mountain ranges. This intermediate range begins with Pine Hill, in Proctor, 945 feet above the valley (latitude 43° 40′), and extends 23 miles south to Danby Hill, 1,500 feet above the valley, a little north of Dorset Mountain (latitude 43° 20′). The width of this range is from 1½ to 2½ miles, averaging about 2 miles.

North of the north end of the Taconic Range the surface between the Green Mountain range and Lake Champlain presents only minor irregularities, but between Middlebury and Monkton (latitude 44° 3′ and 44° 15′) and to the west Snake, Buck, and Hogback mountains rise 700 to 900 feet above the valleys.

The longest marble belt lies partly in the Vermont Valley, between the Green Mountain and Taconic ranges, and partly between the Taconic Range and the intermediate range from Pine Hill to Danby Hill. It also extends north of the Taconic Range, ending between Middlebury and Bristol, and its total length from north to south is about 80 miles.

Beginning in the northern parts of Charlotte and Hinesburg and extending north into Shelburne, Burlington, and Colchester, according to the Vermont report of 1861, is another marble belt, which, however, is not considered in this bulletin. One or two quarries were once opened in it.

Within the Taconic Range itself west of Rutland is still another marble belt, 6 miles long and half a mile wide, occupying a minor longitudinal valley, through which Castleton River flows in the north-south part of its course. This is the West Rutland belt of marble.

At several other points within the Taconic Range, north and south of this minor belt, there are small marble areas which will be considered more fully beyond. Most of these geographic features are shown on the map (Pl. I; see also Pl. IX).[1]

AREAL GEOLOGY.

The geologic map (Pl. I) shows the probable areal distribution of the geologic formations which include or are closely related to the marble areas. Such maps represent the general character of the rock surface as it would probably appear if divested of sand, gravel, clay, soil, marsh, and vegetation.

The rocks of the Green Mountain Range on the east include various gneisses, mostly of igneous origin, mantled on the west side by a belt of quartzite and schist, which prior to metamorphism consisted of sandstone and shales that in turn were originally marine deposits of sand and clay. This formation of quartzite and schist passes under the Vermont Valley and reappears on the intermediate ridge. On the west it is succeeded by a belt of more or less quartzose dolomite, associated in places with quartzitic beds. This extends along the valleys and immediately underlies the belt of calcite marble. To this formation belong the dolomite marbles of Pittsford and East Monkton, described on pages 45–46. Then follows the marble belt proper, consisting of beds of calcite marble alternating with beds of dolomite and in places of graphitic mica schist. The localities where marble has actually been observed, whether of commercial value or not, are indicated on the map by a special symbol and so are also the marble quarries in operation and most of the idle ones. The direction of the dip of the beds is also shown by symbols.

Overlying the marble on the west side of the Vermont Valley is a great mass of schist, a roughly slaty rock, consisting mainly of fibrous white mica and quartz, together with the soda feldspar (albite), graphite, chlorite, pyrite, etc. It includes here and there small beds of quartzite, originally sandstone, of fine quartz conglomerate, and of more or less crystalline limestone, and is generally veined with quartz and contains many quartz lenses. These schists were originally clays of marine deposition brought into the sea by rivers from the erosion of granitic and other rocks on the east. When the calcareous sediments of the underlying series were metamorphosed into marble these clays passed into mica schists and the small sandy beds into quartzite. These schists constitute the considerable mountains

[1] The surface features of nearly all this territory and their relations to the calcareous rocks which include the marbles are shown in the colored relief map, Plate I, of Taconic physiography: Bull. U. S. Geol. Survey No. 272, 1905, also a view of the Vermont Valley in Plate IV of the same bulletin. Plate LXVI of the Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, shows views of the three ranges referred to, and Plate LXX the north face of Dorset Mountain.

VIEW FROM POINT NEAR PITTSFORD ACROSS THE MARBLE BELT. LOOKING N. 75° W. ACROSS THE OTTER CREEK VALLEY.

Showing the Taconic Range (schist) and the marble mill at Fowler. The marble belt occupies the space between the mill and the range.

of the Taconic Range—Dorset, Bear, Equinox, Red, and Grass mountains and Green Peak.

It will be observed from the contours of the map that the boundary between the marble and the schist in the towns of Dorset and Manchester runs at a considerable elevation, being in places at the 2,000-foot and in others even at the 2,500-foot contour, or from 1,350 to 1,850 feet above the valley bottom. The intricate course of this boundary, as shown on the map, is due to the fact that the schist once completely covered the marble area and has been unequally eroded from it. It will be noticed that the reentrant angles in the boundary line generally follow the courses of the streams. This is because the streams have, as it were, eaten their way in the long lapse of time through the schist capping down into the underlying marble. This is a marked feature of the boundary about Dorset, Equinox, and Red mountains. The triangular schist capping of Green Peak in Dorset is a remnant of the schist mass which once connected Dorset and Equinox mountains and filled the Vermont Valley. In the same way the West Rutland belt of marble has become exposed by the erosion of the schist mass which once overlaid it, and so has the small marble area 4 miles north-northwest of it. Between Proctor village and the West Rutland belt of marble are several small marble outcrops which indicate either the presence of small calcareous beds within the schist or else the thinness of the schist mass along a north-northwest line about half a mile east of Castleton River. But the little marble area in Ira seems to be an exposure of the marble series itself.

Attention should be called to a simple but important feature of the marble belts—that the upper part of the marble will always be found, except where faulting has occurred, next to the schist and the lower part next to the underlying dolomite. At the present time the most productive quarries are near the schist.

Finally, where two formations which do not follow one another in the natural order of superposition are brought together at the surface, as shown by a geologic map, a fault or fracture along which one or the other has ridden up or down must have occurred to cause the anomalous juxtaposition. Such faults abound on the intermediate range. There is one at its south end between Danby Hill and Dorset Mountain. Another begins on Clark Mountain and extends to Pine Hill, Proctor, and beyond, bringing the quartzite that underlies the dolomite to the level of the schist that overlies the marble. But these faults have no immediate bearing on the economic geology of the marble belt.[1] Two others, however, not shown on the map because

[1] These faults are described in detail in the writer's paper On the structure of the ridge between the Taconic and Green Mountain ranges in Vermont: Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, pp. 525-549.

of their uncertain course, do affect the marble belt and will be referred to under "Structural relations" (pp. 90, 93).

THE STRATIGRAPHIC SUCCESSION.

Next in importance to determining the boundaries of the marble areas and of the contiguous formations is to ascertain the probable thickness of these formations and to refer them to their respective geologic systems.

The older gneisses of the Green Mountain range have little to do with the marble, and the overlying quartzites and schists not much more. A measurement of the latter on Bald Mountain near Bennington amounts to 1,600 feet, and it is all of Lower Cambrian age. The thickness of the overlying dolomite is still uncertain. It can not be less than 500 feet and may in places be much more. The discovery of Lower Cambrian fossils by Wolff and Foerste in 1890 on the east side of the intermediate range, about 1½ miles north of Rutland, near East Creek, opposite the Baxter farm, in dolomite 500 feet east of the quartzite, fixed the age of the lower 300 feet of the dolomite.[1]

Measurements made in 1891 by the writer near Chippenhook, in Clarendon, along the axis and on the west side of the intermediate range, showed that the dolomite and marble together measure there about 1,200 feet, of which at least the lower 470 feet is mostly dolomite and of Lower Cambrian age.[2]

A measurement made by the writer in 1903 across the syncline of the dolomite cut by Sucker Brook east of Lake Dunmore gives it an approximate maximum thickness of 765 feet.

One estimate of the thickness of the dolomite and marble is 1,200 feet; from this deducting 500 feet for the dolomite would leave 700 feet for the marble. Another estimate made near North Adams, Mass., between the north end of Mount Greylock and the base of the Green Mountain range—that is, between the schists over the marble and the quartzite below the dolomite and marble—yielded 1,400 feet for both; allowing 500 feet for the dolomite would leave 900 feet for the marble.[3] Another estimate, made between the top of the Cambrian quartzite at the north foot of Danby Hill and the base of the schist on the northeast shoulder of Dorset Mountain, gives 1,400 feet for the entire thickness of both, divided about equally between the dolomite and the marble. Hitchcock and Hager[4] estimated the

[1] See Wolff, J. E., On the Lower Cambrian age of the Stockbridge limestone: Bull. Geol. Soc. America, vol. 2, 1891, pp. 331–338.

[2] Dale, T. N., On the structure and age of the Stockbridge limestone in the Vermont Valley: Bull. Geol. Soc. America, vol. 3, 1892, p. 514; Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, pp. 540, 541, 549, Sections A, I, Pls. LXVII, LXVIII.

[3] See Mon. U. S. Geol. Survey, vol. 23, 1894, p. 190.

[4] Hitchcock, Edward, and Hager, A. D., Geology of Vermont, vol. 1, 1861, pp. 417, 418, fig. 264.

thickness of both on Green Peak (Mount Eolus) as 1,970 feet, of which they assigned 707 feet to the marble and 1,263 feet to the dolomite ("limestone"); but as the actual vertical distance between the valley floor at East Dorset (788 feet) and the base of the schist cap (2,500 feet; see contours on geologic map, Pl. I) is 1,712 feet, only 1,005 feet should be assigned to the dolomite, and that figure should be further reduced to allow for the folding in the Vermont Valley.

An estimate by F. H. Moffit, based on the map and his barometric observations at the same locality, makes the thickness of the marble from the dolomite below the Folsom & Kent (now Blue Ledge) quarry to the base of the schist about 500 feet.

The marble has been shown by the investigations of Wing and others to include beds of Chazy age and probably some of Trenton age above them and possibly some of Beekmantown age below them. There is, however, a question as to whether any or how much of the dolomite is of Beekmantown age. As this formation along Lake Champlain is largely dolomite, it would naturally be sought among the dolomite beds of the Vermont Valley. Seely [1] is inclined to correlate some if not the whole of the dolomite with the Beekmantown.

The thickness of the marble as obtained from the records of drill cores and from sections at the quarries (pp. 86, 88, 93, 95) ranges from 335 to 851 feet, measured from the base of the schist downward. A fair average of all the estimates is 663 feet.

The question as to the presence of the Middle and Upper Cambrian in the dolomite can not be discussed here. Thus far no fossils typical of these time divisions have been found in either the dolomite or the marble of the Vermont Valley. From what is known of the Ordovician formations about the Adirondack Mountains and on Lake Champlain it seems probable that the total thickness of the dolomite and marble, after deducting the Lower Cambrian part of the dolomite, is inadequate to fully represent Beekmantown and Chazy time, and that for this reason the two must include some intervals of extremely slow deposition or of nondeposition.

The schist which overlies the marble has been found to range between 2,000 and 2,500 feet in thickness at several points in the Taconic Range in Massachusetts and Vermont. It is in many places much thinner than this, owing to erosion. Its age is regarded as Middle (Trenton) and Upper Ordovician.

The following table is based on the foregoing more or less incomplete data. For each of the formations is given a condensed summary of its rock characteristics. The symbols in the first column correspond to those used on the geologic map (Pl. I).

[1] Seely, H. M., Preliminary report on the geology of Addison County: Seventh Rept. State Geologist, 1910, p. 257, Pl. XLVIII.

Stratigraphic table of the marble areas and adjacent formations.

Map symbol.	Formation.	Rock characteristics.	Geologic age.	Approximate thickness.
				Feet.
Ob	Berkshire schist.	Greenish (chloritic), purplish (hematitic and chloritic), black (graphitic and chloritic) fibrous muscovite (sericite) schist, with quartz, soda feldspar (albite), pyrite, magnetite, pyrophyllite, in places speckled with actinolite. Much quartz in lenses and blades containing chlorite and siderite ($FeCO_3$) more or less altered to limonite. This schist is interbedded with quartzite (much of it chloritic) in small beds (in a few places with chalcocite (CuS_2), siderite, and pyrophyllite). These quartzite beds in places attain 10, 15, 20, or 35 feet in thickness. Within them or separate are beds of conglomerate 1 to 2 feet thick, with pebbles of blue quartz up to three-fourths inch in diameter. The schist is also interbedded here and there with small beds of more or less quartzose dolomite and more rarely with a few feet of bluish calcite marble. The schist is almost everywhere finely plicated, with ensuing slip cleavage, which in many places is so pronounced as to obscure the bedding foliation, and this cleavage itself may in turn have become plicated. Near its contact with the marble the schist is generally graphitic.	Ordovician, probably Upper and Middle (Trenton) Ordovician.	2,000–2,500
Om	Marble	Alternating beds of calcite marble of various grades of texture, white, gray (graphitic), greenish banded (muscovitic, actinolitic), interbedded with bluish or grayish untwinned dolomite, and with muscovite schist in small beds, in places graphitic and up to 40 feet thick. Some of the marble beds are very quartzose and muscovitic. The uppermost part of the marble is generally more or less graphitic, and therefore of various shades of bluish gray. (See for details p. 96.)	Trenton, Chazy, and Beekmantown(?)	500–900
Єd	Dolomite	Thin-bedded crystalline untwinned dolomite, fine grained (grain diameter 0.009 to 0.17 millimeter), generally more or less quartzose, white, grayish, dove, cream, or ivory colored (pyritiferous) or pinkish (hematitic), with many intersecting microscopic joints or quartz veinlets along which the surface weathers in grooves. The pink and cream-colored beds have a brownish weathered surface. Small beds and films of fibrous muscovite schist are common in these dolomite beds. Some of the dolomites, such as the light-gray bed just under the marble at Proctor, consist of dolomite plates, some of which are twinned (grain diameter up to 0.45 millimeter), crowded with dark granules, lying in a matrix of smaller untwinned clear dolomite grains. A black and gray graphitic dolomite in Proctor (p. 128) consists of dolomite plates, some of them twinned, with a grain diameter up to 0.25 millimeter, and graphite in minute bands. (For details as to these dolomites see pp. 46–47.) Near the top of the dolomite and exposed for one-fourth mile on the west side of the intermediate range in West Clarendon (half a mile northeast of Tinmouth River bridge) is a 25-foot bed of dark-gray graphitic dolomite filled with fossil pteropods (Hyolithes) and oolitic nodules up to three-fourths inch in diameter. Each nodule has a pteropod shell as a nucleus. On a polished surface the pteropod sections appear as small white triangles and cones. (See Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, p. 534, fig. 54, and polished specimen in U. S. National Museum.) The base of the dolomite as exposed in Sunderland consists of thick beds of quartzite alternating with quartzose dolomite, fibrous muscovite schist, calcareous quartzite, and exceptionally a few feet of calcite marble. Some of these beds are pyritiferous, and some of them were evidently derived from a mixture of calcareous, quartzose, and argillaceous material. Some of the lower dolomite beds in Sugar Hollow, Brandon, carry small pebbles of fresh purplish potash feldspar and of quartz; and 2 miles south of Silver Lake, in Leicester, the lower beds contain a little metallic and red hematite, the latter in small lenses of concretionary or organic origin. Galenite and zinc blende have been prospected in the dolomite 2½ miles north of Brandon.	Beekmantown(?) and Lower Cambrian.	500–800
Єq	Quartzite and schist.	Largely quartzite (metamorphic sandstone), more or less feldspathic and micaceous, with some beds of conglomerate containing pebbles of blue quartz and of gneiss, in places attaining large dimensions.[a] Interbedded and in places possibly interfolded with these quartzites are various schists and in a few places small beds of dolomite. Some of these schists are coarse biotite-quartz schist, others are muscovite (sericite)-chlorite schist with abundant magnetite, others are very fine grained dark biotite-sericite schist banded with minute quartz and feldspar grayish beds. Generally the dark schist is biotitic, whereas the dark schist of the Ordovician (Berkshire) is graphitic.	Lower Cambrian	1,600
gn		Gneiss of Green Mountain range	Pre-Cambrian	

[a] See Dale, T. N., The Cambrian conglomerate of Ripton, in Vermont: Am. Jour. Sci., 4th ser., vol. 30, 1910, pp. 267–270, figs. 2, 3.

STRUCTURE OF THE MARBLE BELTS.

ORIGIN.

All the materials which now constitute these different series of rocks must, from their parallelism, as far as observations to the present extend, be supposed to have been originally laid down in the sea in horizontal position. Their present generally inclined attitude and incomplete extension are explained by two important events.

1. In consequence of a powerful crustal contraction at the close of Ordovician time, operating mostly in a west-northwest to east-southeast direction, the sediments not only became crystalline, but were intensely folded and in places faulted. It will be noticed from the geologic map (Pl. I) that in the southern part of the marble belt (Arlington, Sunderland, and Manchester) the Vermont Valley and the axes of the folds (strike) have a general north-northeast trend; that in Dorset, Danby, Tinmouth, and Clarendon their trend is more nearly north; that from a point a little north of the Clarendon-West Rutland line the trend changes to north-northwest, and so continues to the north end of the Taconic Range, in Brandon; and that from there on it is again nearly north.

2. During the lapse of ages the crests of these folds have become eroded by atmospheric acids and stream action, so that the schist mass has been removed from the tops of the marble folds and in one place even from the trough of the fold. This erosion has also in places penetrated the underlying marble and thus exposed the dolomite.

GENERAL SECTIONS.

The three general sections on Plate II show the approximate original outlines of these folds and the portions left by erosion. The location of these sections is shown by numbered lines on the geologic map (Pl. I).

Section I runs from a point a mile north of Center Rutland west-northwestward to the top of the Taconic Range, near the Castleton town line. Beginning on the east, it crosses the fault on the intermediate range which begins on Clark Mountain, in Tinmouth, and extends nearly to or possibly beyond the Pittsford-Chittenden line. By this fault the schist and quartzite of the Lower Cambrian have been thrust over the Ordovician (Berkshire) schist, which forms the west side of Pine Hill and which there overlies a narrow belt of marble. This hill is a syncline (trough). The section crosses Otter Creek Valley, which here corresponds to a complex anticline (arch), the dolomite appearing in the center with the marble on both sides. The schist ridge between the West Rutland (Castleton River) Valley and Center Rutland-Proctor (Otter Creek) Valley is a complex syncline. The section next crosses the West Rutland Valley at the Albertson quarry. This valley is an anticline of marble from which the schist has been eroded. The same anticline reappears in the small marble area east of Biddie Knob and 1½ miles west of Fowler. On the west side of the West Rutland Valley the marble dips west under the Berkshire schist, which forms the synclinorium of the Taconic Range. The dolomite is probably not far below the marble floor of the West Rutland Valley.

Section II, made by F. H. Moffit, begins at the east foot of Clark Mountain, in Tinmouth, runs nearly west-northwest, passing about half a mile north of Tinmouth Pond, and extends to the Wells township line. The east side of Clark Mountain is a trough of Berkshire schist underlain by the marble. The fault passes near the top of the mountain, where the Lower Cambrian quartzite and schist have been thrust up, so as to be in contact with the Berkshire schist. West of this the folds are again normal. The quartzite near Tinmouth Pond dips west under the dolomite of the central part of the valley. There must be an anticline on its west side. The marble beds above the dolomite dip west under the schist mass of Tinmouth Mountain and The Purchase. That the structure of these masses is complex is shown by the reappearance of the marble 1½ miles south of the top of Tinmouth Mountain and along its strike between Harrington Hill and Dutch Hill, in Danby and also by the small area of dolomite, probably belonging in the marble, at the west foot of The Purchase.

Section III begins on the Green Mountain range near the head of Downer Glen (Bourn Brook), on the Manchester-Winhall township line, and runs about west-northwest through Manchester village ("Street") and the top of Equinox Mountain, ending at the Sandgate-Manchester town line. At the east end of the section crop out the pre-Cambrian gneisses of the Green Mountain range, whose unconformable relations to the overlying Lower Cambrian are finely exposed in the bottom of Downer Glen.[1] This locality affords evidence of a crustal movement and erosion in the region prior to Cambrian time. In section III the foliation of the pre-Cambrian gneiss is therefore represented as not parallel to the bedding of the overlying Cambrian and also as eroded before the deposition of the latter. These gneisses formed the ocean floor upon which the Cambrian quartzite and schist and the overlying dolomite and marble were deposited. The section next crosses the entire quartzite and schist formation which flanks the range. In the lower part of Lye Brook this formation lies in a syncline in which the lower beds of the dolomite have been preserved from erosion. On this brook near the Manchester-Sunderland town line, about 2½ miles south of the line of section III, a loose rectangular block of coarse micaceous quartzite,

[1] Dale, T. N., Structural details in the Green Mountain region and in eastern New York (second paper): Bull. U. S. Geol. Survey No. 195, 1902, p. 18, fig. 7. By error the strike symbol of the gneiss and its foliation are drawn in this figure N. 68° E. instead of N. 68° W., as marked.

probably from a near-by ledge, was found in 1899 full of impressions of the spines of the trilobite Olenellus, typical of the Lower Cambrian. Between the lower part of Lye Brook and Batten Kill the quartzite forms an anticline. The Vermont Valley from the Batten Kill to a point about three-fourths of a mile west of the Equinox House is occupied by the dolomite and consists of a broad syncline made up of minor folds. The steep east slope of Equinox Mountain up to elevations of 2,300 to 2,400 feet consists of the marble, but with dips indicating at least two minor folds (two anticlines and two synclines). The brecciated marble at the Dyer quarry (p. 97), 2½ miles south of the line of section III, points to a possible fault running between Manchester Street and the beginning of the steep slope of the mountain. Equinox Mountain itself appears to be a flat-topped anticline and thus exceptional among the mountains of the Taconic Range, which are, as a rule, more or less complex synclines.

These sections taken together with the geologic map (Pl. I), will answer as a key to the general geology of the marble belts.

DETAILED SECTIONS.

The general sections are supplemented by nine detailed sections (Pl. III), drawn on the scale of the enlarged map of the West Rutland belt of marble (Pl. IV), as follows:

A, across the east foot of Dorset Mountain north of the Dorset-Danby line.
B, C, D, across the east side of the West Rutland belt of marble.
E, F, across the west side of the same belt.
G, through the village of Proctor.
H, a little south of G.
I, through the Pittsford quarries.

These sections must be regarded merely as approximations and are designed to afford such assistance by way of suggestion as approximations can give. By means of large-scale mapping and careful instrumental work sections of much greater mathematical value could be constructed.

STRUCTURAL NOTES.

The following notes are designed to call special attention to a few points in the map and the sections and also to some structural features which could not be represented or explained in either.

Equinox and Bear mountains.—The contours show that the marble makes up the lower 1,000 to 1,300 feet of these mountains. They are masses of marble and dolomite capped by 1,300 to 1,500 feet of schist.

South Dorset.—The symbols on the map show the unusual change in strike on both sides of the valley near South Dorset and extending to Owls Head, a change from about north to northeast—that is, of 40° to 45°.

Dorset Mountain.—In this mountain the schist cap extends from the 2,000-foot level (exceptionally on the east side of Dorset Hollow 1,600 feet) to the summits, 3,436 and 3,804 feet, and the marble generally from the 1,600-foot to the 2,000-foot level. The mountain is deeply furrowed by erosion and the marble is exposed on its three sides. As shown in section A, the basal dolomite lies in sharp minor folds up to the second bench on the east side. A little above that the marble begins in almost horizontal attitude and extends to the third bench, on the west side of which it is overlain by schist which from that point constitutes the steeper upper 1,600 feet of the mountain. The newly opened quarries are on this third bench. There is a marked southerly pitch in this part of the mass.

West Rutland anticline (Pl. IV).—In exploring the schist mass on the west side of the valley, about half a mile west of the West Rutland station, the schist foliation (slip cleavage) clearly dips 30° E., striking in some places N. 10°–20° E., in others N. 25° W. The bedding, shown by plicated quartz veins, strikes clearly N. 25° W. and dips across the cleavage at steep angles east or west. The underlying marble, therefore, dips either steeply west at the contact or, by overturn, steeply east.

On the north side of the Castleton River east-west cut in the western schist range, about a mile west-northwest of the West Rutland station, the slip cleavage strikes N. 5°–10° W. and dips 10°–20° E., but the bedding strikes N. 30° W. and dips steeply to the west in minor folds, parts of which dip east. On the north side of a disused road which sets off from the highway on the west side of the West Rutland Valley several outcrops show the structure finely.

A little north of the line of section F, about 300 feet east of the road going north, a mass of schist several hundred feet long rises 10 feet above the meadow. It shows slip cleavage dipping 20° E., crossed by plicated bedding dipping steeply west. This is the most easterly outcrop of schist in this part of the west side of the anticline, and its contact with the marble can not be far from it on the east.

In the western schist range at a point about 200 feet above the north-south highway and N. 47° W. of the red schoolhouse above the West Rutland quarries there is a cliff of schist 40 feet high. The bedding, shown by calcareous beds 3 inches thick, dips alternately east and west in minor undulations, with a general horizontal course crossed by low eastward-dipping slip cleavage. The exposure is 60 feet long.

All these data and the observations in the conspicuous schist ledges near the highway, referred to on page 81, have been incorporated in the western part of section F and show conclusively the general westerly dip of the bedding in the schist mass and the probable anticlinal structure of the valley. The marble of at least this part of the anticline probably also dips west.

In the southern part of the anticlinal valley the schist a little south of the Eastman quarry appears to dip 20°–35° E., as it does at the quarry, but on the west side of the first schist knoll half a mile west of that quarry the bedding dips clearly 50° W. and is crossed by slip cleavage dipping 15° E.

That the West Rutland anticline is probably made up of minor folds is indicated by the small synclinal schist tongues which overlie the marble at the north end and near the True Blue quarry, as shown on the map (Pl. I).

Schist ridge west of Proctor and Fowler.—The complex structure of this ridge is indicated by the lenses of marble or dolomite, probably the tops of minor anticlines, shown on the map about midway between the West Rutland and Proctor belts of marble.

The problem as to the dip of the bedding in the schist range west of the West Rutland anticline, and thus as to the dip of the underlying marble, recurs on the east side of the schist ridge west of Proctor and Fowler. Where the quarry railroad cuts the schist nearly west of the north end of the pond the cleavage strikes N. 5°–10° E. and dips 60°–65° E., but the bedding, shown by plicated quartz veins and lenses, dips at a low angle to the west. At a point S. 85° E. of the tower on the Proctor School the schist has a cleavage strike of N. 10° E. and dips 55° E., but with a magnifying glass traces of westward-dipping plicated bedding can be made out in places and are corroborated by plicated quartz veins a little beyond. Again at a point half a mile north-northwest of this last point the cleavage dips 65° E. and the bedding dips at a low angle to the west or is horizontal.

At a point 1¾ miles south of Fowler marble and schist occur in contact. Some large glacial bowlders rest on the marble near by.[1] The marble strikes N. 15° W. and dips in coarse plications at steep angles to the west or stands vertical, and the schist in immediate contact is in like position, but its plicated bedding is crossed by an eastward-dipping slip cleavage. The boundary here turns to a northwest course, and at a point one-fourth mile northwest the two rocks are within a foot of each other, but both strike N. 21° W. and dip 40° E., owing probably to a minor fold in the schist mass.

Opposite the road corner nearly 2½ miles south of Proctor the schist shows cleavage dipping 40° E., but plicated bedding dipping west. This structure is shown in the general section I (Pl. II) which passes half a mile south of this point.

Structure north and south of Center Rutland.—The narrowing of the Proctor-Pittsford belt southwest of Center Rutland, as shown on the

[1] Dale, T. N., Taconic physiography: Bull. U. S. Geol. Survey No. 272, 1905, Pl. VIII, *A*.

map, is not more than would result from the presence of the top of a close-folded anticline at that point. The disappearance of the basal dolomite below the marble a few miles south and 300 feet above that point is presumably the result of a northerly pitch of the folds, and the corresponding disappearance of the dolomite north of Center Rutland (although there are no marble outcrops to fix the exact termination of the dolomite) would be due to a corresponding southerly pitch. These inferential north and south pitches would be just the opposite of those implied in the disappearance of the West Rutland anticline both at the south and the north under the overlying schist.

TRAP DIKES IN THE MARBLE BELTS.

After the folding of the marble and the overlying schist, a shearing or stretching took place which opened narrow fissures here and there, generally more or less transverse to the folds and deep enough to reach the zone of rock fusion. Along these fissures both marble and schist became injected with lava-like but dense molten material which crystallized as it cooled and solidified. Out of sixteen dikes which were measured one was 25 feet wide, eleven 4 to 10 feet, three 1 to nearly 4 feet, and one 2 to 4 inches. Out of twenty whose courses were taken three ran N. 80° to 90° W., eight N. 25° to 40° E., and nine N. 60° to 70° E. Out of eleven which were examined microscopically ten proved to be augite camptonite (plagioclase feldspar, hornblende, augite, magnetite, olivine) and one a camptonite (same as above, with little or no augite). A thin section of the 3-foot augite camptonite dike, which crosses the dolomite half a mile north of Proctor and is exposed in the railroad cut, shows slender crystals of labradorite feldspar, larger augite crystals, fine needle-like prisms of brown hornblende, magnetite, apatite, and calcite.

J. F. Kemp made an analysis of a 3-foot camptonite dike cutting a marble quarry about 2 miles south of Proctor. He found on microscopic examination that it consisted of hornblende, augite, plagioclase, and magnetite.[1]

Analysis of camptonite from quarry south of Proctor.

Silica (SiO_2)	41.00
Alumina (Al_2O_3)	21.36
Iron sesquioxide (Fe_2O_3)	13.44
Lime (CaO)	10.40
Magnesia (MgO)	3.85
Potash (K_2O)	1.31
Soda (Na_2O)	2.86
Loss	5.00
	99.22

[1] Kemp, J. F., and Marsters, V. F., Camptonite dikes near Whitehall, Washington County, N. Y.: Am. Geologist, vol. 4, 1889, p. 101. Analysis repeated in Bull. U. S. Geol. Survey No. 107, 1893, p. 31. See also Am. Jour. Sci., 3d ser., vol. 36, 1889, p. 250.

A. PART OF THE PLATEAU QUARRY AT SOUTH DORSET.

Showing stripping and in the distance the Owls Head and Green Peak. The block being hoisted is for a 32-foot column for the Art Building at Montreal. The black stains on the quarry walls are caused by the smoke of the cutting machines.

B. TUNNEL OF NEW YORK QUARRY, DORSET MOUNTAIN, DANBY, FROM THE NORTHEAST.

Showing two sets of joints at the left of the tunnel due to a trap dike at the south (not shown in the picture). The marble at the tunnel and north of it is free from joints.

A dike described by Hitchcock and Hager [1] as 4 feet thick and 30 feet long, and crossing one of the old marble quarries on Green Peak ("Mount Eolus") was examined by Kemp and found to be an olivine camptonite consisting of olivine, augite, brown hornblende, plagioclase, and a little glassy base.[2]

Near the quarry operated by the Vermont Marble Co. north of the Eastman quarry (see map, Pl. IV), south of West Rutland, a dike with a N. 60°–70° E. course cuts the marble beds. It is about 185 feet long, is 10 feet wide at one end and 4 feet at the other, and reappears at a point about 114 feet east-northeast. It sends out branches 75 feet long southward into the graphitic crinoidal marble beds. In thin section the dike rock has a fine matrix of plagioclase and brown hornblende with porphyritic crystals of micasized plagioclase, of hornblende, and a few of augite, more or less altered to chlorite or to chlorite, hornblende, magnetite, and calcite. It contains also a little magnetite and apatite and some biotite. This rock is an augite camptonite.

On the schist ridge between Proctor and the West Rutland anticline about one-third mile northeast from the now disused Columbian Quarrying Co.'s quarry and 1¼ miles west-southwest of the Proctor station there is an 8-foot dike with a N. 60° E. course, which cuts and terminates on the north a small area of bluish limestone or marble surrounded by schist. In thin section this dike is found to consist of plagioclase, chloritized augite, much magnetite, apatite, and calcite amygdules, and is thus a diabase. This dike probably reappears in Proctor.

The geologic age of these dikes has not been fully determined. They have not suffered metamorphism and are therefore later than the crustal movement which closed Ordovician time, but they can not well be later than the Triassic.

Some of these dikes have a finer-textured, almost glassy rim, due to the more rapid cooling of the part in contact with the rock, and this rim weathers whitish. These dikes have considerable negative economic significance in this region, as the marble for several feet on one or both sides of the dike is usually close jointed parallel to the dike. Plate X, *B*, a view of the tunnel to the New York quarry on Dorset Mountain, shows the marble full of joints over a space of 80 feet from the upper side of an augite camptonite dike, but the marble is sound on the under side of it. It is not clear whether these joints were formed by the strain that opened the fissure occupied by the dike or whether they were due to the heat of the dike rock.

[1] Hitchcock, Edward, and Hager, A. D., Geology of Vermont, vol. 2, 1861, p. 587.

[2] Kemp, J. F., and Marsters, V. F., The trap dikes of the Lake Champlain region: Bull. U. S. Geol. Survey No. 107, 1893, p. 39, fig. 31.

Hager[1] gave a sketch of two dikes in limestone (dolomite?) on Danby Mountain which shows such joints parallel to a dike crossing the bedding. Many of the dikes extend for hundreds or thousands of feet horizontally and some of them send off minor ramifications where the rock was shattered.

GEOLOGIC HISTORY OF THE MARBLE BELTS.

The origin of marble and dolomite has been treated (pp. 21, 33); the areal geology of the region has been explained (p. 62 and Pl. I) and its structure shown in the sections (Pls. II, III, and p. 67); and the stratigraphic succession has been given (p. 66). In order to bind all these facts together and complete the geologic treatment of the marble belts it remains to outline very briefly from all these data the probable geologic history of the marble region.

1. After a very long period of atmospheric erosion the gneiss mass which is now exposed on the Green Mountain Range and which must also be supposed to continue westward under the Vermont Valley and the Taconic Range became gradually submerged, at least in its western part. The ocean which then occupied the central portion of the continent advanced eastward. The action of its waves and the erosion by the streams which emptied into it supplied beach and stream pebbles and sand from the gneisses of the land. At times and in places the product of erosion was clay or a mixture of clay and sand. These pebbles, sands, and clays were spread over the ocean floor throughout the region of the marble belts, the coarser material remaining near shore. From the great thickness of the Cambrian rocks which these sediments now form this kind of sedimentation must have continued for a very long period.

2. Next came the calcareous sedimentation represented by the dolomite of the table (p. 66). In view of the uncertainty which still hangs over the origin of dolomite we may suppose either the deposition, largely by the agency of marine organisms, of several hundred feet of calcitic sediments which subsequently suffered dolomitization under water or else the existence of conditions favorable to the chemical precipitation of magnesium and calcium carbonate or dolomite. In either case the sedimentation during this period included a little mechanical sedimentation of clay and quartz and feldspar sand. The graphitic dolomite beds point to a carbonaceous sediment of organic origin, possibly from marine algæ. The pteropods of the graphitic dolomite of West Clarendon (p. 66) are gastropods adapted for swimming. At the present day pteropods frequent the ocean surface.

During periods 1 and 2 we must suppose a slow subsidence of the sea bottom to make room for sediments of such great thickness.

[1] Hager, A. D., Geology of Vermont, 1861, vol. 2, p. 586, fig. 318.

Whether this subsidence was intermittent or alternated with slight reelevations can not yet be determined.

3. Conditions of sedimentation suffered a marked change at the time corresponding to the beginning of the formation of the marble deposit, so that the sediments became very largely calcitic and but exceptionally dolomitic, or, if the theory of dolomitization is accepted, there came a time when dolomitization occurred only at intervals, most of the beds retaining their calcitic composition. The calcitic sediments out of which the calcite marble beds were later formed were largely of organic origin. Crinoids, corals (not reef builders), gastropods, cephalopods, and brachiopods were the principal animals concerned in the physiologic process of extracting lime from sea water and contributing their calcareous parts to the calcitic sediment. There may have been at the same time also some chemical precipitation of calcium carbonate. In order to account for the dolomite interbedded with the calcite marble we must suppose intervals of the submarine dolomitization of calcitic beds largely of organic origin or else intervals during which the conditions were favorable to the chemical precipitation of dolomite, and organic sedimentation largely ceased.

Even during this period of mainly organic calcareous sedimentation the streams continued to bring into the sea, again and again, a little clay and sand which were distributed over the ocean floor and became interstratified with the fragments of crinoids, corals, etc., and the calcitic ooze originating from their disintegration and partial solution. During the later part of the calcitic deposition the sediments in many places became darkened by carbonaceous matter, probably derived from decaying marine algæ, etc.

4. Owing to some far-reaching geographic change on the land mass, probably an elevation of the land that increased the erosive power of streams, the sea, which during the entire period of calcareous sedimentation (corresponding to both the dolomite and the marble) had received but little clay or sand from the land, began now to receive large amounts of these materials, particularly of clay. This was distributed throughout the area of calcareous sedimentation and, to judge from the great thickness of the schists into which this material was later metamorphosed, this kind of sedimentation must have continued for a long time. A gradual subsidence of the ocean floor along the coast line must also have kept pace with the accumulating sediments.

5. At the close of Ordovician time a powerful but slow crustal movement took place, affecting the whole eastern part of the United States. It consisted in a contraction across a laterally undulating axis with a general northeast to north-northeast trend. The effect of this movement upon this region was fourfold. (*a*) It metamor-

phosed all the sediments overlying the pre-Cambrian gneisses; the sands and sandstones became quartzite, the clays and shales became mica schist, and the calcareous beds became crystalline dolomite and calcite marble. (*b*) It folded the entire series and these folds became more or less compressed and inclined, mostly to the east; and, owing possibly to a minor contraction operating at right angles to the main one, the axes of the folds were made to undulate in a vertical direction, thus producing pitching folds. (*c*) One of the first effects of this folding was the emergence of the rock surface above the sea and the westward retreat of the shore line. (*d*) One of the later effects of the folding was microscopic faulting throughout the schist mass and in some of the marble beds, producing an eastward-dipping slip cleavage, and also the formation of secondary mica along these fault planes or the transfer of graphite to them. Faulting on a large scale also occurred, thrusting whole series of beds up or down in places a quarter of a mile. Various longitudinal and transverse strains, compressive and tensional or torsional, formed various systems of joints.

6. As soon as the rock surface emerged from the sea atmospheric erosion began to operate upon it. The streams, taking advantage of joints, made transverse cuts in the schist folds and also eroded longitudinally in the ruptures along anticlinal axes. In the course of time erosion reached the marble beds, forming both anticlinal and synclinal valleys; and the solubility of the marble by carbonic acid greatly accelerated the process. In places the entire set of marble beds was eroded, exposing the underlying dolomite, as shown on the map.[1]

7. The region probably suffered again during the crustal movements which occurred at the close of Devonian and Carboniferous time. The metamorphism of the conglomerate of Bird Mountain, which lies only 3 miles west of West Rutland, in the Taconic Range, on the Berkshire schist, and contains pebbles of calcareous quartzite and dolomite, may have to be assigned to one of these movements.[2] The trap dikes described on page 72 afford tangible evidence of a crustal movement which affected all the formations, but was unaccompanied by metamorphism. This movement produced many fractures in the marble beds.

8. To a still later date, the close of Cretaceous time, some geologists assign the general elevation of the region to an altitude that is considered greater than the present height of the Vermont Valley above sea level; the erosion of the lower part of the valley must therefore have taken place subsequent to this elevation. To the several post-Ordovician crustal movements is probably to be attributed the shattering of so many beds of otherwise good marble.

[1] The process and effects of erosion in western Vermont are more fully elucidated in Taconic physiography: Bull. U. S. Geol. Survey No. 272, 1905.

[2] Dale, T. N., A study of Bird Mountain, Vermont: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 2, 9100, pp. 15-23.

9. Of comparatively recent geologic date was the covering of the entire region by the continental ice sheet, which moved across it, according to the striated ledges, in south, south-southeast, southeast, and east-southeast directions, gouging, scratching, polishing, and potholing the exposed marble and other beds, strewing the hillsides and valleys with bowlders and leaving mounds of gravel. Some furrowed and polished marble surfaces are shown in Plates XV, *B*, and XVI, *A*.

10. The glacier in its retreat so blocked the natural drainage of the valleys into Hudson River and Lake Champlain as to dam the rivers swollen from the thawing ice and to fill the valleys of the marble belts with lakes. These lakes deposited finely stratified clay upon the glaciated marble surfaces, protecting them from further erosion. (See Pl. XVI, *A*.) They also formed the horizontal sand terraces and shore lines which are so conspicuous in Dorset Hollow, Manchester, and Sunderland at the 1,000, 1,100, and 1,200 foot levels.

GEOLOGIC PRINCIPLES GOVERNING THE MARBLE BELTS.

The following paragraphs treat of those elementary geologic principles a knowledge of which should underlie the quarrying of marble in the Taconic region. Such knowledge is even more important than that required to qualify a mining engineer in the anthracite region of Pennsylvania, for the stratigraphy of the marble in this region of folds is quite as complex as that of the Pennsylvania coal beds and the difficulties are much enhanced by the intense metamorphism which the beds have undergone.

CONTINUITY OF THE STRATUM.

Other things being equal, the same kind of marble is more likely to be found along the same bed than across adjacent beds for the reason that marine sediments of the same sort are generally formed at the same time over considerable areas, but are more apt to vary from time to time at the same place. The distance of a few feet across the stratum represents a considerable number of years, and therefore much greater probability of change of character than the same distance along the stratum. Of course there are changes along the stratum, due to contemporary changes of sediment, as one stream may carry more sand into the ocean at one point while another, a mile or two away, may be discharging more clay at the same time. On the other hand, geologic history may in smaller cycles repeat itself. Similar conditions of erosion and sedimentation may after many years recur at the same place and result in similar beds. The marble series illustrates these facts very well. Where a bed has been elongated or faulted the original continuity has been modified or interrupted.

FOLDED BEDDING.

The western Vermont marble region, as shown by the general and detailed sections (Pls. II, III), is one of folding, so that horizontal beds are exceptional. They are only to be expected at the bottoms of the troughs or the tops of the arches of the folds, and therefore can hardly retain their horizontality for any great distance. An idea of the folds of the region can be obtained by observing the minute folds in the little grayish dolomitic beds within the clouded marbles. These small folds, as it were, epitomize the large ones. The folding of the strata is the fundamental character of the region and the primary factor controlling the vertical and horizontal distribution of the marble. If a series of beds plunges in at one point it should emerge at another, for it is but part of a fold, and for the same reason if a series of beds emerges at one point, unless it is at the actual offshore beginning of the formation or unless faulting has occurred, the beds should be found to the east or west going down again and completing the original arch of the fold. The whole marble region should be thought of as originally corrugated on a large scale, the corrugations running in a north-northeast or north-northwest direction.

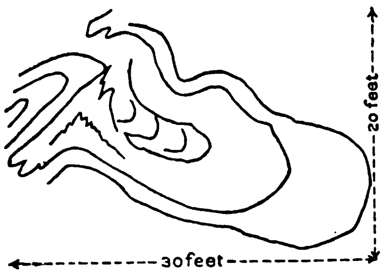


FIGURE 10.—Bottle-shaped fold in disused marble quarry 3 miles south of Brandon.

CHARACTER OF THE FOLDS.

The folds are rarely symmetrical—that is, with both sides equally inclined—and the angles of a symmetrical fold may vary from a few degrees away from the horizontal to the vertical. Folds are known as open or close. A close normal fold is one shaped somewhat like a letter U, with both limbs parallel and pressed together. Most of the folds in the Taconic region are made up of minor folds. This is shown on a large scale in the east limb of the anticline exposed in the West Rutland quarries (fig. 17, p. 122, and Pl. XII). The limbs of close folds in this region are in places so compressed as to resemble in cross section the longitudinal section of a bottle. A small fold of this kind near Brandon is shown in figure 10. When such a fold makes up a ridge or hill and stands erect a syncline may easily be mistaken for an anticline.

LATERAL INCLINATION OF THE FOLDS.

Folds of the various sorts described may be laterally inclined at any angle. Those on Green Peak (fig. 14, p. 103) have horizontal axial planes. The bottle-shaped marble fold shown in figure 10 is inclined 20°. The compressed marble folds shown in figure 11 have axial planes dipping about 50°.

PITCH OF THE FOLDS.

One of the more important economic features of a fold is the pitch of its axis. In the region here discussed this pitch will be found to be alternately north-northeast and south-southwest, or north-northwest and south-southeast, or north and south, according to the general direction of the corrugation of the portion of the belt containing the fold. The degree of pitch is generally small, 5° to 20°, but it may be greater. The practical effect of the pitch is that in working along the strike of a series of beds the same bed will be found at greater or lesser depth. A syncline at the Albertson quarry pitches alternately north and south. (See p. 123.) The termination of the West Rutland anticline both on the north and south (Pls. I, IV) is presumably due to pitch, the marble fold pitching under the overlying schist mass. The low southerly dips in the northern part of the Dorset Mountain mass are evidently due to pitch. The cause of pitching folds is not perfectly understood.

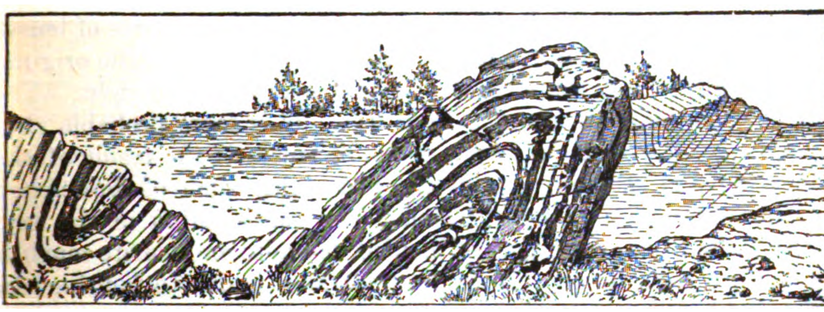


FIGURE 11.—Overturned marble folds with eastward-dipping axial planes at Lenox, Mass., north side. The dark layers, really yellowish, are due to oxidation of iron. The folds are thickened at the apex and drawn out, and some faulting has occurred in the upper beds of the anticline.

ELONGATION AND FLOWAGE.

The weight of nearly half a mile of superincumbent schist upon the calcareous sediments at the time of the folding and the intensity of the compressive force which produced the folds were both so great that the calcareous beds became effectually plastic. Had this compression occurred with less overlying weight the beds would have either been simply folded or possibly brecciated or granulated. The result of this plasticity is seen in the elongation and thinning of the beds along the limbs of the folds and their thickening at the ends, as in the marble folds shown in figure 11. To this process the variation in the thickness of the marble beds is largely due. The process did not stop here but in places resulted in actual flowage. The extremely extended compressed folds on Green Peak (fig. 14) and such structures as that in the center of the bottle-shaped fold near Brandon (fig. 10) and that near the Owls Head (Pl. XVI, B) can be explained in no other way. As the flowage of marble under compression has been demonstrated experimentally (p. 17), the probability that the crystallization of the limestone beds into marble occurred during an early stage in the process of folding does not involve any theoretical difficulties. The economic bearing of this feature of the marble in the Taconic region is that wherever the folding has been very intense thinning, thickening, and flowage are to be expected in the marble beds. This is probably the greatest irregularity to be met with in a stratified calcareous rock.

PINCHING OUT OF BEDS.

At the True Blue quarry (p. 125), there is a fine exposure of an unusual occurrence in the marble belts. (See Pl. XV, *A*.) A 15-foot bed of alternating graphitic dolomite and calcite marble stops abruptly along an eastward dipping cleavage plane, but a 3-foot bed of black dolomite veined with white calcite and quartz which forms the upper part of the 15-foot bed resolves itself into a series of lenses that continue in the marble in the direction of the dip of the original bed and have been found in the tunnel below on the right. The first of these lenses is about 3 by 2 feet. It is more probable that this change of a stratum into a series of lenses is the result of the elongation and pinching out of the bed rather than of diminished sedimentation or of dolomitization. The continuation of the rest of the 15-foot bed, consisting of banded dolomite and calcite marble, has not yet been found. If its disappearance is due to faulting the bed should reappear at the west.

This illustrates what may happen to a bed of dolomite within a series of marble beds. The fact that the position of a missing bed may be fixed by that of a series of lenses is a principle which may be very helpful in solving certain practical stratigraphic problems.

RELATION OF MARBLE TO SCHIST.

The relations of the marble to the overlying schist have been shown in the general sections, Plate II, and in the detailed sections on Plate III.

The first inference from the parallelism of the two formations is that wherever the base of the schist occurs the marble should immediately underlie it.

The next inference is that the strike and dip of the bedding of the schist at its base indicate approximately those of the underlying marble.

These inferences are of economic importance wherever the marble along the marble-schist boundary is covered. Thus on the west side of the West Rutland anticline, opposite the quarries of the east side, the marble is covered, but unless a fault intervenes, of which there is no indication, the probable dip of the marble can be determined by ascertaining that of the schist.

BEDDING AND CLEAVAGE IN SCHIST.

As the bedding of the schist is locally obscured by slip cleavage and the two foliations in many places dip in opposite directions, cleavage is easily mistaken for bedding. The two features can be distinguished by the following criteria:

Slip cleavage is generally, although not invariably, in straight or very slightly undulating planes; bedding is in small or minute plications, in places even of microscopic size, and is generally crossed by the cleavage at various angles.

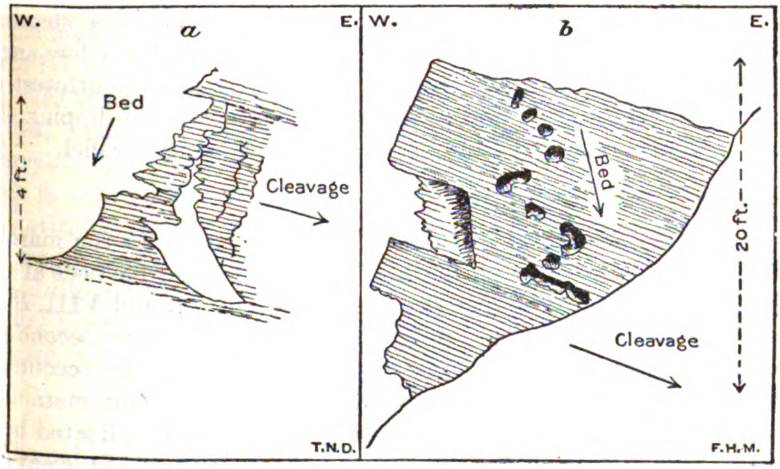


FIGURE 12.—Bedding and cleavage in schist. *a*, On Dorset Mountain; *b* (by F. H. Moffit), on Bear Mountain, Sandgate. In *a* a columnar plicated bed has been isolated by the erosion of a bed which may have been slightly calcareous. In *b* the course of the bedding is shown by cavities 6 to 8 inches wide formed by the partial erosion of a calcareous bed.

Bedding is determinable by the course of small calcareous or quartzitic beds (not to be confounded with quartz veins, which occur in both cleavage and bedding foliation). In those rare localities where the cleavage foliation has been subsequently plicated so as to resemble bedding the evidence of such small beds of different sediment is very necessary.

One of the most interesting localities where these phenomena may be studied in the Taconic region, described and illustrated in 1892 and 1893,[1] is opposite (west of) the eastern West Rutland quarries. (See Pl. IV and p. 70.) The marble which crops out on the line of the strike south of West Rutland, about the Eastman and adjacent quarries, is here covered by meadows. A line of conspicuous schist ledges forms the base of the hill (Taconic Range) west of the highway, and the schist appears to dip east and thus to underlie any marble that might be concealed by the meadows, but closer inspection shows low westward-dipping calcareous beds in the schist crossing the deceptive eastward-dipping cleavage and indicating that the marble of the meadows dips under the schist and should be found under the schist with that dip. As this eastward-dipping cleavage in parts of these ledges is plicated, the usual criterion as to bedding fails here. The structure of the schist at this locality and the probable structure of the concealed marble are shown in section F, Plate III. Other illustrations of the same principle in Sandgate and Dorset are given in figure 12.[2]

At a point 1¼ miles northwest of Proctor station similar relations exist between the marble and schist. The schist has a cleavage dipping 65° E., but its bedding is horizontal or dips at a low angle to the west. On the other hand at a point 1½ miles southwest of Pittsford station marble and schist are in contact, both dipping 40° E. and the cleavage and bedding of the schist being parallel.

CLEAVAGE IN MARBLE.

Some of the structural features of the schist recur in the marble. The planes laden with graphite which intersect the marble beds at the Albertson and True Blue quarries (p. 123; Pls. V, *A*, and VIII, *B*, *b*) are planes of slip cleavage. As graphite is here hardly a secondary mineral its abundance along the cleavage planes may be accounted for by transfer during the compression and its attendant metamorphism. The planes dipping 30° E. crossing the 80° W. plicated beds at the Landon quarry in Pittsford are possibly planes of slip cleavage also. But there are other parallel close fractures crossing the marble beds at many points and known as "reeds" by quarrymen which are not so clearly slip cleavage. They may be close joints due to some later crustal disturbance. These are rather common on Dorset Mountain and generally dip eastward, as, for example, at the Imperial and White Stone Brook quarries (pp. 108, 109). At the abandoned quarry about half a mile south of the Proctor quarry the marble beds dip 70° E.

[1] Dale, T. N., Plicated cleavage foliation: Am. Jour. Sci., 3d ser., vol. 43, 1892, p. 317; The Rensselaer grit plateau in New York: Thirteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1893, pp. 321–324.

[2] The whole subject of the relation of cleavage and bedding in schist is more fully explained in the following papers: Pumpelly, Raphael, Wolff, J. E., and Dale, T. N., Mon. U. S. Geol. Survey, vol. 23, 1894, pp. 139–140, 149–154, 158, 188; Dale, T. N., On the structure of the ridge between the Taconic and Green Mountain ranges in Vermont: Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, pp. 537, 538, 546; Structural details in the Green Mountain region and in eastern New York: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 1, 1896, pp. 559–568; Slate deposits and slate industry of the United States: Bull. U. S. Geol. Survey No. 275, 1906, pp. 24, 25.

but the reeds 20°. Of course, wherever the marble is very "reedy" it is valueless.

JOINTING.

Certain joints or systems of joints characterize the marble beds generally; others, to be considered later, are related to the trap dikes or are altogether irregular joints. The most prevalent set of joints strikes N. 65°–80° W. with its complementary set N. 10°–20° E.; another set strikes N. 75°–80° E. with its complementary set N. 10°–20° W. There are also two less common diagonal sets striking N. 30°–55° E. and N. 30°–35° W., the former of which is probably related to dikes.

IRREGULAR FRACTURES.

Some fractures, like those shown in figure 19 (p. 129), are so irregular that it may be inferred that they were produced by an exceptional crustal movement.

FAULTS.

The faults along the intermediate range and on Pine Hill are shown on the map (Pl. I) and on sections I and II, Plate II, and section G, Plate III, and are explained on pages 67–68. Faulting has also been regarded as possible between South Dorset and the Owls Head quarries (p. 93) and in Sunderland near the Dyer quarry. Wherever in quarrying operations such a dislocation is encountered the first thing to do is to ascertain the direction of the thrust and then the amount of vertical or lateral displacement so as to know where to look for the continuation of the lost bed or beds. For these purposes some core drilling may be necessary. Wherever in the marble belts the folding is very sharp faulting is likely to occur. The displacement in many such faults may, however, amount to only a few feet.

DIKES AND THEIR EFFECTS.

The subject of dikes and their effects has been dwelt upon already (p. 72) and illustrated in Plate X, *B*. The dikes are usually associated with close jointing in the marble, on one or both sides, and in some places with two sets of such joints. Therefore the presence of a dike should be regarded as an indication of close jointing in the marble in proximity to it. The dikes also send out small ramifications into the marble. It is the practice, therefore, to allow a generous unworked margin in the neighborhood of a dike. The most prevalent course of the dikes is N. 60°–70° E.; the next N. 25°–40° E. A few run about east and west.

The marble which underlies the dikes at the New York quarry, on Dorset Mountain (p. 110), which dip 65°, has no close joints, but at the White Stone Brook quarry, not far away, there are close joints on the upper side of the dike and an intersecting set on the under side (p. 108). In view of the origin of these dikes it is hardly necessary to state that they can not be eradicated. Where a stone crusher is available they furnish the best material for quarry roads. Owing to its considerable content of magnetic iron the dike rock is apt to deflect the magnetic needle. Surveyors therefore need to be cautious in running lines near them.

EROSION OF FOLDS.

The importance of erosion in the history of the region has already been pointed out. As all the marble strata which crop out at the surface must once have been horizontal, and as they can not be put together in imagination as blocks in their original position, and as in exposed cross sections the beds are found forming arches and troughs, their present fragmentary condition is manifestly to be attributed to the truncation of folds by erosion. The correctness of this view is corroborated by the presence of the schist formation on the uneroded portions of the marble folds.

At the West Rutland quarries of the east side the first question which suggests itself to a structural or economic geologist is as to the location of the continuation of the beds whose edges border the quarries and form the hillside. If these beds are part of an eroded fold, the same beds should recur, in inverse order, between the quarries and the schist ledges on the west. The arch which joined the east and west limbs of the anticline has been removed by erosion, as shown in the sections. The exposures to the north and south are insufficient to enable us to reconstruct the minor folds in the eroded arch, but that it is an anticline is evident south of West Rutland, where some of the beds of the east side recur. The practical outcome of such schematic reconstruction of the marble folds is to facilitate the search for those remnants of them which are concealed by gravel, sand, or clay, of glacial and postglacial date. The principle of the erosion of folds should be applied to the explanation of every considerable exposure of marble beds in this region.

UNDERGROUND SOLUTION.

The formation of caves in limestone and marble regions by the solution of underground water carrying carbonic acid of atmospheric origin, if not also organic acids of plant origin, is a familiar occurrence. Such caves are not uncommon in the marble belt of the Taconic region. The best known of them is that on Green Peak [1] (see Pl. I, point C), which is in marble near the overlying schist,

[1] Hitchcock, Edward, and Hager, A. D., Geology of Vermont, vol. 2, 1861, p. 891.

about on the 2,400-foot level. Exploration of it is reported to be dangerous owing to the presence of carbonic-acid gas. A little over a mile farther north, on the west side of the north-south part of Dorset Mountain, at the contact of marble and schist, near the 1,700-foot level, a brook flowing west toward Dorset Hollow disappears in a cave. Nearly a mile west of this and a little east of the road corner a small brook, known as Cold Brook from its very low temperature in midsummer, passes out of a dolomite or marble cave 600 feet north of the bed of the brook coming down from the other cave. This brook is usually dry.

The process of cave formation by solution is finely shown on a small scale in the wall of the Florence No. 1 quarry in Pittsford (Pl. XVII) and also on the walls of the disused Proctor quarry. The water gains admittance along steeply inclined bedding planes and thence passes along intersecting joints, forming a series of small caves along both sets of planes. Although some of the larger caves may be helpful in locating marble beds, these smaller ones are a serious hindrance in channeling. Their occurrence can not be foretold.

EFFECTS OF GLACIATION.

The gouged, striated, and polished marble ledges, their large potholes (p. 126), the sand, stony clay, and gravel which conceal large parts of them, and the abundant bowlders are the effects of glacial erosion. In view of the great thickness of the ice sheet under which the region was buried these mechanical effects are not surprising. Plate XVI, *A*, shows a broad glacial gouge at a now disused quarry in Pittsford, and Plate XV, *B*, shows a recently exposed striated and polished surface of graphitic marble near the Florentine quarry in Pittsford.

PROTECTION BY CLAY BEDS.

Where the glacial deposits have been removed from the marble beds or where the marble is covered by sand and gravel, it is generally more or less weathered to a depth of 20 feet. But where the marble is covered by pebbly glacial clay (till) or by beds of clay deposited in a postglacial lake, the imperviousness of the clay has protected the marble from the action of surface water. In such places fresh marble can usually be obtained within a few inches of the surface, as at the Riverside quarry in Proctor and at the quarry shown in Plate XVI, *A*. The glaciated marble surface shown in Plate XV, *B*, is also very fresh. The imperviousness of the clay is shown by the preservation of the most delicate striation and the polish, which, however, soon disappear on exposure to the weather.

THE MARBLE BEDS.

From the detailed sections made at the quarries and the core-drill records obtained the general facts as to the succession and thickness of the marble beds can be determined. These facts will be grouped geographically.

EAST SIDE OF WEST RUTLAND ANTICLINE.

Measurements made by the writer with a steel tape of the beds between the east wall of the upper Gilson quarry and the probable line of contact between the marble and the schist on the east give the following succession. The schist contact is about 248 feet east of the east side of the red schoolhouse on the brow of the ridge.

Section of marble beds between Gilson quarry and schist contact.

	Ft.	in.
East wall of Gilson quarry.		
White marble	11	6
Graphitic marble, including fossiliferous beds	135	6
Light marble	2	
Graphitic marble	73	
East side of schoolhouse.		
White marble with small lenses of dolomite	25	
Covered interval, probably graphitic marble with interbedded dolomite; estimated dip 15°	58	
Schist.		
	305	

These measurements generalized and added to those obtained from core-drill records and other measurements made by the Vermont Marble Co. in its quarries give the following succession for the east side of the West Rutland anticline, beginning at the schist:

Section of marble beds on east side of West Rutland anticline.

Marble varieties.	Feet.	Series.
Schist.		
Covered area, probably graphitic ("blue") marble with interbedded dolomite	58	Upper graphitic series (293 feet).
White marble with dolomite lenses	25	
Graphitic ("blue") marble, including 2 feet white	210	
White marble (11 feet 6 inches of this is east of east wall of Gilson quarry)	31	Mixed marble series (261 feet).
White marble, finely banded with gray	90	
White, graphitic ("blue"), and muscovitic ("green") marble in alternating beds (for details see pp. 117, 118)	140	
Dolomite	40	Lower graphitic series (296 feet).
Mainly graphitic marble, but with 18 feet 6 inches of white, 34 feet of muscovitic (green), and 73 feet 9 inches of dolomite in beds 1.8 inches to 16 feet thick	250	
Muscovitic (green) marble	12	
Graphitic marble	34	
	890	

The True Blue quarry is situated in the upper graphitc series of the foregoing table—that is, in the unquarried beds on the ridge east of the West Rutland quarries. The beds at this quarry are approximately these:

Section of marble beds at True Blue quarry.

	Feet.	
Schist.		
Graphitic marble, about	30	Upper graphitic series (112 feet).
Graphitic dolomite and marble	15–20	
Graphitic marble of various shades, average	62	
Graphitic schist	40	

At the Albertson or Esperanza quarry the following section is exposed:

Section of marble beds at Albertson quarry.

	Feet.
Graphitic marbles above floor of tunnel	105
Graphitie marbles below floor of tunnel	20
Dolomite	23
Marble, some of it greenish	19
Dolomite	22
	199

As the schist boundary is a considerable distance east of the east wall of the Albertson quarry, and as the series exposed at the True Blue quarry only measures about 112 feet from the schist down, the series at the Albertson quarry either includes but a part of the True Blue section or else is entirely below it. The absence of the 40-foot schist bed here would have to be accounted for thus, or else by a change in sedimentation in the space of a mile along the strike. The open syncline of the Albertson tunnel is probably a continuation of one of the minor folds at the True Blue but lower down.

It will be noticed that the graphitic beds of both the True Blue and the Albertson quarries belong to the upper graphitic series in the West Rutland section.

WEST SIDE OF WEST RUTLAND ANTICLINE.

The most complete exposure on the west side of the West Rutland anticline is at the Eastman quarry, about 1½ miles nearly south of the West Rutland station, where, however, owing to a minor westward overturned fold in the western half of the anticline the beds dip east at the surface. (See section E, Pl. III.) The schist boundary on the west is covered by pasture land. Graphitic marble is exposed for 100 feet from a point 50 feet west of the west edge of the quarry. If a dip of 35° E., like that at the quarry, is assumed for this marble and also for the 50 feet covered by turf, the series generalized is as follows:

Section of marble beds at Eastman quarry.

	Feet.
Graphitic marble, exposure 100 feet wide, at 35°	57
Graphitic marble, covered area, 50 feet, at 35°. Of this 28 feet 22 feet has been found by core drilling from the quarry to be graphitic marble	28
West edge of quarry.	
Graphitic marble	17
Total graphitic marble	102
Assorted marbles, cream colored, muscovitic (green), white, etc. (for details see p. 113)	73⅓
East edge of quarry.	
Gray dolomite (from core drilling)	3
Graphitic marble (from core drilling)	3½
White marble (from core drilling)	13½
	195⅓

In the gravel pit north of the new Roman Catholic Church and cemetery about a quarter of a mile west-southwest of the West Rutland station a probable outcrop of graphitic marble has been exposed with the normal strike of the West Rutland belt, N. 25°–30° W., and dips on the east of 30° E. and on the west of 60°–70° W. The nearest schist outcrop and the probable boundary between marble and schist is about 400 feet west of this graphitic marble.

If the space between the two rocks here is all marble and the dip is 60° W. the thickness of the marble would be 320 feet, or, roughly, 300 feet. If the graphitic beds in and west of the Eastman quarry are regarded as part of this series, it would only be necessary to add to these beds the rest of the beds in the Eastman quarry in order to obtain an estimate of the series on the west side of the West Rutland anticline as far as exposed or indicated. The succession would be as follows, beginning on the west:

Section of marble beds on west side of West Rutland anticline.

	Feet.
Graphitic marble, possibly with some interbedded dolomite	300
Cream-colored, white, muscovitic, and other marbles of Eastman quarry	73⅓
Gray dolomite (from core drilling east of quarry)	3
Graphite marble (from core drilling east of quarry)	3½
White marble (from core drilling east of quarry)	13½
	393⅓

Inasmuch as the graphitic beds on the east side of the West Rutland anticline aggregate 293 feet (p. 86), the prognostication of 300 feet for the west side is but very little out. Furthermore, inasmuch as the marble of the Eastman quarry aggregates only 111 feet there should be, to judge from the succession on the east side of the anticline, some 200 feet more of assorted marbles east of the Eastman quarry unless some structural feature not shown at the surface intervenes to cut them off.

That the marble of the Eastman quarry does not correspond bed for bed to that exposed in the quarries on the east side of the anticline is probably to be attributed to minor changes of sedimentation in the distance of a mile along the strike and a quarter of a mile from east to west. A little more clayey sediment in the sea at one point than another would suffice to make the difference between a muscovitic (green) marble and an almost white one.

PROCTOR.

There is no place in the marble belts where the need of a large-scale topographic map accurately showing all the surface details, coupled with ample time for geologic investigation, is more striking than the area extending from Otter Creek on the east three-fourths of a mile to the schist ridge on the west and a mile from north to south, containing the village of Proctor. A complex topography of more or less wooded little hills and hollows and an irregular network of streets coincide here with an area of complicated stratigraphy. The main features, however, are the schist ridge on the west under which the marble dips and the dolomite on the east dipping under the marble, as shown at the Proctor or Sutherland Falls quarry. The marble belt thus bounded is here from 1,650 to 2,200 feet wide. The general structure is shown approximately in sections G and H, Plate III.

The marble beds of the Proctor and Columbian quarries and of a disused quarry between these belong apparently to the base of the marble series, as do also the beds of the Riverside quarry, 2 miles south of Proctor. At the Proctor quarry the thickness exposed is less than 200 feet, for the beds are doubled over in a minor anticline on the west. At the disused quarry on the knoll one-third mile to the south marble about 185 feet thick is exposed. At the Riverside quarry marble measuring 85 feet is in sight and 170 feet more have apparently been crossed by core drilling westward, giving a total of about 250 feet. As the dolomite series and the overlying marble a little farther south dip in the opposite direction from those in the quarry, there is probably a syncline here and the beds prospected east of the quarry may be mostly the same as those in the quarry.

West of the Proctor quarry the marble dips under an overlying mass of dolomite 840 feet wide which extends to the pond. Its thickness depends on the number of folds and the inclination of their sides. The dips range from 35° to 75° E. If there is one syncline and one anticline in this mass the thickness would be about 264 feet, which, to judge from that of the corresponding dolomite in the Pittsford section, is probably not far from correct.

The conspicuous marble knoll half a mile south of Proctor and north of the Columbian quarry (see map, Pl. I) presents an interesting problem. Its probable structure is shown in section H, Plate III.

Its west side is pretty clearly an anticline with an almost vertical west limb and a narrow horizontal or nearly horizontal top and core, followed on the east by a compressed syncline overturned to the west, the upper beds of the dolomite overlying the marble with easterly dip, as at the Proctor quarry. In this dolomite a test pit has exposed a graphitic dolomite like that of the prospect 2 miles north of Proctor (p. 128). Although the marble of this knoll apparently belongs to the Proctor quarry line of beds, yet its strike is in line with the marble beds of the Shangrow quarry and with the pond west of the Proctor quarry. Furthermore, in the dolomite east of the knoll there is a small strip of white marble about 20 feet wide cut off by dolomite on the south, which is in line with the marble of the disused quarry in the village and of the Proctor quarry. There may be a lateral dislocation here along a fault line passing between the north side of the marble knoll and the dolomite cliff on the next knoll north; and this 20 feet of marble may be a small bed in the basal dolomite. If there is such a dislocation the intermediate dolomite which lies west of the Proctor quarry passes west of the marble knoll and is covered by drift. As a large part of the top of the knoll is covered by vegetation, it is uncertain whether the intermediate dolomite is represented in the synclinal part of the knoll. Hence the interrogation mark over that part of the section. The entire thickness of the marble beds here approximates 264 feet, but if they were quarried in the mass across the folds from east to west it would measure not far from 740 feet.

West of the intermediate dolomite, which at any rate forms the hill west of the Proctor quarry, is an upper set of marble beds well exposed in the now disused Shangrow quarry and other neighboring quarries and at several points in the village. This marble is mostly graphitic and in places finely banded. The space between the dolomite at the pond and the schist boundary on the west is roughly about 600 feet and that between the marble knoll three-fourths of a mile south of the Proctor quarry and the schist boundary, after deducting 272 feet for the covered dolomite, is about 500 feet. The structural relations call for an easterly inclined syncline next to the dolomite and a normal anticline west of it. If these folds were compressed and vertical the space at the pond would admit of beds 200 feet thick, but as the beds dip from 55° to 65° E. on the east side and 25° to 45° W. on the west their thickness can hardly exceed 150 feet. If the folds are steeper west of the steep marble knoll to the south their thickness might be 150 feet. The greatest thickness of the graphitic beds exposed at any one quarry is 135 feet. The reason for the fault shown in section G will appear after considering the Pittsford section. (See p. 91.)

These graphitic marbles extend to the schist ridge, where they dip west under the schist, the plicated bedding of which also dips west, although crossed by a more conspicuous eastward-dipping slip cleavage. The presence of at least one anticline in the basal dolomite at Proctor is shown by the 50° westward dip of the dolomite back of the Y. M. C. A. Building and the town hall. This dip becomes 75°–80° W. a few hundred feet farther south, back of the post office, whereas the prevalent dip west of these points is 70° E.

The marble of the entire Proctor section thus appears to consist of the following members, so far as the data obtained indicate, beginning on the west and at the top.

Section of marble beds at Proctor.

	Feet.
Schist.	
Graphitic marble of Shangrow and other neighboring quarries, with some interbedded dolomite	150
Dolomite (knoll west of Proctor quarry)	264
Marble, bluish white, clouded	172–264
Dolomite.	
	586–678

PITTSFORD.

In Pittsford the marble belt widens out to 0.7 mile west of Fowler and to 0.9 mile east of the Florentine quarry. The first inference from this widening is that the schist has been eroded from a wider surface of the marble belt and that its structure consists of minor folds. The difficulty in obtaining satisfactory estimates of thickness in this locality is great. A view across the marble belt here is given in Plate IX.

At the Florentine quarry, where the contact between schist and marble is visible, the graphitic upper part of the marble beds is well exposed and measures about 150 feet.

At the old Hollister quarry, beginning at a point about 127 feet west of the west wall of the quarry and counting eastward and downward, the following section has been made out:

Section of marble beds at Hollister quarry.

	Ft.	in.
Marble, mostly light bluish gray, about	90	
Clouded marble	16	
Bluish marble, "blue vein"	14	
Marble, white and muscovitic, including beds M and N	15	
West edge of quarry.		
Light bluish-gray marbles, including beds K and I	12	6
Inferior	7	
Marbles, light bluish gray, mottled, beds A–F, 9 to 32 feet, average	20	6
East edge of quarry.		
Marble, white or light bluish gray (core drilling)	47	10
	222	10

East of these beds there are 146 feet of strata to a dolomite. If these are all marble and dip not higher than 50° they would amount to a thickness of 112 feet. In view of the uncertainties these strata are not counted. As beds A to F measure 32 feet at a depth of 175 feet but only 9 feet at the surface, and dip 87° E. on the east side but 90° on the west, they might be regarded as the core of an anticline, but the quarrymen report that the character of the marbles does not indicate duplication here. The entire series is so thick, however, as to point strongly to such duplication.

At the Florence No. 1 or Hogback quarry, besides the 85 feet of pale-gray mottled marble exposed in the quarry, core drilling has crossed 110 feet of similar marbles on the west and 50 feet on the east followed by 20 feet of white near the dolomite. The succession here, beginning on the west, is as follows:

Section of marble beds at Florence No. 1 quarry.

	Feet.
Marble west of quarry crossed by core drilling, 110 feet; if dipping 70° measures	102
Light-gray clouded marbles exposed in quarry	85
Similar beds crossed by core drilling east of quarry, 50 feet at 70°	47
White marble crossed by core drilling east of quarry, 20 feet at 70°	18
	252
Dolomite east of above beds, 270 feet at 70°	252
Outcrops of light marbles east of dolomite, 100 feet at 70°	93
Dolomite.	
	597

Another estimate of the lower part of the marble of the Pittsford section was obtained at the Pittsford Italian and Florence No. 2 quarries. At the Florence No. 2 quarry there are 45 feet of light-gray mottled marbles, including a 9-foot bed of dark-gray marble, dipping 82°. Drilling has been done to a point 170 feet east of the quarry, showing the same marbles extending almost to the underlying dolomite. The succession at both quarries is as follows:

Section of marble beds at Florence No. 2 and Pittsford Italian quarries.

	Feet.
Florence No. 2 quarry, light-gray clouded marble and beds east of it, 215 feet at 76° (average of 82°, dip at quarry, and 70°, dip of dolomite)	208
Dolomite east of this, 259 feet at 70°	242
Pittsford Italian quarry, white clouded marble exposed at quarry, 70 feet at 75°	65
Outcrops at either side of quarry, 150 feet at 75°	142
Dolomite.	
	657

At the Landon quarry about 80 feet of mottled light-gray marble has been exposed, belonging near the base of the Pittsford section.

From these several sets of measurements and estimates the marble of the Pittsford section appears to consist approximately of the following members, beginning at the top and west:

Section of marble beds at Pittsford.

	Feet.
Schist.	
Graphitic marble, with some interbedded dolomite (Florentine quarry), about	150
"Florence No. 2" and "Hollister" marble beds, light bluish gray, mottled with dark gray (208 to 252 feet), average	230
Intermediate dolomite (242 to 252 feet), average	247
"Pittsford Italian" marble beds, slightly bluish white mottled with medium gray (92 to 209 feet), average	151
Dolomite.	
	778

SOUTH DORSET.

The marbles of South Dorset not only differ texturally and mineralogically from those already described, being generally coarser and containing actinolitic beds, but they appear to be structurally isolated from the marble beds on Dorset Mountain and Green Peak by a fault or faults whose course is concealed. The marble in the quarries about a mile northeast and 500 feet above the Norcross-West South Dorset quarries lies in nearly horizontal folds of unusual character, as shown in figure 14 and on page 102. If such horizontal or low-dipping folds have been produced by extreme lateral compression and a subsequent erection of folded series so as to give the beds a general dip across the folds of about 80° S. 45° W., a fracture must have occurred between those beds and the gently folded beds exposed in the Norcross-West Valley quarry. In any case the structure west and southwest of the Owls Head is evidently very different from that southeast of Green Peak.

The exposures at the two quarries of the Norcross-West Marble Co. and the core-drill records of the company indicate the following succession, beginning at the top:

Section of marble beds at Norcross-West quarries, South Dorset.

	Feet.
Alternating white and white mottled with light and dark gray marble, with some actinolitic beds, 125 feet, dipping 20° (the dip of 20° is assumed here)—that is, crossed by drill at 70°	116
Dolomite exposed in Main quarry (10 feet) and also crossed by drill, 20 feet at 30° (crossed by drill at 60°)	10– 17
Gray marbles, 60 feet, dipping 30° (crossed by drill at 60°)	51
	177–184

As there is no evidence that the drilling reached the basal dolomite series nor any obtainable data as to the vertical distance between the uppermost bed in these quarries and the base of the schist mass, the figures simply show the thickness explored thus far. The entire marble series here should be much thicker. The problem is to ascertain how much marble has been eroded from the surface now quarried and how much intervenes between the lowest bed reached by drilling and the top of the underlying dolomite series.

DORSET MOUNTAIN, OWLS HEAD, AND GREEN PEAK.

The State report of 1861 in a section [1] referred to on page 64, shows 86 feet of "blue compact siliceous limestone," presumably gray dolomite, immediately under the schist mass, and states [2] that near the cave "blue limestone" about 100 feet thick underlies the schist and overlies about 100 feet of coarse marble. Mr. Moffit found on the east side of Green Peak a quartzose dolomite 50 feet below the schist cap and on the north side a 4-foot bed of quartzite 10 feet below the schist. Below the cave he noted 60 to 80 feet of marble. The upper tier of quarries west of the Owls Head is reported by the owners as capped by 50 feet of dolomite. At the Blue Ledge quarry (p. 104) dolomite 25 feet thick overlies 60 feet of mottled marble, which the State geologists [2] report as being 100 feet thick 10 rods west of the quarry; and Mr. Moffit found the upper beds of the dolomite series along the 1,900-foot level about 100 feet below this quarry. The inference from these data is that on Green Peak there is an upper set of marble beds, separated from the overlying schist in places by at least 50 to 100 feet of dolomite, and a lower set of marble beds, separated from the upper set by an intermediate dolomite in places 100 feet thick, and that these lower marble beds rest upon the basal dolomite.

At the Freedley quarries, on the east side of Dorset Mountain, the following section is exposed, beginning at the top:

Section of marble beds at Freedley quarries.

	Feet.
Schist.	
Covered, dolomite (probably)	90–100
Bluish dolomite	10
Marble, graphitic or banded with muscovite	92
Dolomite	8
Marble, including gray beds	70
White marble	45
Micaceous bed	1
White marble	44
Dolomite.	
	360–370

At the White Stone Brook quarry of the Norcross-West Co., on the east side of Dorset Mountain, north-northwest of North Dorset, the series includes the following beds:

[1] Geology of Vermont, vol. 1, 1861, p. 418. [2] Idem, vol. 2, 1861, p. 759.

Section of marble beds at White Stone Brook quarry.

	Feet.
Dolomite	10
Graphitic marble	10
White marble	68
Graphitic marble	13
White marble	3
Banded marble	5
	109

At the Imperial and New York quarries of the Vermont Marble Co., a little farther north in Danby Township, the following series has been made out by quarrying and core drilling:

Section of marble beds at Imperial and New York quarries.

	Feet.
Dolomite (?)	10+
White marble, exposed in New York quarry	35
Marble, white, mottled, gray in alternating beds and including three beds of dolomite 1 foot 6 inches to 6 feet thick, crossed by core drilling from bottom of tunnel in New York quarry	105
Marble and dolomite (50 feet (?)) between end of above drill core and roof of tunnel in Imperial quarry	135
Marble, white, mottled, striped and light gray, in alternating beds, crossed by core drilling from top of tunnel in Imperial quarry; 198 feet, dip 10° from surface = 198 feet at 80° to drill hole =	192
	477

There may be a few feet (25 to 50 feet?) between the dolomite series and the lowest point reached by core drill from the tunnel in the Imperial quarry.

By collating these various estimates the following section is obtained for Dorset Mountain and Green Peak:

Section of marble beds on Dorset Mountain and Green Peak.

	Feet.
Schist.	
Quartzose dolomite	20–100
Marbles, white, graphitic, mottled, banded, muscovitic, in alternating beds and including small micaceous beds and a few of dolomite	100–175
Dolomite	50–100
Marbles, generally white or mottled	165–242
Dolomite.	
	335–617

THE ENTIRE MARBLE SECTION.

By abridging and arranging the West Rutland, Proctor, Pittsford, and Dorset Mountain and Green Peak estimates in one table we obtain a view not only of the general character of the marble but also of its local variations, as well as somewhat satisfactory estimates of its maximum and minimum thickness. The beds of South Dorset can not well be tabulated with the others, as their position either with reference to the base or top of the marble can not yet be determined.

Marble beds in western Vermont.

	West Rutland anticline, east side.	West Rutland anticline, west side.	Proctor.	Pittsford.	Dorset Mountain, Owls Head, and Green Peak.
Schist.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Upper graphitic marbles, including some dolomite and, exceptionally, schist.	199-293	300	150	150	[a] 20-100
Average	(246)				
White, graphitic, and muscovitic marbles, alternating.	180-222	93 (Rest not reached.)	Absent..	Absent..	100-175
Average	(201)				
Upper clouded light-gray marbles	Absent..	Probably absent.	Absent..	230	
Intermediate dolomite	40	Not reached	264	247	50-100
Lower clouded white marbles	Absent..	Probably absent.	172-264	151	165-242
Lower graphitic marbles	296	Not reached	Absent..	Absent..	
Dolomite.					
Total	715-851		554-678	778	335-617
Average	783		616		476

[a] Mostly if not all dolomite.

Among the most striking features in the table is the disparity in thickness of the intermediate dolomite in the West Rutland and Dorset Mountain sections on the one hand and the Proctor-Pittsford belt on the other. The absence in the Proctor section of both the West Rutland assorted marbles and the Pittsford clouded light-gray marbles, between the intermediate dolomite and the upper graphitic marbles, points to the possibility of a longitudinal fault between the dolomite and the graphitic marbles. The irregularity of the relations north of the anticlinal marble knoll between the Columbian and Proctor quarries has already been pointed out, and the Pine Hill overthrust fault is only 2 miles east. (See map, Pl. I.) Section G (Pl. III) has been drawn tentatively to explain the anomalous character of the Proctor succession. The upper clouded marbles and the white and muscovitic marbles, which normally occur above the intermediate dolomite, are shut out by an overthrust fault which brings that dolomite next to the upper graphitic marbles. Furthermore, the thinning out of the upper graphitic marbles in the Dorset Mountain and Green Peak sections should be noticed. Some of these differences are evidently due to local changes in the character of the sediments in which the marble beds originated.

This table is to be regarded as a summary of such measurements and estimates as are practicable at present and is designed to afford a basis for the more exact determinations which further quarrying, core drilling, and geologic exploration will make possible. It is a tentative section of all the marble beds.

THE MARBLES AND MARBLE QUARRIES.

CALCITE AND DOLOMITE MARBLES.

The details as to the quarries and their product will be given in the following order: (1) Name and location of quarry; (2) approximate dimensions; (3) operator's name and address; (4) marble section and thickness of marble beds; (5) principal marbles, scientific and trade names; (6) their colors and mineral composition; (7) texture and textural grade number; (8) analyses and tests, if any; (9) geologic structure; (10) uses of product; (11) location of specimen edifices or monuments.

The more improved machinery in use either at the quarries or the finishing works is referred to on page 156.

The quarries are taken up by groups in geographic order from south to north. Some idle ones are included on account of their economic or scientific interest.

MANCHESTER.

DYER QUARRY.

The Dyer quarry is on the south foot of Equinox Mountain, on the D. H. Dyer farm about 250 feet south of the Dyer house (see map, Pl. I), a mile north-northwest of the Sunderland station in the town of Manchester. The quarry is not operated. The opening is small and only 30 feet deep.

The marble (specimens D, XVIII, 137, a, c, d, g, rough; D, XXXI, 81, a, polished) is a breccia with bright brick-red cement and fragments of (1) pinkish to cream-colored and (2) bluish-gray calcite marble, and also of (3) a deep-reddish hematitic calcitic dolomite marble. The breccia is described more fully on page 48 and its general character is shown in Plate VIII, *B*, *a*. The pinkish marble belongs to grade 4, the bluish gray to grade 5, and the reddish to grade 2.

The beds undulate in small folds, striking N. 20°–25° E. The brecciated bed is reported to have been core drilled to a vertical depth of 200 feet. It is bordered on both the east and the west by a light bluish-gray calcite marble like that of some of its fragments. At a point about 3,400 feet S. 25° W.—that is, along the strike—close to the Sunderland line, a much jointed gray marble has been prospected, which has dolomite east of and under it. West and south of this prospect, on the cross road, the dips are low to the west. These facts indicate that the breccia will probably be found to be underlain by the dolomitic series at no great depth. There may, however, be a fault along the brecciated bed.

Columns of the breccia 13 feet long have been obtained. The problem is to determine how much of the brecciated bed is free from fragments large enough to deprive it of ornamental quality. The weakness of the marble as a whole is no more of a detriment than that of the imported breccias.

SOUTH DORSET.

A few data were obtained in or as to three idle quarries near South Dorset village. The locations are shown on the map (Pl. I).

BENNINGTON QUARRY.

The Bennington quarry, a little east of the village, is owned by the Bennington Marble Co., St. James Building, Broadway and Twenty-sixth Street, New York.

KENT & ROOT QUARRY.

The Kent & Root quarry, a little south of the village, is 50 by 60 feet in area and more than 100 feet deep. The marble strikes N. 5°–10° E. and dips 45° W., but to judge from the blocks on the dumps is much folded.

CONTINENTAL MARBLE CO.'S QUARRY.

The Continental quarry is a mile west-northwest of the village. The marble is gray and white banded and is overlain by dolomite. The beds, though nearly horizontal, show a minor fold striking clearly N. 55° E. One set of joints strikes N. 30° W.; another N. 65° W.

VALLEY QUARRY (NORCROSS).

The Norcross-West Marble Co.'s Valley quarry is a mile north-northwest of South Dorset village, and about 2½ miles S. 79° W. from the top of Green Peak, the southern outlier of Dorset Mountain, in the southwestern part of Dorset Township. (See map of Equinox quadrangle, U. S. Geol. Survey, and geologic map, Pl. I.) It was opened in 1785, was worked in 1870, and reopened in 1902. It measures about 500 feet in a northeast direction by 100 feet across and averages 70 feet in depth.

Operator, Norcross-West Marble Co., Dorset, Vt.

The marble beds consist, beginning at the top, of 116 feet of marbles, white and white mottled with light and dark gray, underlain by 10 to 17 feet of dolomite, and that in turn by 51 feet of gray marbles. (See p. 93.)

The marbles of this quarry are known as "Dorset A" and "Dorset green bed."

"Dorset A" (specimens D, XXXI, 4 b, rough; e, f, g, polished) is a calcite marble of cream tinted to very light, faintly greenish smoke color, and of coarse irregular texture with grain diameter of 0.07 to 1.25, exceptionally 2 millimeters, but mostly of 0.25 to 0.75, averaging by a Rosiwal estimate 0.208 millimeter and thus of grade 5 (coarse). (See p. 54.) It contains semitranslucent nodules of uncertain composition (carbonate ? or silicate) and sparse small grains of quartz. The greenish smoky tint, in places in streaks, appears to be due mainly to the nodules and muscovite, but in places also to pyrite, which measures up to 2 millimeters. The polish when examined with a magnifier is only fair. A thin section of this marble is shown in figure 13.

The following analysis of this marble, recently made at the Worcester Polytechnic Institute for the firm, is published here for reference:

Analysis of calcite marble from South Dorset.

Calcium carbonate ($CaCO_3$)	98.43
Magnesium carbonate ($MgCO_3$)	.26
Iron oxide (FeO)	.38
Moisture (H_2O)	.44
Loss and undetermined	.49
	100.00

The results of physical tests of this marble will be found on page 101.

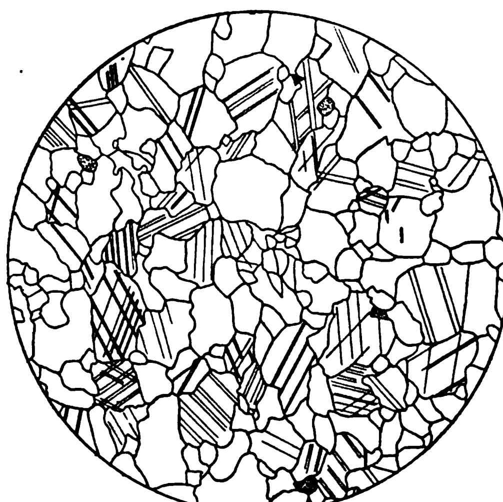


FIGURE 13.—Thin section of "white" calcite marble, "Dorset A," from the Norcross-West Valley quarry near South Dorset. Texture, grade 5. Dotted particles are quartz. Enlarged 20 diameters.

"Dorset green bed" (specimens D, XXXI, 4, a, rough; c, d, polished) is an actinolite-calcite marble of faintly greenish to pale cream color with very dark to light greenish-gray streaks, really beds, not over 0.1 inch thick (where single and straight), acutely plicated at intervals. Its texture is coarse but more regular than that of "Dorset A." As its grain diameter is 0.12 to 1, mostly 0.25 to 0.62 millimeter, it is also of grade 5. The little gray-greenish beds consist of fibrous actinolite with a little quartz and irregular semitranslucent nodules of uncertain character and bluish-green tourmaline. Pyrite is plentiful up to 0.5 millimeter in diameter. Some limonite stain appears, presumably from the oxidation of the pyrite. The polish over the actinolite streaks is naturally poor.

The pilasters of the "green bed" shown in Plate VII, which were cut parallel to the strike of the bed, seem to indicate some brecciation in that direction.

The structure at this quarry seems to be that of a very gentle anticline with a N. 70° E. strike, but at the northeast end of the quarry the beds rise in minor folds with an average dip of 30°–40° NNW. and a pitch of 10° N. 30° E. and the dolomite bed which underlies the marble of the center of the quarry reaches the surface with a thickness of 10 to 12 feet. This indicates a syncline between the northeast wall and the anticline of the quarry. Two vertical joints occur along the east wall with strike of N. 20° E. The strike of the marble (N. 70° E.) seems to be related to the N. 55° E. strike at the Continental quarry, a mile nearly southwest, and at the quarries near the Owls Head, a mile northeast. The dolomite is crossed by cleavage planes filled with quartz dipping about 20° E. A thin section of this rock is described on page 30.

The product of this quarry will be given in connection with the Plateau quarry for the reason that in many structures the marbles have been combined.

PLATEAU QUARRY.

The Plateau quarry of the Norcross-West Marble Co., situated 480 feet northeast of the Valley quarry, is of irregular form and averages about 90 by 80 feet and 15 to 40 feet deep. The stripping consists of 10 to 16 feet of gravel and fine sand. A view of part of the quarry is shown in Plate X, *A*.

The relation of the marble beds in this quarry to those in the Valley quarry is very uncertain, as neither the outcrops nor the core-drill records make it clear. These records indicate at least 80 to 100 feet of marble beds at this quarry. The marble, known as "Dorset B," is of a darker shade than "Dorset A."

"Dorset B" (specimens D, XXXI, 4B, a, rough; 4B, b and c, polished) is a calcite marble of light cream color, clouded with light-gray to smoke tint, and of coarse texture, somewhat less irregular than that of "Dorset A," with a grain diameter of 0.07 to 1.12, mostly 0.25 to 0.62 millimeter, of grade 5. It contains some grains of quartz, groups of grains of granitic or vein quartz, rare grains of potash feldspar (microcline), stringers of fibrous muscovite, and plates of white mica, also irregular minute semitranslucent nodules like those of "Dorset A" and a little pyrite in fine particles and crystals and limonite stain. The gray shade appears to be due to the muscovite, the pyrite, and the nodules.

The structure at the northeast end of this quarry shows a strike of N. 70° W. At the southeast end the marble is intensely and acutely plicated; the little folds are 6 inches wide and 5 feet long.

It is not clear whether these are horizontal folds in a vertical stratum or minor folds along a very gently dipping one.

Tests of compressive and transverse strength of the marbles of the Valley and Plateau quarries were made for the company at the United States arsenal at Watertown, Mass., on March 5, 1903, with the following results:

Results of physical tests of marble from South Dorset.

Compression tests.

[6-inch cubes.]

Marble.	Strength per square inch, tested on bed.	Strength per square inch, tested on edge.
	Pounds.	*Pounds.*
Dorset A	11,270	8,400
Dorset B	11,170	9,460
Dorset green bed	11,460	9,440
Average	11,300	9,100

Transverse tests.

[Samples 26 inches long and 3 inches square; supports 24 inches apart; load applied at middle.]

Marble.	Ultimate transverse strength.			
	Tested on bed.		Tested on edge.	
	Pounds.	Modulus of rupture.	Pounds.	Modulus of rupture.
Dorset A	657	860	655	840
	605	780	564	720
Dorset B	787	1,010	774	1,010
	776	1,010	682	890
Dorset green bed	594	780	650	850
	625	620	781	1,010
Average	674	843	684	886

The marble of the Plateau quarry, "Dorset B," and the "Dorset A" from the Valley quarry are used for construction and the "green bed" for internal decoration.

Specimens: A triangular block of white marble taken from a building close to the main quarry, inscribed "A. D. 1831," in which the letters and figures have preserved their sharp edges and which in all probability came from the adjacent quarry opened 46 years earlier, is regarded as the best evidence of the weathering quality of "Dorset A" marble.

The more important edifices made from these marbles are the New York Public Library, Forty-second Street and Fifth Avenue (except the approaches); the entire group of buildings of the Harvard Medical School; the John Hay Memorial Library, Brown University, Providence, R. I.; the Memorial Continental Hall, Washington (except northwest corner), including 13 monolithic 27-foot columns, (Pl. XI); the Royal Bank of Canada, Toronto; the Art Association Building, Montreal, with four 32-foot monolithic columns (see Pl. X, *A*); the portico and columns of the residence of Mr. W. T. Sessions, Bristol, Conn.; and the Congregational Church at Dorset, Vt.; and of "Dorset B" the exterior of the residence of Henry Phipps, Fifth Avenue and Eighty-seventh Street, New York.

The "green bed" supplied the panels and wainscoting of the National Commercial Bank, Albany, N. Y.; the interior of the American Trust & Savings Bank, Chicago; and the interior marble (except flooring) of the Hampden County courthouse at Springfield, Mass., including the columns in the rotunda and the pilasters shown in Plate VII.

OWLS HEAD QUARRIES.

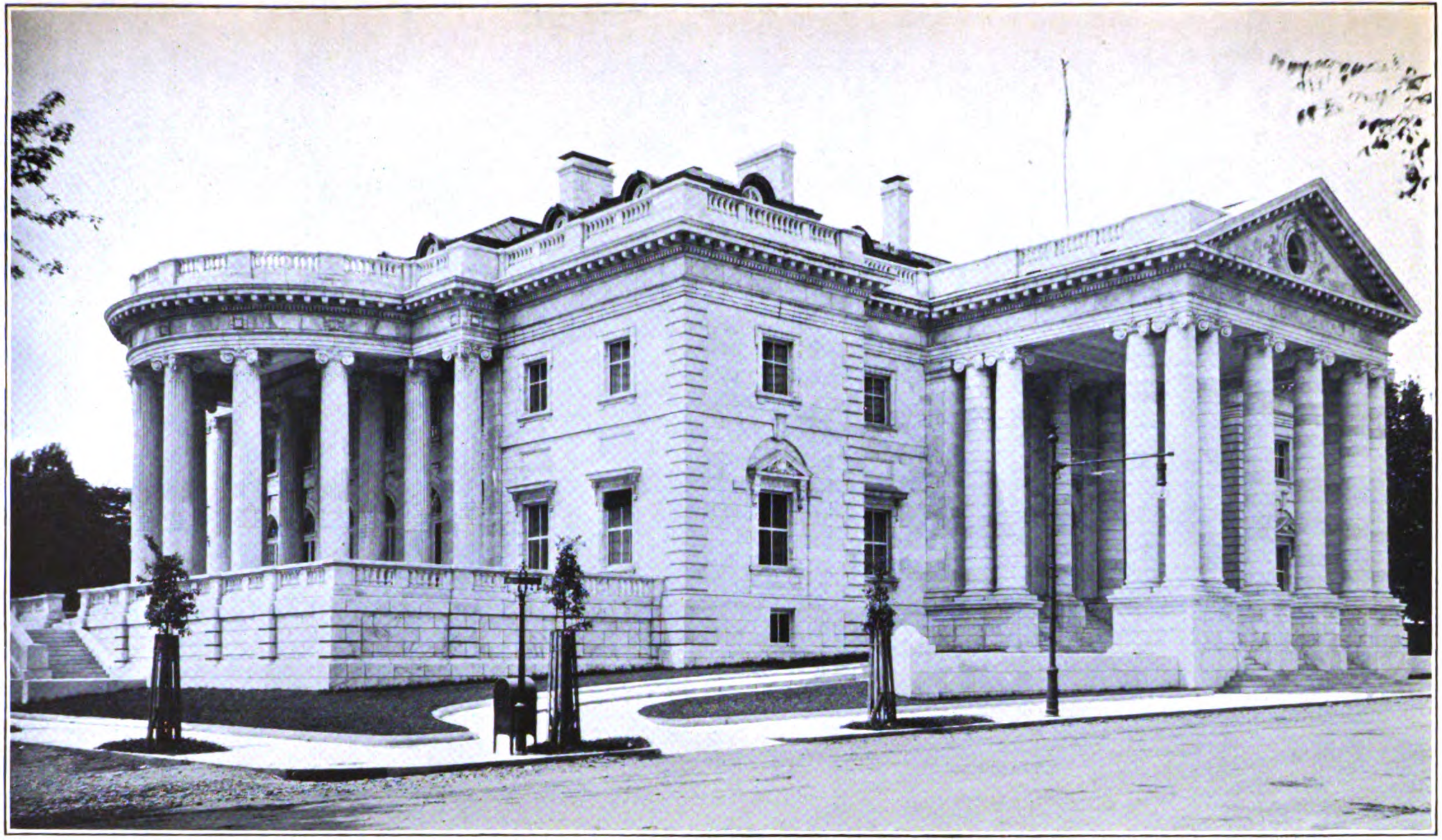
There are two quarries in an upper and two in a lower tier, situated about half a mile west of the Owls Head, about 1½ miles north of South Dorset village, on the 1,400 and 1,670 foot levels—that is, 500 and 770 feet above the village. The Owls Head is the western summit of the schist outlier of Dorset Mountain, of which Green Peak is the eastern and higher point. (See map, Pl. I.) One of these quarries is reported to have been reopened in 1903; the others have been idle many years. The property is said to be controlled by the Dorset Mountain Marble Co., of East Dorset, Vt.

The marble of the upper two quarries is reported as measuring altogether 150 feet, covered by 50 feet of dolomite, and that of the lower ones as consisting of 80 feet of mixed white and gray marbles. That these apparent thicknesses are not the actual ones is evident from the facts given in the discussion of structure (p. 93). Wherever the beds are not doubled over on themselves the thickness must be much less.

A specimen of white marble from the northwestern or tunnel quarry of the upper tier is a coarse white calcite marble with grain diameter of 0.05 to 1.37, mostly 0.25 to 0.75 millimeter, and belongs to grade 5. A specimen of clouded white marble from the lower tier has a grain diameter of 0.07 to 1.12, mostly 0.25 to 0.62 millimeter, and is also of grade 5. It contains plentiful quartz grains in places, with stringers of muscovite and a little pyrite.

The structure at these quarries is of very intricate character,[1] as shown by figure 14 and Plate XVI, *B* (p. 132). In the northwestern upper quarry, where an apparent thickness of 100 feet is exposed with an apparent dip of 5°–10° N. 55° E., the marble consists of minor folds drawn out in an almost horizontal direction by flowage, so that a fold

[1] Hitchcock and Hager noticed some structural irregularity here (Geology of Vermont, vol. 2, 1861, p. 756, fig. 325).



MEMORIAL CONTINENTAL HALL, WASHINGTON, D. C.

With columns of calcite marble from South Dorset.

measuring only a foot in thickness at its thickest part, where doubled, has its apex 60 feet away. One fold 25 feet long by 5 feet in width, doubled, is probably altogether 50 feet long and 6 feet across at its widest part. (See fig. 14, *a*.) In the southeasterly quarry of the upper tier marble and dolomite are interbedded, as shown in figures 5 and 14, *b*. In the lower tier of quarries similar compressed and elongated folds occur (fig. 14, *c* and *d*).[1] The axes of these folds strike N.

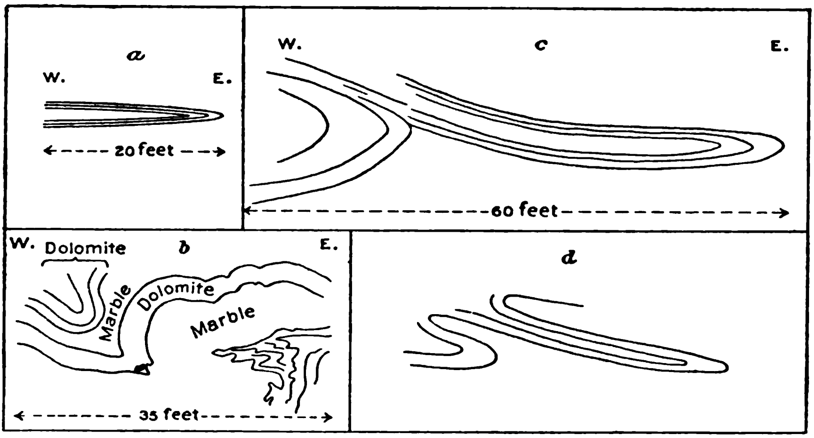


FIGURE 14.—Marble folds in quarries near Owls Head. *a*, Elongated fold; *b*, untwinned dolomite and calcite marble interbedded; *c*, present structure; *d*, probable structure of *c* at an earlier stage.

15°–60° E. The first inference from such structure is that no reliable measures of the thickness of the marble can be taken in this part of the mountain. A vertical joint in the tunnel quarry strikes N. 50°–55° E., and at the eastern one the joints strike N. 25° E. and dip 35° S. 65° E.

GREEN PEAK QUARRIES.

Green Peak (Hitchcock's Mount Eolus), altitude 3,185 feet, although popularly confounded with Dorset Mountain, is properly an outlier of that mountain and of its schist mass. (See map, Pl. I; also maps of Pawlet and Equinox quadrangles, U. S. Geol. Survey.) Marble was early quarried on its southeast side at the 2,100-foot level, or about 1,300 feet above the Vermont Valley at East Dorset.

DEAF JOE QUARRY.

There are two small and disused marble openings about three-fourths of a mile and 1 mile roughly southwest of Green Peak, one of which is known as the Deaf Joe quarry. At the lower one, on the 1,450-foot level, a white marble strikes N. 60° E. and dips 25° N. 30° W. At the upper one, on the 1,800 to 1,870 foot level, mottled marble about 20 feet thick is exposed with a very low westerly dip.

[1] This interbedding of dolomite and marble has been referred to on p. 31 and also in Bull. U. S. Geol. Survey No. 195, 1902, pp. 13–15.

BLUE LEDGE QUARRY.

The Blue Ledge quarry, opened in 1825 or earlier, was known as the Holley, Fields & Kent, or Kent quarry, later as the Blue quarry.[1] It is about on the 2,000-foot level, half a mile S. 60° E. from Green Peak and a mile S. 80° W. from East Dorset village, in the township of Dorset. (See map, Pl. I.) The view from the top of the dumps of this quarry, looking down the Vermont Valley, is one of the finest in the State. The quarry measures about 350 feet north to south by 100 feet across and has walls 60 to 85 feet high. It has recently been reopened. Operator, Norcross-West Marble Co., Dorset, Vt.

The marble beds exposed here consist of 60 feet of mottled marble overlain by 25 feet of bluish dolomite, but the 1861 Vermont report[2] states that this dolomite bed measures about 100 feet 10 rods west of the quarry. As there is marble above the dolomite this may be an intermediate dolomite.

The marble (specimens D, XXXI, 9, a, rough; c, d, e, polished), "Dorset Mountain," is a calcite marble of faintly bluish white tint, irregularly mottled with very light gray and of irregular texture, consisting in the darker mottling of untwinned dolomite grains with a diameter of 0.02 to 0.12 millimeter and thus of grade 1, but in the general white mass of twinned denticular calcite grains with a diameter of 0.25 to 0.75 millimeter and thus of grade 5. It contains sparse quartz grains up to 0.32 millimeter, somewhat plentiful, pyrite crystals and particles, rare muscovite, and very minute undetermined black particles. The stone takes a fair polish, but the dolomitic mottling, being harder than the calcite ground, projects in minute relief on the polished face.

The marble and dolomite beds dip 10° SSE. and 5° NNW., forming a very gentle anticline with an axis pitching gently south. The chief joints strike N. 10° E. and N. 80° W. and are steep or vertical. The marble beds or some of them are separated by beds an inch thick of white pyritiferous, quartzose, micaceous dolomitic calcite marble which weathers light brown. In thin section this rock consists of calcite grains up to 0.5 millimeter in diameter, with finely disseminated limonite and crystals of pyrite passing into limonite, many quartz grains, fibrous muscovite, large scales of chlorite and muscovite, and also nodules of dolomite up to 0.3 inch. This marble has not yet been used to any great extent.

FOLSOM QUARRY.

Between one-fourth and one-third of a mile south-southwest of the Blue Ledge quarry is the long disused Folsom quarry (see map, Pl. I), the floor of which is but a few feet higher than that of the Blue

[1] Hitchcock, Edward, and Hager, A. D., Geology of Vermont, vol. 2, 1861, pp. 757-759.
[2] Idem, p. 759.

Ledge. The quarry is about 100 feet square and has walls 50 feet high. Its floor is underlain by 10 feet of dolomite, upon which lies more or less mottled calcite marble, about 50 feet thick.

The beds strike N. 60° W., dip 10° N. 30° E., and are crossed by vertical joints striking N. 80° W. and N. 15° E., which form three walls of the quarry. At the west wall is a vertical dike from 1 foot to 2 feet 6 inches wide, becoming 8 feet a little beyond, with a N. 35°–40° E. course. The dike above the quarry floor has been quarried away or is covered with débris. The marble on either side of it is incrusted with limonite and stained red with hematite. On the quarry side the marble for 2 to 3 feet from the dike is much shattered and veined with calcite in crystals.

EAST DORSET ITALIAN QUARRY.

The East Dorset Italian quarry, also idle in 1910, is between the Folsom and Blue Ledge quarries about 300 feet south of the latter. Owner, Dorset Mountain Marble Co., East Dorset, Vt.

In 1900 marble about 35 feet thick was in sight and drillings at the bottom of quarry showed 17 feet more—beginning above, three 3-foot beds, one 2-foot, and one 6-foot.

Specimens M, IV, 192, a to d, from the west side, floor and 10 and 20 feet up, and from the south side, show a coarse white calcite marble of grade 5, in places with grayish bands or with limonitic bands from oxidized pyrite. A polished specimen (D, XXXI, 79, a) is of light bluish-gray color, with little plicated dark-gray graphitic beds.

The beds are horizontal; vertical joints strike N. 80° E. and N. 10° W., and one dipping 70° N. 55° W. strikes N. 35° E.

QUARRIES ON DORSET MOUNTAIN.

FREEDLEY QUARRIES.

The Freedley quarries include four openings: (1) The Tunnel quarry, opened about 1790, is about a mile west of Freedleyville, 1,160 feet above it, on the 2,040-foot level. It is on the east side of the southern and eastern spur of Dorset Mountain, in the town of Dorset. (See map, Pl. I, and map of Pawlet quadrangle, U. S. Geol. Survey.) This quarry has an east-west tunnel 160 feet long. (2) The Upper quarry, north of the Tunnel quarry, is also of very early date. (3) The Open quarry, begun in 1909, is about 500 feet northeast of the Tunnel quarry and about 100 feet lower. (4) The Scotchman's quarry, begun in 1910, is over half a mile north of the Open quarry.

Operator, Manchester Marble Co., East Dorset, Vt., also Graham Avenue and East River, Astoria, Long Island City, N. Y.

The marble beds, as reported by the superintendent, include the following:

Section of marble beds at Tunnel and Open quarries, Freedleyville.

	Feet.
Tunnel quarry:	
Marble, mostly banded with muscovite	92
Dolomite	8
Marble, white and gray	70
Open quarry:	
White marble	45
Micaceous bed	1
White marble	44
Dolomite.	
	260

Mr. Moffit in 1900 noted the following section at the Upper quarry:

Section of marble beds at Upper quarry, Freedleyville.

	Feet.
Bluish dolomite	10
Light-gray marble ("Manchester blue")	26
White marble	4
White marble ("mahogany bed"), including two 1-foot micaceous and quartzose beds	10

At the Tunnel quarry Mr. Moffit observed a dolomite overlying 15 feet of coarse white marble. He reported 110 feet of marble in all, three-fourths of which was good. He also found the schist boundary a little farther north, 100 feet above the bluish dolomite.

The marble of the Open quarry (specimen D, XXXI, 8, a, rough) is a translucent, faintly cream tinted coarse white calcite marble with a grain diameter of 0.12 to 1, mostly 0.25 to 0.5 millimeter, and thus of grade 5. The "Manchester blue" (specimen M, V, 6, j) of the Upper quarry is a very light bluish-gray coarse calcite marble with a grain diameter of 0.05 to 1.37, mostly 0.25 to 0.75 millimeter, also of grade 5. It contains rare minute quartz grains, a few stringers of fibrous muscovite and plates of muscovite, and cubes and spherules of pyrite, to the oxidation of which the cream tint is probably due. The "mahogany" (specimen M, V, 6, h) of the same quarry is a milk-white calcite marble of very irregular texture, with grain diameter ranging from 0.05 to 1.5, mostly 0.125 to 0.75 millimeter, and thus also of grade 5. It contains a few small quartz and feldspar (plagioclase) grains.

A hand specimen (M, V, 6, m) from the 15-foot bed of the Tunnel quarry resembles the white of the Open quarry. A polished specimen of the "white" (D, XXXI, 8, c) from one of the beds now worked is of extremely light bluish-gray color and of irregular texture, with grain diameter up to 2 millimeters. A polished specimen of the "cloud" (D, XXXI, 8, d) is of very light bluish-gray color with a medium gray dolomitic bed up to 0.2 inch wide and irregular gray spots near it. The texture is uneven and irregular, with grain diameter in the calcitic part up to 1.5 millimeters. Both specimens take a good polish, but the dolomitic bands project in minute relief. A specimen (D, XXXI, 8, b) of one of the micaceous beds consists of light bluish-gray and white calcite marble with grayish micaceous and pyritiferous lenses or beds, some not over 0.02 inch and others 0.1 inch thick. In thin section these lenses consist of fibrous muscovite and quartz with lenses and crystals of pyrite. The marble parts also contain a few quartz grains, muscovite scales, and a little pyrite.

The older openings were made between two trap dikes about 200 feet apart. The eastern dike is about 6 feet wide, strikes N. 25° E. and dips 80° W. The marble beds are horizontal. Vertical joints strike N. 10° E. and N. 65° W.; others strike N. 30° E. and dip 65° E., and still others strike N. 20° E. and dip 60° W., which is not far from the course of the eastern dike.

The marble is used for interiors and exteriors of buildings. Specimens: Soldiers and sailors' monument, Riverside Drive; Drexel Building, southeast corner of Wall and Broad streets, New York.

WHITE STONE BROOK QUARRY.

The recently opened White Stone Brook quarry is on the east flank of the northern part of Dorset Mountain, about 200 feet above the most conspicuous bench or shoulder, the second one from below, and about 1,180 feet above the railroad in the valley. It lies about N. 80° W. of a steep ravine in the Green Mountain range, shown in Plate III, section A. The quarry is a little south of the Danby-Dorset town line, which is also the Rutland-Bennington county line, in the township of Dorset. It has a working face 78 feet high. Operator, Norcross-West Marble Co., Dorset, Vt.

The marble beds exposed here and prospected by drilling are, in natural order:

Section of marble beds at White Stone Brook quarry.

	Feet.
Dolomite	10
Gray marble	10
White marble in beds 5 to 10 feet thick separated by 2 or 3 inches of schist	68
Gray marble	13
White marble	3
Banded white and gray marble	5
	109

The marble beds mostly alternate with beds of slickensided pyritiferous quartzose mica schist a few inches thick, the pyrite crystals elongated in the direction of slickensiding. This schist consists of calcite and vein quartz in lenses or beds alternating with fibrous muscovite, containing chlorite and lenses up to 0.25 millimeter thick, probably of some carbonate. In parts calcite, quartz, and sericite also occur mingled.

The marble (specimens D, XXXI, 5, a, rough; c, d, e, polished), "White Stone Brook," is a coarse calcite marble of faintly cream-tinted, somewhat translucent color, with fine yellow-greenish-gray streaks and spots hardly apparent in the rough but showing on a polished or rubbed face, and of very irregular texture, with grain diameter of 0.05 to 1.5, exceptionally 2.5 millimeters, mostly 0.25 to 0.75 millimeter, and of grade 5. An estimate by the Rosiwal method shows the average grain diameter to be 0.239 millimeter. The marble contains also sparse quartz in grains up to 0.3 millimeter in diameter, pyrite next in abundance, a few muscovite scales, rare grains of feldspar (plagioclase), and minute black particles of uncertain nature. The streaks and spots are caused by collections of these accessory minerals. This marble takes a good polish. A thin section of it is shown in figure 15.

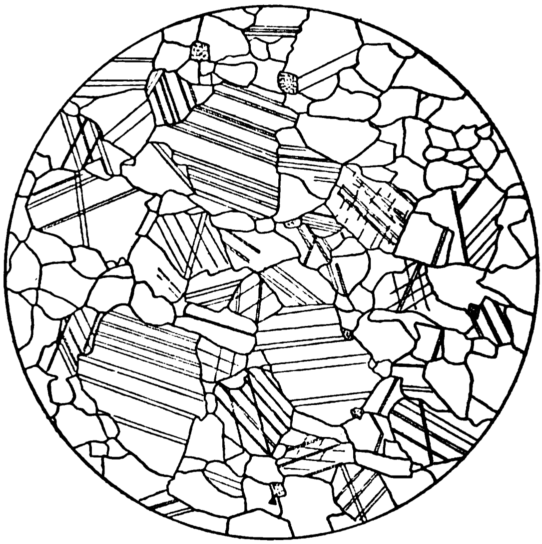


FIGURE 15.—Thin section of white calcite marble from White Stone Brook quarry, Dorset Mountain. Dotted particles are quartz; black are pyrite. Enlarged 20 diameters.

The beds dip in gentle undulations 5° to 10° E. In the front (east) part of the quarry is a trap dike, not studied microscopically, 3 to 4 feet thick, with a N. 35° E. course and a dip of 70° N. 55° W. Joints in the marble parallel to the dike and also fractures east of it, striking N. 55° E. and dipping 50° SE., deprive the marble there of value. The outer surface of the marble beds is also crossed by cleavage planes ("reeds"), striking N. 27° E., dipping 30° S. 63° E., and spaced 2 inches to 0.25 inch apart, which have the same effect.

The product is used for construction.

IMPERIAL QUARRY.

The Imperial quarry is on the east flank of the northern part of Dorset Mountain, in the town of Danby, in Rutland County, a little north of the Danby-Dorset town line, about 700 feet above

Danby station, or 1,690 feet above sea level, N. 60° W. of a conspicuous steep ravine in the Green Mountain range. For its general position see Plate I and map of Pawlet quadrangle, United States Geological Survey, and for the general form of benches and knolls of this side of Dorset Mountain, see Plate III, section A. The quarry, opened since 1900, consists of a tunnel running 160 feet in a N. 70° W. direction by 45 feet in a N. 10° E. direction and 50 feet high, with an offset 25 feet square on the floor level. Operator, Vermont Marble Co., Proctor, Vt.

The marble beds here, as exposed in quarrying and core drilling, consist, measuring from the roof of the tunnel downward and making deduction for inclination of the bed, of about 192 feet of light marbles, creamy white, bluish white, mottled, banded, clouded, or gray in various alternations. Beds of marble 4 to 8 feet thick are separated by very thin beds of mica schist. In a now disused open cut above and west of the tunnel from 30 to 40 feet of light marbles are exposed. Here the schist beds are as much as a foot thick, are rather quartzose, and contain calcite crystals an inch across.

The marble (specimen D, XXXI, 6, c, rough; a, cube; b, polished), "Danby," is a coarse calcite marble of faintly cream-tinted, somewhat translucent color with yellow-greenish-gray irregular streaks or mottlings which are much more conspicuous on the polished face than on the rough, of irregular texture, with a grain diameter of 0.07 to 1, mostly 0.17 to 0.62 millimeter, and thus of grade 5. It contains sparse quartz grains and some pyrite (rarely as large as 2 millimeters), some muscovite scales, and minute black specks. The greenish-gray streaks and clouds are due to muscovite and pyrite in very minute particles. The polish is good but is affected slightly by the composition of the little beds. The general texture of the marble is similar to that shown in figure 15.

The beds strike N. 40° W. and dip 10° S. 50° W. In the open cut above the tunnel the marble is in open folds 50 feet in diameter, with a N. 40° E. strike. At the mouth of the tunnel cleavage planes ("reeds") strike N. 15° E. and dip 35° E.; these decrease in abundance within the tunnel. Joints in upper beds of the open cut strike N. 33° E. and also less commonly N. 57° W., both sets being of steep dip. There is a 3-foot bed in the open cut full of "reeds" dipping 40° E. These are reported by the foreman as being less abundant in the micaceous beds.

NEW YORK QUARRY.

The New York quarry is about one-fourth mile west of the Imperial quarry and about 240 feet above it (see map, Pl. I) and of more recent date. It has a tunnel 150 feet wide and 35 feet high running 215 feet southwest. The northeastern part of this tunnel has been deepened to 100 feet over a space 55 feet square; 125 feet north of this tunnel is another 40 feet wide and 20 feet high, running 80 feet southwest. This northern tunnel is shown in Plate X, *B*.

The marble beds here include, in natural order:

Section of marble beds at New York quarry.

	Feet.
Dolomite (?) above tunnel	10
White marble exposed in south tunnel	35
Bluish, cream, white mottled, and light-gray calcite marbles in alternating beds, including three beds of dolomite (1 foot 8 inches, 1 foot 6 inches, and 6 feet) all crossed by drilling	105
	150

The marbles are not essentially different from those of the Imperial quarry, described above.

The beds are inclined 10° to 15° S. 15° W. This probably represents a very low, nearly west dip combined with a southerly pitch of the fold. At the north side of the southern tunnel is a dike of augite camptonite (see p. 72) 5 feet 6 inches wide with a N. 25° E. course and a dip of 65° N. 65° W. For a space of 80 feet northwest of the dike—that is, above it—the marble is crossed by many joints parallel to the dike, and these are crossed by another set, as shown in Plate X, *B*. Although the marble above the dike has been thus rendered valueless, that on the other side, under the dike in the southern tunnel, is sound. Fifty feet northwest of the northern tunnel another dike of augite camptonite only 2 to 4 inches thick cuts the marble with a N. 30° E. course and a dip of 70° N. 60° W., and the marble for a space of 30 feet above and northwest of this dike also is much jointed.

The marble of both the Imperial and New York quarries is used largely for construction, but some is suitable for monuments. The Chelsea Bank, Chelsea, Mass., and the Wheeler residence, Chicago, were made almost entirely of this marble.

CLARENDON QUARRIES.

CLARENDON VALLEY QUARRY.

The Clarendon Valley quarry is on the east side of the intermediate range, on the J. D. Pratt farm, about 1¼ miles south-southeast of Clarendon village church and 2 miles southwest of East Clarendon, in the Otter Creek Valley, half a mile east of the creek, in Clarendon Township. (See map of Rutland quadrangle, U. S. Geol. Survey.) The quarry, opened in 1909–10, is 50 by 35 feet and 9 feet deep. Operator, Clarendon Valley Marble Co., 29 Broadway, New York, or Clarendon, Rutland County, Vt.

The marble beds exposed here consist of at least 70 feet of calcite marble.

The marble (specimens D, XXXI, 28, a, rough; b, c, polished), "Clarendon Valley gray," is a calcite marble of very light bluish-gray color, with fine, closely and acutely plicated dark-gray dolomite beds. The calcite marble of the ground is of irregular texture, with grain diameter of 0.5 to 2, mostly 0.12 to 0.5 millimeter, and thus of grade 5 (coarse). The little dolomite beds consists of irregular and rhombic untwinned dolomite with a grain diameter of 0.025 to 0.1, mostly 0.05 to 0.07 millimeter, and thus of grade 1. Graphite abounds in the dolomite beds, but occurs also sparsely throughout the calcite marble, as does also quartz. There are rare grains of feldspar (orthoclase, plagioclase, and microcline), muscovite flakes, sericite stringers, and small particles of pyrite in the calcite, but pyrite abounds in the dolomite bands. The polish is good except on the dark bands. Some of the marble, "Clarendon white," is a trifle lighter and has fewer gray streaks.

The beds strike N. 55°–60° E. and dip 25° N. 33° W. They are crossed by cleavage dipping 25° E. There are large exposures of either the basal dolomite or the intermediate dolomite with a westerly dip between the quarry and Clarendon village, on the east side of the road. The marble of the quarry evidently belongs between the basal and intermediate dolomite, probably near the former.

CLARENDON QUARRY.

The Clarendon quarry is east of the foot of the Taconic Range, 3 miles south-southeast of West Rutland, in the township of Clarendon. (See Pl. I and map of Castleton quadrangle, U. S. Geol. Survey.) The quarry, an old one, abandoned before 1900 but reopened in 1909, is about 100 feet north to south by 51 feet across, with an average depth of 30 feet. Its length is being extended 40 feet. Operator, Clarendon Marble Co., West Rutland, Vt.

The marble beds exposed and prospected are, in natural order, as follows:

Section of marble beds at Clarendon quarry.

	Feet.
Graphitic marble	50
Graphitic schist	7
Graphitic banded marble	19
White marble, slightly mottled ("Clarendon A")	17
White marble, mottled and banded	34
Mixed mottled marble	99
Dolomite	20
Graphitic variegated marble	81
	327

The schist boundary must be very near the top of the series.

"Clarendon A" (specimen D, XXXI, 27, a, rough; f, polished) is a calcite marble of bluish-white color, with little bands or rows of spots of medium gray shade. It is of uneven texture, consisting of coarser white parts with grain diameter of 0.12 to 1, mostly 0.25 to 0.62 millimeter, and thus of grade 5, and of finer dolomitic gray parts from 0.1 to 0.2 inch in width, and thus of grade 1. The white parts contain some minute grains of quartz and of pyrite and minute black specks of uncertain nature. The gray spots and bands are graphitic. The marble takes a high polish, the dolomitic bands and spots standing out in minute relief.

The dark-gray banded marble of the 19-foot bed (specimen D, XXXI, 27, b, c) is a graphitic calcite marble, in some beds almost black, alternating with dark bluish-gray bands from 0.05 to 0.2 inch wide without plications, but in other beds of light-gray calcite marble alternating with similar bands of dark-gray shade. It has a grain diameter of 0.05 to 0.5, mostly 0.12 to 0.37 millimeter, and is thus of grade 4. It is graphitic throughout but particularly so in the dark bands, and pyritiferous, with quartz grains rare and small, and limonite stain. This marble takes a high polish.

The variegated rock of the lowest bed is a graphitic calcite marble of very dark bluish-gray color, mottled or irregularly banded with very light bluish gray, almost bluish white, and of grade 4.

The beds strike N. 10° W. and dip 42° W. A section of the graphitic schist (7-foot bed) shows it to be a sericite-quartz-graphite-calcite schist. It is finely plicated and crossed by slip cleavage and is veined with quartz, calcite, and pyrite. This is the typical schist of the base of the schist formation of the Taconic Range. The marble is cut by joints striking N. 35° W., dipping 45° N. 55° E., and spaced 3 to 7 feet. The marble beds at the surface are finely glaciated and the glacial polish has been preserved by a bed of clay which at the back of the quarry, over the small schist bed, is very graphitic and measures 7 feet in thickness, and a little farther west measures 30 feet and contains bowlders and sand.

The marble is used for construction. Specimen of "Clarendon A": The free-standing, iron-centered columns of the State Educational Building at Albany.

RUTLAND QUARRIES.

FOLEY PROSPECT.

The Foley prospect is about three-fourths of a mile west of the southeast corner of Rutland Township. The outcrop extends here and there, it is reported, into the township of Clarendon, toward a well-known bed of kaolin on the north bank of Cold River. Prospective operator, Edward H. Foley, 147 South Main Street, Rutland, Vt.

The beds, to judge from their geographic position, probably belong not far above the basal dolomite.

The marble (specimen D, XXXI, 86, a, polished) consists of alternating beds of very light gray calcite marble from 0.2 to 0.5 inch wide, alternating with irregular beds of very dark gray graphitic untwinned dolomite from 0.04 to 0.1 inch wide, both sets being most intricately plicated together. The calcitic parts polish well but the dolomitic not at all. Associated with these beds are also whitish calcitic marbles more faintly mottled with graphitic dolomite.

The beds are reported to lie in vertical position.

WEST RUTLAND QUARRIES, WEST SIDE.

EASTMAN QUARRY.

The Eastman quarry is at the east foot of the Taconic Range, on the west side of the West Rutland anticline, about 0.7 mile S. 10° W. from the West Rutland station, in the township of West Rutland. (See Pls. I and IV and map of Castleton quadrangle, U. S. Geol. Survey.) The quarry, which was reopened a few years ago, now measures 126 feet north to south by 105 feet across (at the bottom) and is 135 feet deep. Operator, George P. Eastman, Rutland, Vt., or care of Tompkins-Kiel Marble Co., 505 Fifth Avenue, New York.

The marble exposed in and west of the quarry and by core drilling on both sides of it comprises the following beds, in natural order:

Section of marble beds at Eastman quarry.

	Ft.	in.
Graphitic gray marble	57	
Graphitic (?)	6	
Graphitic gray marble	22	
West edge of quarry.		
Graphitic gray marble	14	
Same with some white bands	3	
Cream-colored marble	4	
Muscovitic (green) marble with beds of cream-colored marble in coarse plications ("Kiel's green")	7	
Purplish-gray marble	1	6
Muscovitic (green) marble, plicated, with slip cleavage dipping 5° to 10° E	2	
Dolomite and marble mixed	2	10
Cream-colored marble with faint green and yellow bands (bed H)	4	6
Muscovitic (green solid) marble	11	
White marble, pure	4	
Cream-colored marble with muscovitic (green) bands	4	6
Muscovitic calcite marble (bed F)	3	
Muscovitic plicated marble (bed BC)	4	6
Cream-colored marble	4	6
White marble (bed IJ)	5	
Muscovitic (green) marble, plicated (bed K)	4	6
White marble (bed L)	5	6
White marble with small muscovitic (green) beds (bed M)	5	
East edge of quarry.		
Gray dolomite	3	
Graphitic marble	3	6
White marble	13	6
	196	4

Eight of these marbles, the more important and typical ones, were examined microscopically.

"Eastman blue" (specimens D, XXXI, 29, b, rough; r, polished), the 14-foot bed, is a graphitic calcite marble of medium bluish-gray color and of even and fine texture, with grain diameter of 0.05 to 0.37, mostly 0.12 to 0.25 millimeter, and thus of grade 3 (fine). The texture is peculiar in that the particles are elongate and the longer axes of the different grains are parallel, imparting some schistosity to the marble. (See fig. 6, p. 41.) The marble contains sparse quartz and muscovite grains. The polished specimen, which was cut across the bed, shows little beds alternately more and less graphitic and in places (by the raised surface) dolomitic; all are in somewhat angular plications with a tendency to slip cleavage.

"Kiel's green" (specimens D, XXXI, 29, d, rough; l, polished) consists of interbedded cream to flesh colored calcite marble of coarse irregular texture, with grain diameter of 0.05 to 1.5 millimeters and thus of grade 5, and of a bright greenish-gray schistose muscovitic and chloritic calcite marble of medium elongated texture, with grain diameter of 0.05 to 0.55, mostly 0.12 to 0.37 millimeter, and thus of grade 4. The cream-colored beds are from 0.5 to 1 inch thick and the green beds from 0.1 to 1 inch thick. Both are acutely plicated, the limbs of the plications reaching 5 inches in length, and crossed by slip cleavage. A small polished specimen is shown in Plate VIII, *A*, *b*. Both marbles contain extremely fine black particles of uncertain nature. The light beds abound in quartz grains up to 1.87 millimeters in diameter, contain some muscovite, and show the effect of secondary strain in bent twinning planes. The green beds contain some fine grains of quartz and its calcite grains are elongated and roughly parallel. In the lower part of the 7-foot bed which furnishes this marble the light beds give place to the green ones and the marble becomes a solid greenish muscovitic calcite marble of medium texture (specimen D, XXXI, 29, g). Although the quartz of the light beds and the muscovite of the green ones interfere somewhat with the polish, the colors and designs of this marble are so unusual and attractive as to offset such imperfections.

A slightly purplish gray marble (specimen D, XXXI, 29, f) is a sericitic calcite marble with grain diameter mostly under 0.02, rarely 0.37 millimeter, and thus between grades 1 and 2. A little of the calcite is twinned. The rock contains abundant magnetite in plates and some quartz. The schistosity is parallel to the bed, with traces of secondary minute plications transverse to it.

"Green-veined cream statuary," bed H (specimens D, XXXI, 29, k, rough; l, polished), is a calcite marble of delicate cream color in bands up to 2 inches thick alternating with slightly plicated bands (beds) of yellowish and very pale greenish tint up to 0.1 inch thick.

It is even and regular in texture, with grain diameter like that of bed F, averaging about 0.2 millimeter, and is of grade 3. Exceedingly fine black specks occur sparsely throughout. The bands appear to be due to the oxidation of varying quantities of pyrite in very minute particles. The marble takes a high polish.

The green marble of the 11-foot bed, "solid green" (specimen D, XXXI, 29, e), is a muscovitic quartzose calcite marble of bright greenish-gray color and of irregular elongated parallel texture, with grain diameter of 0.02 to 0.3, mostly 0.04 to 0.09 millimeter, and thus of grade 1. The larger elongated and parallel grains are irregularly mingled with smaller ones of more or less roundish outline. Quartz is very plentiful. The muscovite is in scales and fibers.

"Cream statuary," bed F (specimens D, XXXI, 29, i, rough; m, polished), is a calcite marble of delicate cream color with very pale brown, minutely plicated beds up to 0.1 inch thick. It is even and regular in texture, with grain diameter of 0.05 to 0.37, mostly 0.12 to 0.25 millimeter, and is thus of grade 3. It contains rare small grains of quartz and sparse exceedingly minute black specks of uncertain nature. The stone takes a high polish.

"Light cipolin," bed BC (specimen D, XXXI, 29, o, polished), is a muscovitic calcite marble of light greenish-gray color in which the muscovite occurs in many close, fine, broadly plicated beds. In texture it belongs in grade 4. The polish is only fair because of the mica.

"Blanc clair," bed IJ (specimens D, XXXI, 29, h, rough; p, polished), is a calcite marble of milk-white to faintly clouded milk-white color and of irregular fine texture, with grain diameter of 0.04 to 0.42, mostly 0.12 to 0.25 millimeter, and thus of grade 3 (fine). It contains sparse minute black grains, rare pyrite, and quartz, and takes a high polish. Its texture is less regular and a grade coarser than that of Rutland Italian (p. 119).

"Dark cipolin," bed K (specimens D, XXXI, 29, a, rough; n, polished), is a muscovitic calcite marble of generally bright light-greenish color, with alternating more muscovitic (greenish) and more calcitic (whitish) little beds in broad plications 1 to 2 inches wide. Its texture is medium, with a grain diameter of 0.05 to 0.67, mostly 0.12 to 0.37 millimeter, and it is thus of grade 3. The grain form is elongate and also irregular. There are quartz grains up to 0.37 millimeter, muscovite in scales and fibers, and chlorite mingled with a little epidote, besides some minute nodules (possibly titanite) and a little blue-green tourmaline. The green color is due mainly to the muscovite and chlorite. The polish is only fair owing to the mica.

The white marble with greenish bands of bed M (specimen D, XXXI, 29, j) is a calcite marble of milk-white color, with straight, parallel delicate green muscovitic beds from 0.1 to 0.4 inch wide. Its texture is regular and fine, with grain diameter of 0.05 to 0.5, mostly 0.12 to 0.25 millimeter, and it is thus of grade 3. It contains rare particles of quartz and sparse minute black grains of uncertain nature. The bands are largely sericite.

Owing to the variation in the proportion and arrangement of the accessory minerals in each bed the varieties of commercial marbles produced by this quarry are many.

The probable structure is shown in section E, Plate III. The beds strike N. 20° W., but owing to a minor overturned fold they dip east (35°) instead of west and are therefore in inverse order. At the bottom of the quarry, 135 feet below the surface, they begin to turn, being almost vertical. The dolomite at the east edge of the quarry is described on page 30.

The product is used mainly for interior decorative work, the blocks being shipped to Astoria, N. Y., where the cutting and polishing are done. Specimens: Interior of Greenpoint Savings Bank, Brooklyn, N. Y. (green beds); interior of Prudential Building, Newark, N. J. (green and cream-pink); mantels in United States Senate Office Building, Washington (cream and white); carved work border near ceiling and a large mantel, New York Public Library (cream and white); interior of Connecticut Savings Bank, New Haven, Conn. (white); interior of railroad station, Schenectady, N. Y.

MORGAN QUARRY.

The Morgan quarry is a few hundred feet north of the Eastman quarry. (See Pls. I and IV.) It has been recently reopened by the Vermont Marble Co. The beds are the same or very nearly the same as those at the Eastman quarry; the strike is N. 25° W. and the dip vertical, changing to east. There is a very low eastward-dipping cleavage in some of the beds. An augite camptonite dike with a N. 65° E. course cuts the beds near the quarry. (See further, p. 73.)

UMBRELLA QUARRY.

The Umbrella quarry, a disused opening belonging to the Columbian Marble Co., lies a few hundred feet north of the Morgan quarry. (See Pl. IV.) An 8-foot bed of fine-grained marble is exposed, striking N. 5° W. and dipping 40° E.

RUTLAND-FLORENCE QUARRY.

The Rutland-Florence quarry is about 300 feet north of the Umbrella, and is also out of use. It is owned by the Vermont Marble Co., Proctor, Vt. There are beds of white marble in the quarry, west of it lie 57 feet of beds covered by turf, and west of these are 70 feet of graphitic marbles. The strike in and west of the quarry is N. 15° W. and the dip 35° N. 75° E.

McGARRY QUARRY.

At the McGarry quarry, a small disused opening south of the schoolhouse (see Pl. IV), graphitic marble about 10 feet thick overlies white marble, with a strike of N. 30° W. and dip of 30° N. 60° E. Back of the schoolhouse and about 225 feet northwest of the quarry is a small anticline of dolomite 5 feet thick, the axis of which appears to pass west of the beds exposed in the quarry but may really pass east of it.

WEST RUTLAND QUARRIES, EAST SIDE.

VERMONT MARBLE CO.'S WEST RUTLAND QUARRIES.

The West Rutland quarries of the Vermont Marble Co. lie on the east side of the West Rutland anticlinal valley, along the west foot of the synclinal schist ridge which intervenes between the Taconic Range proper and the intermediate range. (See Pls. I and IV.) There are in all 11 openings, including the disused ones: Three (Covered quarry, New opening 1906, and Upper Gilson quarry) in an eastern upper series of beds, and eight (Gilson, Ripley, Baxter, a prospect, Clement, Foster, Sherman, and Old Open quarries) in an adjoining western and lower series of beds. Inasmuch as the slope of the schist and marble ridge near West Rutland bends around to the southeast, the quarries (with the exception of the Upper Gilson), although apparently in line, are on different sets of beds. The entire line, beginning at a point about 0.4 mile north-northwest of the West Rutland station, extends 0.8 mile north-northwest. These quarries will not be described in detail, as it will suffice to bring out the general facts concerning them all. They are narrow openings along the strike and follow the dip of the beds more or less closely, with foot and head walls dipping 35° to 45° E. In some places the supporting walls between the quarries have been excavated below, leaving narrow rock bridges at the top, as shown in Plate XII. As the beds turn eastward in synclinal attitude the quarrying has followed them, and by means of an irregular distribution of the supporting piers the Gilson, Ripley, and Baxter quarries have at the turn of the syncline, at a depth of 250 feet, been so combined as to admit of a continuous electric mine railroad 1,300 feet long. In the Ripley quarry, at a depth of 225 feet, tunneling has been done in a westerly direction for a distance of 340 feet, and in the Gilson quarry the beds have been followed eastward to a point 300 feet east of the west wall of the quarry.

The complete succession of the beds will be found in generalized form on page 86. Some of the best-known commercial marbles of these West Rutland quarries belong between the upper graphitic marble and the intermediate dolomite and occur as shown in the following section, beginning with the beds of the Upper Gilson quarry on the east in natural order:

Section of marble beds at West Rutland quarries of Vermont Marble Co.

	Feet.
White marble ("top white"), about	50
Graphitic (gray) marble	20
White and graphitic (includes green bed, "olivo")	50
White (includes "second statuary")	3
Muscovitic, banded	4–5
White and graphitic ("monument," light cloud)	6
White ("Rutland statuary"; only 4 feet thick east of turn in syncline)	7–11
Muscovitic (dark greenish, "average")	4
White	3–4
Muscovitic, fine banded, plicated ("light brocadillo," "brocadillo," "pavonazzo")	5–6
White ("mottled Smith," "best light cloud")	6–10
Muscovite banded ("Jackman," "light Smith," "listavena")	4
White	1–4
Muscovitic, banded (dark greenish, "hard layer," "verdoso")	2–4
White	1–3
Dolomite	1–4
Muscovitic, banded ("double belt")	2–3
White ("Rutland Italian")	3–6
Graphitic, with abundant Maclureas in upper part ("dark blue," "extra dark blue," "livido")	8–25
Dolomite	40
	220–262

Graphitic marbles are worked for 300 feet west of and below this series, in the west tunnel of the Ripley quarry. Core drilling has also been done west from the west end of that tunnel, exposing the following succession:

Section of marble beds west of west tunnel of Ripley quarry.

	Ft.	in.
Graphitic marble	8	
White marble	11	
Dolomite	10	
White marble	4	
Muscovitic marble (light green)	1	4
White marble	3	6
Muscovitic marble (light green)	1	
Graphitic marble in 12 beds aggregating 105 feet, alternating with 12 beds of dolomite aggregating 106 feet 8 inches	211	8
	250	6

A number of the marbles have been examined microscopically with these results: "Statuary Rutland" (specimen D, XXXI, 80, b), is a calcite marble of milk-white color and of very fine, regular, somewhat even texture, with grain diameter of 0.05 to 0.5 mostly 0.07 to 0.25 millimeter. By the use of the Rosiwal method the average diameter was found to be exactly 0.1 millimeter and the texture is therefore of grade 2 (very fine). A camera-lucida sketch of a thin section of this marble is reproduced in figure 16. There are rare grains of quartz and plagioclase feldspar and infinitesimal opaque particles of irregular form, some of which, to judge from the effect of a magnet on the powdered marble, are magnetite. The marble takes a high polish.

The "second statuary Rutland" (specimen D, XXXI, 80, c), is a calcite marble of milk-white color with faint grayish-yellow clouds and of fine, somewhat irregular texture, with grain diameter of 0.05 to 0.57, mostly 0.12 to 0.25 millimeter, and thus of grade 3 (fine). It contains minute sparse black particles and very rare quartz grains. The polish is high.

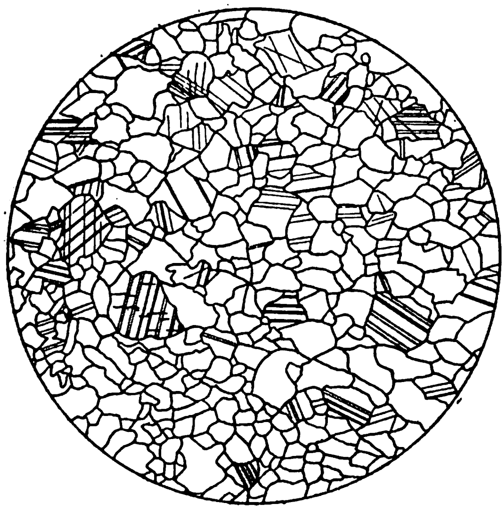


FIGURE 16.—Thin section of white calcite marble, "statuary Rutland," of texture grade 2. Enlarged 27 diameters.

"Rutland Italian" (specimens D, XIX, 143, b, rough; D, XXXI, 80, d, polished) is a calcite marble of faintly bluish white color with faint irregular grayish and yellow-brownish mottlings. The mottling is more pronounced than in the "second statuary." It is somewhat irregular in texture, with grain diameter of 0.05 to 0.87, mostly 0.12 to 0.5 millimeter, and thus of grade 4. It contains minute black specks and some spherules of pyrite, some quartz grains, and rare scales of muscovite. The polish is high.

"Dark-blue Rutland" (specimens D, XXXI, 80, a, rough; k, polished) is a graphitic calcite marble of dark bluish-gray color mottled with white, apparently in fine plications, and with some fine black streaks. Its texture is irregular, with a grain diameter of 0.05 to 0.57, mostly 0.12 to 0.25 millimeter, and it is thus of grade 3 (fine). It contains minute grains of graphite and rare scales of muscovite. It takes a high polish. This is the bed which carries in places sections of Maclureas (see p. 22) in white calcite.

A section of "extra dark blue" obtained in 1900 is of similar irregular texture, with grain diameter of 0.025 to 0.37, mostly 0.075 to

0.175, and averaging possibly about 0.11 millimeter and thus of grade 2.

"Brocadillo" (specimens D, XXXI, 80, e, polished; D, XIX, 143, c, rough) is a muscovitic calcite marble of faintly greenish-white ground, with fine greenish-gray plicated beds and straight streaks (cleavage planes?) to 0.2 inch wide. Its texture is irregular, in places elongated parallel, with grain diameter of 0.05 to 0.62, mostly 0.12 to 0.37 millimeter, and it is thus of grade 4 (medium). The accessory minerals, in descending order of abundance, are quartz, with some feldspar (plagioclase), up to 0.62 millimeter in diameter, muscovite in scales and fibers, epidote with a little zoisite, brownish translucent lenses (carbonate?), chlorite, minute spherules and crystals of pyrite, and still more minute opaque particles (pyrite?). The marble takes a high polish, to which the sparseness of the micaceous bands contributes.

"Livido," from the bottom "blue bed" (specimen D, XXXI, 80, i), is a slightly graphitic calcite marble of medium to delicate light bluish-gray shade, with plicated dark-gray dolomitic beds up to 0.1 inch wide. Its texture is irregular and uneven. The calcitic parts have grain diameter of 0.05 to 0.62, mostly 0.1 to 0.25 millimeter, and are thus of grade 3 (fine), but the dolomite has grains measuring 0.009 to 0.02 millimeter and is thus of grade 1 (extra fine). The dolomite is very irregularly distributed in the more graphitic little beds. No mica or quartz was detected. The polish is high.

"Olivo" (specimen D, XXXI, 80, h) is a muscovitic calcite marble of light greenish-gray and pale greenish-white color, in undulating bands up to half an inch thick, and of an elongated parallel texture, with grain diameter of 0.07 to 0.75, mostly 0.12 to 0.37 millimeter, and thus of grade 4 (medium). Besides muscovite it contains plentiful quartz, rarely a grain of feldspar (plagioclase), some irregular minute, barely translucent lenses (carbonate?), and very minute black specks. This marble is more micaceous than the "brocadillo" and its general color resembles that of specimens 29, n and o, from the Eastman quarry. The polish is fair but poor where mica abounds.

The following were not studied microscopically: "Verdoso" (specimen D, XXXI, 80, g) is a muscovitic calcite marble with minute plicated dark-greenish beds on a white ground. It may contain chlorite. The texture is medium and the polish poor.

"Rubio" (specimen D, XXXI, 80, f) is a calcite marble of very delicate pinkish tint, with thin plicated greenish muscovitic beds. The pinkish tint proceeds presumably either from a mineral containing manganese oxide or from hematite, possibly due to oxidation of magnetite, but in either case in very minute particles. Its texture is fine and its polish good.

"American pavonazzo" (specimen D, XXXI, 80, j) is a calcite marble with milk-white ground and chloritic dark blue-greenish plicated beds of irregular width and distribution. The polish is good except over the chloritic beds. The mantel and wainscoting in Plate XIV, *B*, are made of this marble.

An analysis of the graphite in the "dark-blue Rutland" is given on page 40 and one of the white marble on page 12. The following analyses of the blue, white, and statuary are quoted here for reference:

Analyses of marbles from Vermont Marble Co.'s quarries at West Rutland.[a]

	Blue.		White.		Statuary.
	1	2[b]	3	4[b]	5
Carbon dioxide (CO_2)	43.82	44.00	43.66	43.80	43.65
Lime (CaO)	55.27	55.15	55.26	54.95	55.50
Magnesia (MgO)	.28	.57	.15	.59	Trace.
Alumina and iron sesquioxide (Al_2O_3), (Fe_2O_3)	.30	....	.20	....	.15
Silicate of alumina ($Al_4Si_2O_6$)	....	.22	....	.62	....
Insoluble	.28	....	.40	....	.70
Organic matter	....	.05	....	....	....

[a] Day, W. C., Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5, continued, 1897, p. 985.
[b] Analyses by J. N. Harris.

The following compression tests were made at the United States arsenal at Watertown, Mass., April 1, 1893:

Compression tests of marble from West Rutland quarries.

No.	Marble.	Compressive strength (pounds per square inch).
9061	Extra dark blue	13,639
9063	Rutland Italian	14,068
9059	Rutland statuary	11,525

The following transverse tests were made at the same place in November, 1895. The blocks were supported 20 inches apart and loaded in the middle.

Transverse tests of marble from West Rutland quarries.

No.	Marble.	Modulus of rupture per square inch.
414	Rutland white	1,202
415	Rutland blue	2,069
416	....do	2,045

The following shearing tests were made at the same time and place. The distance between supports was 6 inches, the width of block to which pressure was applied 5 inches, and the thickness of block tested 6 inches.

Shearing tests of marble from West Rutland quarries.

No.	Marble.	Shearing area (square inches).	Transverse fracture developed (pounds).	Shearing strength per square inch (pounds).	Surfaces sheared.
272	Rutland white	47.72	18,400	1,100	2
273	.....do	48.	18,200	946	1
274	Rutland blue	48.32	20,600	1,519	1
275	.....do	48.04	22,100	914	2

Tests of expansion made at the Watertown Arsenal in November, 1895, determined the coefficient of expansion in water per degree Fahrenheit of Rutland white marble as 0.00000312 inch; that of the mottled marble of the Proctor quarry was 0.00000550 inch, and that of a dark graphitic marble from the Shangrow quarry was 0.00000433 inch. These tests were made in water baths between temperatures of 32° and 212° F. The transverse strength was found to be greatly lowered by such treatment.

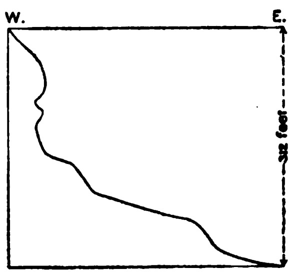
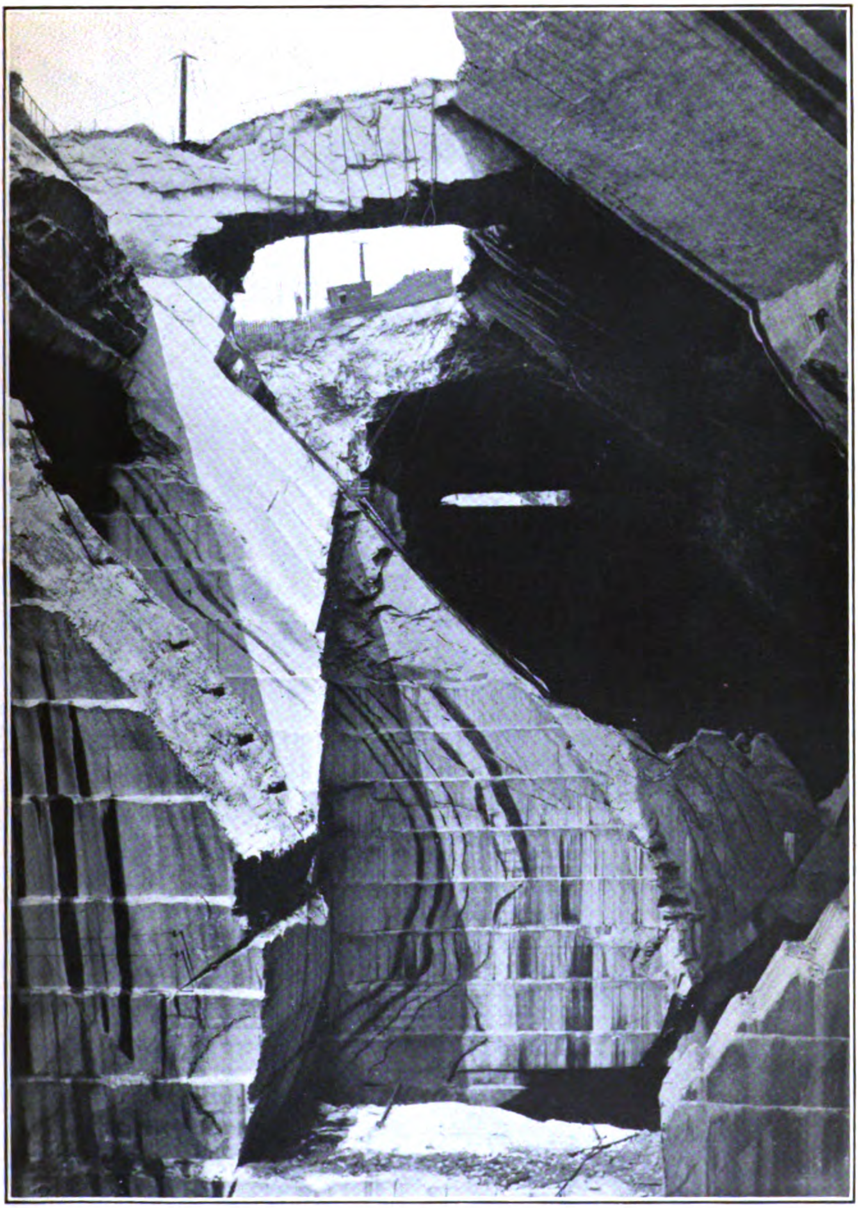


Figure 17.—Course of east limb of the West Rutland anticline or the west limb of the syncline.

The probable general structure of the West Rutland anticline is given in sections B and F, Plate III. The quarries lie on the east limb of the anticline, the top of which has been eroded, or along the west limb of a syncline of marble overlain by schist. In passing from quarry to quarry along the strike, the supports left between the walls and also between adjacent quarries show on their smoothly cut surfaces various minor undulations in the limb of the syncline, so that in a series of cross sections of the limb 200 feet apart no two would be identical. Here and there a little faulting or pinching out of smaller beds is also evident. Figure 17 shows the approximate character of the anticlinal or synclinal limb at the Ripley quarry. The steeper upper part of it is also shown in Plate XII. At the prospect (quarry No. 7 on map, Pl. IV) a trap dike 10 inches to 6 feet wide cuts the marble beds with a N. 60° E. course and a dip ranging from steep to 30° S. 40° E. The dike has a glassy rim 0.12 inch wide, weathered whitish. The presence of many joints on the south side parallel to the dike wall probably caused the discontinuance of the quarry.

The marbles from these quarries serve a great variety of purposes. Many of the beds are used for interior decoration panels, wainscoting, etc., some for interior or exterior carving, and others for construction. Some of the graphitic marbles are in demand for electric switchboards. Among the more notable buildings and attractive monuments of recent date made of the marble of these quarries are



VIEW FROM THE SOUTH WALL OF THE GILSON QUARRY, WEST RUTLAND, AT A POINT 70 FEET BELOW THE SURFACE.

Showing part of the east limb of the West Rutland anticline and three of the quarry openings. Vertical black streaks at the left due to smoke.

WILSON PORTRAIT STATUE, SEATTLE, WASH.

White calcite marble, "light Rutland Italian."

the Senate office building, Washington, from West Rutland marble, with some from Danby; the marble and statues of the Chamber of Commerce Building, New York, from West Rutland marble; the Wilson portrait statue at Seattle, Wash. (Pl. XIII), of "light Rutland Italian;" the Taylor mausoleum, Woodlawn Cemetery, New York, of "best white Rutland building marble;" the Kimball monument at Graceland Cemetery, Chicago (Pl. XIV, *A*), of "second statuary" and the mantel and wainscoting in the First National Bank, Hazleton, Pa. (Pl. XIV, *B*), of "American pavonazzo."

ALBERTSON QUARRY.

The Albertson quarry (formerly known as the Esperanza) is also on the east side of the West Rutland anticlinal valley, 2¼ miles north-northwest of West Rutland station in the township of West Rutland. (See Pls. I and IV and map of Castleton quadrangle, U. S. Geol. Survey.) The quarry measures 500 feet in a N. 17° W. direction by 110 feet across and 115 feet in depth. An area 150 by 110 feet at the north end is worked out as far down as a certain dolomite bed. There is a tunnel, 80 to 175 feet wide and 40 feet high, on the west side, extending about 630 feet in a N. 30° W. direction and reaching a point 75 feet west of the west wall of quarry. Operator, Vermont Marble Co., Proctor, Vt.

The marble exposed and explored here consists of the following beds:

Section of marble beds at Albertson quarry.

	Feet.
Graphitic marble	135
Dolomite	23
Marble, some of it greenish	19
Dolomite	22
	199

The marble, "extra dark Albertson" (specimens D, XXXI, 26, a, b, polished), is a graphitic calcite marble of medium bluish-gray shade, with thin, minutely plicated black streaks (beds) and here and there whitish streaks of like character, both crossed at various angles by cleavage planes slightly undulating and also black. A piece of this marble is shown in Plate VIII, *B*, *b*. The texture is regular, with grain diameter of 0.05 to 0.62, mostly 0.17 to 0.37, millimeter, and it is thus of grade 4 (medium). It abounds in graphite, particularly along the little black beds and the planes of slip cleavage, and contains rare minute cubes of pyrite and still more muscovite scales and quartz grains. The amount of graphite in it is probably like that in the West Rutland blue (p. 40). The marble takes a high polish without dolomitic protuberances.

The beds strike about N. 25° W. The north wall shows a syncline in cross section, and for about 400 feet south of that point the syncline pitches 10° about north, and then for 130 feet 5° about south. On the north face of a jog in the west face near the south end the west limb of this syncline dips 15° to 20° E. The tunnel, which makes an angle of 13° with the west wall of the quarry, follows the axis of a syncline. About 315 feet from that wall this syncline on its west side strikes N. 35°–40° W. and dips 28° E., and its east side also dips at a low angle. The entire width of the syncline is about 200 feet and it opens northward. The beds on the east wall of the quarry are crossed by a conspicuous slip cleavage dipping 20°–30° east or southeast. (See for general structure Pl. III, section C.)

The marble of this quarry is used largely for monumental and electric work, but some for construction. St. Ann's Roman Catholic Church at Fall River, Mass., is made of it.

TRUE BLUE QUARRY.

The True Blue quarry is also on the east side of the West Rutland anticlinal valley, three-fourths of a mile north-northwest of the Albertson, and 3 miles north-northwest of West Rutland station, in West Rutland Township. (See Pls. I and IV and map of Castleton quadrangle, U. S. Geol. Survey.) The quarry is about 112 feet north to south by 100 feet east to west in its southern half and 75 feet in the northern half, and about 100 feet deep. From the south wall, at a point 75 feet below the surface, a tunnel, 50 to 75 feet wide and 30 to 40 feet high, extends 113 feet southward, to a point where its floor is about 130 feet below the surface.

Operator since May, 1911, Vermont Marble Co., Proctor, Vt.

The marble beds exposed and explored here consist of the following:

Section of marble beds at True Blue quarry.

	Feet.
Schist.	
Graphitic marble	30
Dolomite with some graphitic marble	20
Graphitic marble of various shades	60–65
Graphitic schist	40
	150–155

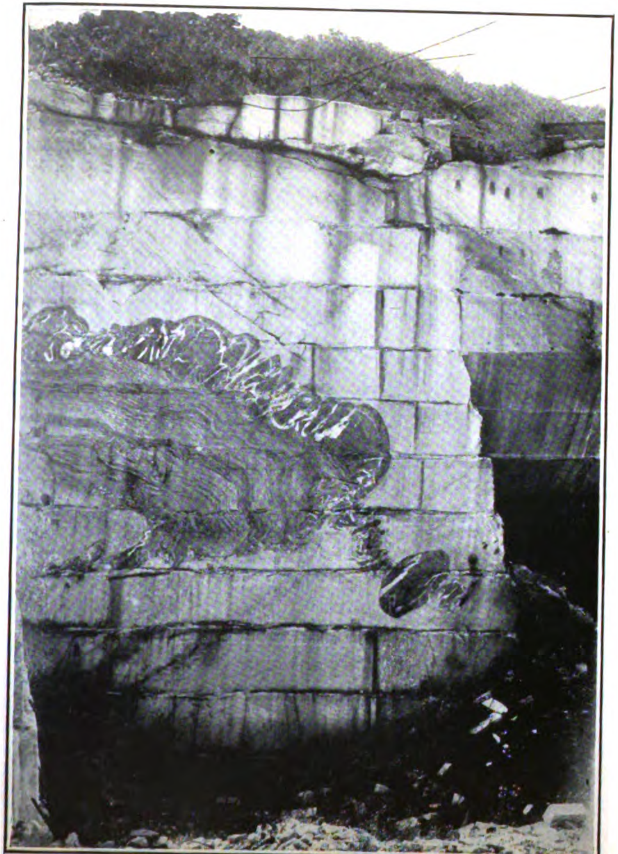
The marble, "True Blue" (specimens D, XXXI, 25, c, rough; 25, b, and XIX, 138, d, e, polished), is a graphitic calcite marble of medium-gray shade, with more or less finely plicated black (graphitic) bedding planes crossed at various angles by slightly flexed slip-cleavage planes, also black and graphitic. A photograph of a slab showing this feature is reproduced in Plate V, *A*. Its texture is even, regular, and on the fine side of medium, with grain diameter of 0.05 to 0.75, mostly 0.12 to 0.37 millimeter, and thus of grade 4. It abounds in graphite in minute grains and contains a few minute cubes of pyrite and rare and small grains of quartz. It takes a high polish without dolomitic protuberances.

A. KIMBALL MONUMENT, GRACELAND CEMETERY, CHICAGO, ILL.

Columns of "second statuary Rutland" calcite marble.

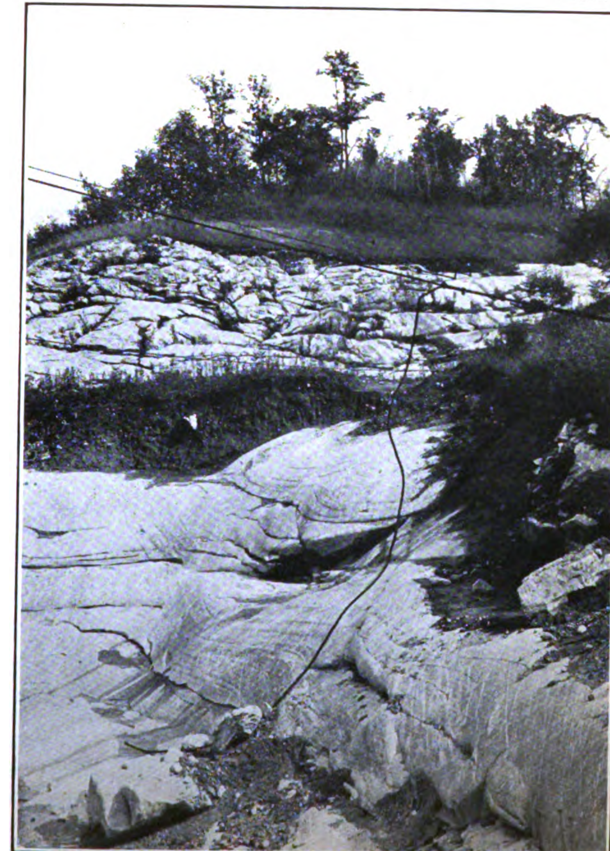
B. MANTEL AND WAINSCOTING IN FIRST NATIONAL BANK, HAZLETON, PA.

Muscovitic calcite marble, "American pavonazzo," from West Rutland.



A. SOUTH WALL OF TRUE BLUE QUARRY, WEST RUTLAND.

Westward-dipping beds of graphitic calcite and dolomite marble. The upper part of the 15-foot bed, consisting of very dark dolomite veined with calcite and quartz, passes into a group of nodules. The lower part of the bed seems to have been cut off by a fault parallel to the eastward-dipping cleav-



B. RECENTLY UNCOVERED GLACIATED BEDS OF GRAPHITIC CALCITE MARBLE AT FLORENTINE QUARRY, PITTSFORD.

Looking S. 32° E., nearly along the strike of the beds.

As will be seen by the geologic map, the quarry is very near a southward-pointing tongue of schist. In 1900 the north wall of the quarry was at the south end of this synclinal tongue. The structure on the north wall of the present quarry (75 feet south of the old north wall) shows four minor folds overturned toward the east in a space of about 70 feet and these folds consist of graphitic marble, dolomite, and schist about 50 feet below the rock surface. This is probably the same schist which reappears at the bottom of the tunnel and which has been core drilled to a depth of 40 feet. On the south wall (as shown in Pl. XV, *A*) east of the tunnel a 15-foot bed of graphitic dolomite veined with white (calcite and quartz probably) dips west, toward the tunnel, but has been partly faulted out along an eastward-dipping cleavage foliation and partly pinched out during elongation and flowage and has been transformed into a series of oblong or spherical nodules of graphitic dolomite up to 3 by 2 feet, which continue in the direction of the dip within the quarry. The approximate structure at this quarry is shown in figure 18. The general structure is

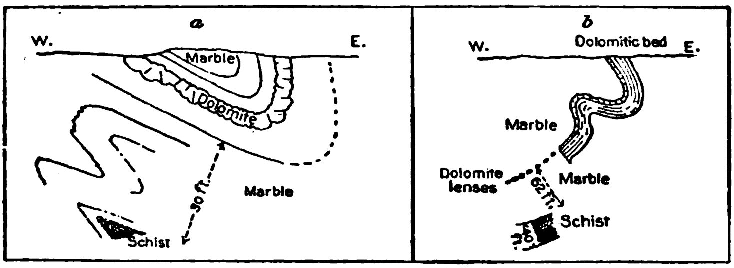


FIGURE 18.—Approximate structure at True Blue quarry. *a*, Structure on north wall; *b*, general relations in quarry and on south wall.

shown in section D, Plate III. The pitch of this whole series here is about 15° S. and the slip cleavage in the marble dips 30° E. This structure is shown in the slab pictured in Plate V, *A*. The proximity of the schist tongue shows that the beds here belong to the uppermost part of the upper graphitic series, and the presence of the lower schist bed shows that during the closing part of the period of calcareous deposition argillaceous sediments alternated with calcareous sediments for a time before crowding out the latter altogether. The presence of such schist beds near the top of the limestone formation is not unusual along the Taconic Range. They should not be confounded with synclinal tongues or lenses belonging to the main schist mass itself. Marble should recur below the schist bed of the True Blue quarry.

The schist of the top of the 40-foot bed is very graphitic and contains veins and lenses of pyritiferous quartz parallel to its schistosity. The schist consists of stringers of muscovite and chlorite with graphite and quartz, rarely a grain of feldspar (plagioclase). It is a pyritiferous graphite-calcite-quartz-muscovite-chlorite schist.

About 300 feet south of the south wall of the quarry is a 4-foot trap dike with a N. 70° E. course, and many joints parallel to it occur in a space of 30 feet on its north side.

PROCTOR.

RIVERSIDE QUARRY.

The recently opened Riverside quarry is 2 miles south of Proctor station, between Otter Creek on the west and the railroad on the east, in the township of Proctor. (See Pls. I and IV and map of Castleton quadrangle, U. S. Geol. Survey.) It is about 100 feet square and 70 feet deep. Operator, Vermont Marble Co., Proctor, Vt.

Assuming that the dip of 60°, which is that of the beds exposed in the quarry, prevails throughout the 200 feet of marble which has been core drilled west of it, the marble here measures 255 feet and is close to the top of the dolomite, which crops out a little farther east. Some 100 feet of marble beds have been explored between the east edge of the quarry and the dolomite, but as the dolomite and overlying marble a little to the south dip west, most of these beds are probably continuations of those in the quarry.

The marble, "Riverside" (specimens D, XXXI, 15, a, rough; b, polished), is a coarse calcite marble of translucent, slightly bluish white color, with dark-gray spots and bands at irregular intervals along the planes of bedding, and of uneven texture, with grain diameter in the white calcitic ground of 0.05 to 1.0, mostly 0.25 to 0.5 millimeter, and thus of grade 5 (coarse). The thin sections did not cross any of the dark spots. That these spots are largely dolomite is evident from their standing out in minute relief on the polished face and being easily scratched with a knife; and that they are also graphitic is evident from the nature of other similar clouded marbles. The average grain diameter in the dolomitic passages would be about 0.05 to 0.1 millimeter. The calcitic parts contain sparse quartz particles, some up to 0.32 millimeter, and also pyrite, some of which is oxidized.

The marble beds strike N. 5° W. and dip 60° E. The dolomite along the base of the Pine Hill ridge one-fourth mile southeast of the quarry has a like strike but dips about 50° W., and the marble at an idle quarry a little south and west of the dolomite boundary strikes N. 15° W., dips about 67° W., and has an exposed thickness of 90 feet. Unless faulting intervenes a synclinal axis passes between these two quarries. The marble surface at the Riverside quarry had a glaciated surface protected by a covering of till. Glacial potholes 10 to 15 feet by 6 to 8 feet were found, and near the old quarry to the south-southeast are others 8 to 10 feet in diameter.

COLUMBIAN QUARRY.

The Columbian quarry, in operation in 1900, was idle for some time prior to August, 1910, but was then about to be reopened. It is about three-fourths of a mile south-southwest of Proctor station in Proctor Township. (See Pl. I.) It is 100 feet or more in diameter and 150 feet deep. Operator, New Columbian Marble Co., State Street, Rutland, Vt.

The marble is white clouded. The beds strike N. 10°–15° W. and dip 50° E. A complete analysis of the stone is given on page 13.

About 100 feet north of the quarry along the strike the same beds, recently uncovered, with a glaciated surface and pothole 5 feet by 4 feet 6 inches, strike N. 20° W. and dip very steeply to the east. The marble exposed measures about 60 feet. East of it is the boundary of the dolomite series.

The general structure on both sides of the quarry is shown in section H, Plate III.

PROCTOR QUARRY.

The Proctor quarry, in full operation in 1900 but idle since 1907 and full of water in 1910, is about 0.4 mile northwest of Proctor station, on the north side of the village, a mile north of the Columbian quarry. (See Pl. I.) It is about 200 feet square, with an offset on the east side, and in 1900 was 175 feet deep. Owner, Vermont Marble Co., Proctor, Vt.

Marble 70 to 185 feet thick is exposed, lying between the uppermost bed of the dolomite series on the east and the intermediate dolomite on the west.

The marble, "Sutherland Falls" (specimens D, XIX, 140, c, d), is a calcite marble of bluish-white color with thin dark-gray spots and bands, probably dolomitic, along the bedding plane. Its texture is uneven and of grade 5 (coarse). It resembles very closely the "Riverside" marble, described on page 126.

The general structure is shown in section G, Plate III. The marble beds form the eastern limb of a syncline about 150 feet in depth, but, instead of curving over directly on the east to form an anticline, they turn sharply to dip at a low angle to the east for a space of 50 feet and then turn again to resume the direction of the synclinal limb. The effect of this minor fold in the anticlinal part of the fold is to double over some of the marble beds in the lower eastern part of the quarry and reduce the apparent thickness. Between 1900 and 1907 the quarry was also worked toward the east. The section on the north wall of this eastern extension shows the eastward-dipping beds of this minor easterly overturned fold crossed by low eastward-dipping joints, along which several caves as much as 3 feet in height have been eroded by percolating water. The dolomite which overlies the marble on the west differs microscopically from that of the dolomite series which underlies it on the east. (See p. 30.)

It is reported that the reasons for abandoning this quarry were the abundance of joints and the thinning of the beds at the turn of the syncline.

PARKER & PINCKNEY PROSPECT.

The Parker & Pinckney prospect, tested in 1910, is 1½ miles north of Proctor and 1¾ miles south-southwest of Pittsford village, in Proctor Township. (See Pl. I.) Operators, Parker & Pinckney, Pittsford, Vt.

The marble (specimen D, XXXI, 53, C) is a bluish-black or very dark bluish-gray graphitic dolomite marble, already described on page 46. It belongs in the basal dolomite. It takes a good polish.

The beds explored consist, beginning on the west, of 75 feet of bluish-black dolomite, followed by about 250 feet of buff dolomite and then by about 250 feet of bluish dolomite of various shades. The structural relations of these beds are not clear. The eastern and western belts probably belong at the same horizon. The strike is N. 5° W. and the dip 60° E., but this may vary, reducing the figures given for at least the larger thicknesses.

SHANGROW QUARRY.

The Shangrow quarry, abandoned between 1900 and 1910, is 1¼ miles north-northwest of Proctor station and 1½ miles N. 15° W. of the Proctor quarry, in Proctor Township. (See Pl. I.) Owner, Vermont Marble Co., Proctor, Vt.

The marble beds exposed in 1900 consisted, beginning at the top, of 32 feet of banded graphitic marble overlying 14 feet of graphitic quartzose dolomite veined with quartz, under which was an unknown thickness of banded marbles like those above it. The beds belong to the upper graphitic series of the marble formation.

The marble, "mountain dark" (specimens D, XIX, 149, b, c, rough), is a graphitic banded calcite marble of alternating dark-gray to black and light bluish-gray bands (beds) ranging from 0.1 to 0.3 inches in width and of uneven and irregular texture, with grain diameter of 0.05 to 0.62, mostly 0.12 to 0.37 millimeter, and thus of grade 4 (medium); one grain seen measured 0.37 by 2.37 millimeters. In the graphitic bands the calcite grains are generally of smaller diameter, ranging from 0.05 to 0.17 millimeter. The marble contains small quartz particles, small cubes of pyrite, quartz lenses up to 0.37 millimeter in diameter, and in the dark bands abundant graphite. Some bands are muscovitic and pyritiferous.

PITTSFORD.

FLORENCE No. 2 QUARRY.

The Florence No. 2 quarry is 0.9 mile southwest of Fowler station and 1¼ miles nearly west of Pittsford station, in Pittsford Township. (See Pl. I and map of Castleton quadrangle, U. S. Geol. Survey.) The quarry measures 70 feet north to south by 45 feet across, and is 63 feet in depth. In May, 1911, it passed into the hands of the Vermont Marble Co.

The marble beds exposed in the quarry and explored by drilling to a point 170 feet east of it consist of about 210 feet of light and grayish calcite marbles including 8 feet of dark stone. They belong above the intermediate dolomite. (See p. 93.)

The marble, "Florence No. 2" (specimens D, XXXI, 27, a, rough; b, polished), is a calcite marble of very light bluish-gray color with whitish and dark-gray (graphitic and dolomitic) streaks and spots parallel to the bedding. It is uneven in texture, with grain diameter, in the calcitic parts, of 0.075 to 1, mostly 0.12 to 0.37 millimeter, and is thus of grade 4 (medium). The very irregular dolomitic lenses, which in thin section are not sharply separated from the calcitic ground, have a grain diameter mostly of 0.05 to 0.25 millimeter and are thus of grade 3 (fine). The dolomite is untwinned and some of the grains have rhombic outlines. Associated with it are a few small quartz grains and muscovite scales. Minute black grains (probably graphite) occur throughout, but more abundantly in the dolomitic lenses, and also a little pyrite. The marble takes a high polish, but the dolomite mottling shows in minute relief on the polished face.

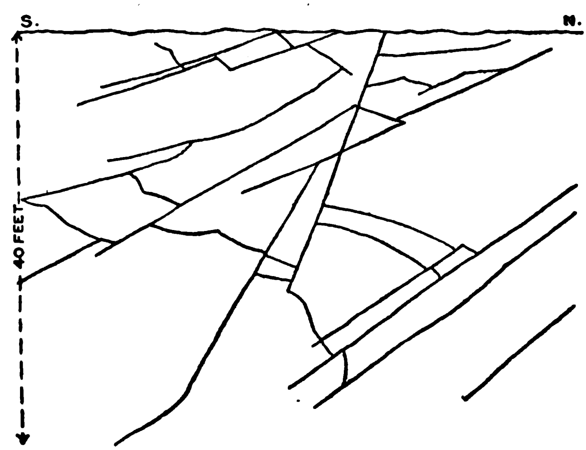


FIGURE 19.—Irregular joints and fractures on west wall of Florence No. 2 quarry, Pittsford.

The general structure here is shown in section I, Plate III. The beds strike N. 25° W. and dip 82° N. 65° E. The west wall shows very irregular jointing. (See fig. 19.)

PROSPECT WEST OF FLORENCE No. 2 QUARRY.

An east-west trench dug in 1900 across the low ridge immediately west of the site of the Florence No. 2 quarry exposed a handsome white marble interbedded with a coarser one of medium bluish gray banded with black (specimen D, XIX, 202, b), containing a few scales of biotite.

The white (202, a) is a calcite marble of milk-white color and of irregular texture, with grain diameter of 0.05 to 0.75, mostly 0.12 to 0.5 millimeter and of about grade 4 (medium). It contains a few pyrite grains up to 0.03 millimeter, rare grains of quartz, and sparse very minute black particles of uncertain nature.

TURNER QUARRY.

The Turner quarry is less than 1,000 feet northeast of the Florence No. 2 and about three-fourths of a mile southwest of Florence station, in Pittsford Township. (See Pl. I.) The opening, which is of recent date, is about 500 feet north of the Central Vermont Marble Co.'s quarry, which was operated in 1900 but is now disused. It is about 140 feet north to south by 70 feet across and 86 feet deep in one half and 49 feet in the other. It has a tunnel at the south end, 43 feet below the rock surface, 70 feet wide, and extending 35 feet to the south.

In May, 1911, this quarry passed into the hands of the Vermont Marble Co., Proctor, Vt. The marble exposed in the quarry and cropping out on both sides of it consists of the following beds, beginning at the top and west:

Section of marble beds at Turner quarry.

	Feet.
Intermediate dolomite	242
White mottled marbles	207
Dolomite series.	
	449

Its position is therefore identical with that of the marble in the Proctor quarry (p. 127).

The marble, "Pittsford Italian" (specimens D, XXXI, 21, c, rough; f, polished; a, rough and polished), is a calcite marble of slightly bluish-white color, with finely plicated beds and irregular mottlings of medium gray (graphitic dolomite). One of these little beds is shown in figure 20. They are from half an inch to 3 inches apart. The calcitic part has a grain diameter of 0.05 to 0.87, mostly 0.12 to 0.37 millimeter, and is thus of grade 4 (medium). The grain diameter of the little dolomite beds and lenses (not crossed by the sections obtained) is probably, like that in the "Pittsford Italian," mostly 0.05 to 0.25 millimeter, and these are thus of grade 3 (fine). The general texture is irregular and uneven. There are very minute black particles (graphite?), a few of pyrite, and rare small quartz grains. The marble takes a high polish, but the darker dolomitic passages project in very minute relief on the polished face.

The beds strike N. 25°–30° W. and dip 75° ENE. The dolomite on the west strikes N. 20° W. and dips 70° N. 70° E. Both the underlying and overlying dolomite and the intervening marble belong to the east limb of an eastward-inclined syncline, as shown in section I, Plate III. The economic significance of this relation is that eventually, as the quarry deepens, the underlying dolomite will be encountered.

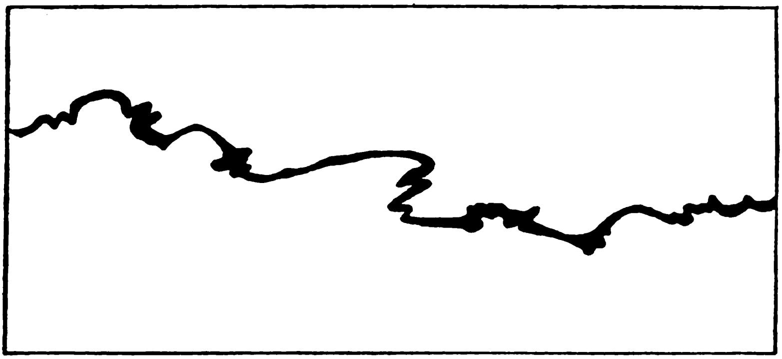


FIGURE 20.—Minute dolomite bed in lower mottled marble, "Pittsford Italian" (specimen D, XXXI, 21, c). Natural scale.

FLORENCE No. 1 (HOGBACK) QUARRY.

The Florence No. 1 is a new opening, southwest of the now disused "Valley quarry," about three-fourths of a mile west of Florence station, in Pittsford Township. (See Pl. I.) It is 90 feet east to west by 70 feet across. One-half of it is 112 feet deep and the other 70 feet. In May, 1911, the quarry passed into the hands of the Vermont Marble Co., Proctor, Vt.

The marble beds exposed and prospected here, beginning above and on the west, are as follows:

Section of marble beds at Florence No. 1 quarry.

	Feet.
Light mottled marble including a 9-foot bed of darkish gray, "mountain dark"	234
White marble	18
Intermediate dolomite	254

The position of the beds is thus above the intermediate dolomite and corresponds to that of the beds in the Florence No. 2 quarry. (See p. 92.)

The marble, "Florence No. 1," is a calcite marble of light bluish-gray color with fine dark-gray streaks (graphitic and dolomitic beds) parallel to the bedding. On the bed face these dolomite beds appear as an irregular mottling. It is practically identical with "Florence No. 2," described on page 129. Its texture is medium (grade 4), but it is regarded as slightly coarser than "Pittsford Italian."

The beds strike N. 25° W. and dip 70°–75° ENE. The marble and the intermediate dolomite east of it both belong to the east limb of an eastward-inclined syncline. Therefore as the quarry is deepened the underlying intermediate dolomite should eventually be struck, although no indications of dolomite or of any turning of the beds have been found at a depth of 70 feet below the bottom of the quarry. Conspicuous joints dip to the southwest at low angles. Percolating water has by means of its content of carbonic acid formed a series of caves, first along the bedding and then along these joints, as shown in Plate XVII. One of these caves 100 feet below the surface is 10 feet high. These caves occasion much inconvenience in adjusting the cutting machines. An east-west compressive strain has been noticed at this quarry.

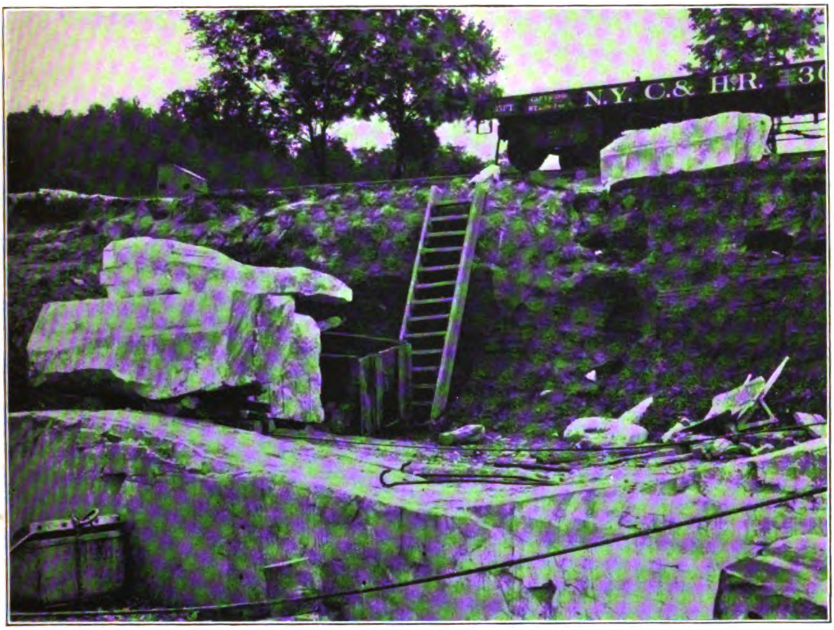
FLORENTINE QUARRY.

The Florentine quarry is at the east foot of the Taconic Range, 1½ miles N. 72° E. of Biddie Knob and 1¼ miles west of Florence station, in Pittsford Township. (See Pl. I and map of Castleton quadrangle, U. S. Geol. Survey.) The quarry, a new opening a little west of a disused quarry, measures about 200 feet north to south by 100 feet across and is 100 feet deep in one half and 42 feet in the other. In May, 1911, it passed into the hands of the Vermont Marble Co., Proctor, Vt.

The marble beds exposed and prospected here include 150 feet of graphitic marbles immediately underlying the base of the schist of the Taconic Range and thus belong to the upper graphitic series. In the quarry there is an irregular bed of graphitic untwinned dolomite veined with quartz and white calcite.

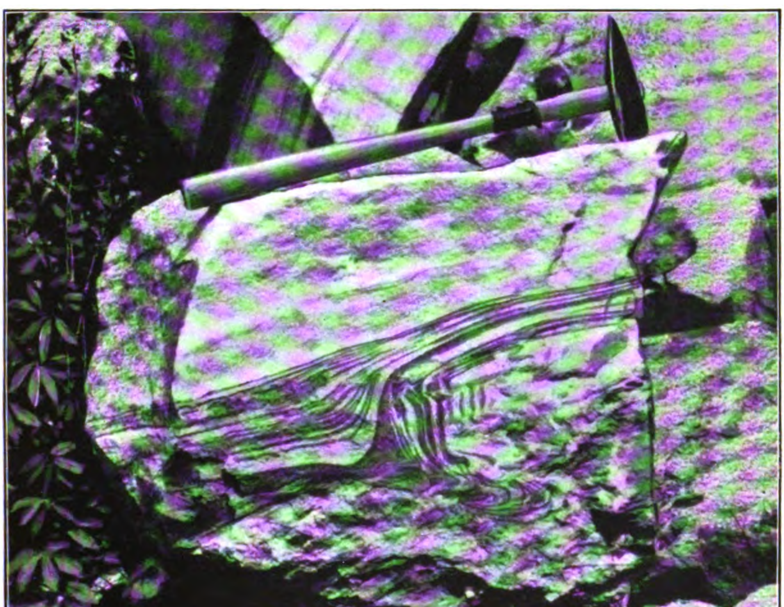
The marble, "Florentine blue" (specimens D, XXXI, 24, c, rough; d, polished), is a graphitic calcite marble of dark bluish-gray color, with fine very dark and light gray unplicated bands, and of even, regular texture, with grain diameter of 0.05 to 0.75, mostly 0.12 to 0.25 millimeter, and thus of grade 3 (fine). It abounds in minute particles of graphite and contains rather plentiful pyrite up to 0.12 millimeter in diameter and rare grains of quartz. This stone takes a very high polish without any protuberances.

The marble strikes N. 25° W. and dips 60° W. at the surface of the quarry, turning to 70° at the bottom. In the disused quarry about 200 feet farther east the dip is at a low angle to the west. At the contact with overlying schist 60 feet west of the quarry the schist is graphitic and has a cleavage foliation striking N. 5° W. and dipping 20°–25° E. The marble at the contact curves from 90° to steep west, and the bedding of the schist, obscured by cleavage, is presumably parallel to it. The marble beds belong to the east limb of a syncline.



A. GLACIAL FURROW IN WHITE CALCITE MARBLE, PITTSFORD.

The marble is in close erect folds striking N. 20° W., but the furrow runs S. 20° E. Thin-bedded clay 20 feet thick, probably deposited by a glacial lake, overlies the marble and has preserved it from weathering, so that good stone occurs at the rock surface.



B. PINCHED FOLD OF WHITE CALCITE MARBLE, DUMPS OF OWLS HEAD QUARRIES, SOUTH DORSET.

Showing the prolongation of the apex of the fold by flowage. The bed about and below the fold is dolomite. Hammer 21 inches.

EFFECT OF UNDERGROUND SOLUTION, SOUTH WALL OF FLORENCE NO. 1 QUARRY, PITTSFORD.

The lowest cave is 15 feet long. The smaller ones are along a bedding plane.

Between the quarry and the schist contact the marble beds, recently divested of their protective covering of till, are highly glaciated, as shown in Plate XV, *B*.

HOLLISTER QUARRIES.

The Hollister quarries are 1¼ miles northwest of Florence station and half a mile west of Florence Cross Roads, in Pittsford Township. (See Pl. I and map of Castleton quadrangle, U. S. Geol. Survey.) The quarries comprise two openings on the same beds—the southern one, the original Hollister quarry, which at the surface measures 150 feet north to south by 25 feet across, but at the bottom, 316 feet down, is 189 by 125 feet, and a new one, 200 feet north, the Valley quarry, which measures 100 feet north to south by 25 feet across at the surface, but 125 feet at the bottom, 85 feet down. From the south end of the original quarry a tunnel, 60 feet wide and 40 feet high, has been drilled 70 feet west.

Operator, Vermont Marble Co., Proctor, Vt.

The marble beds exposed and prospected here, given in more detail on page 91, comprise, beginning on the west and above:

Section of marble beds at Hollister quarries.

	Feet.
Light bluish-gray marbles	90
Clouded marble	16
"Blue vein"	14
Alternating clouded, muscovitic, and light bluish-gray marbles	102
	222

This set of beds apparently lies a little above the intermediate dolomite. (See p. 93.)

The marble, "Pittsford Valley" (specimens D, XIX, 148, a, rough, from bed A; and D, XXXI, 16, a, polished), is a calcite marble of light bluish-gray color with little medium to dark gray (graphitic and dolomitic) plicated beds which on the bed surface appear as irregular mottling. Its texture is uneven. The grain diameter in the calcitic parts is 0.05 to 0.75, mostly 0.12 to 0.37 millimeter, and thus of grade 4 (medium). In the dolomitic parts the grain diameter is 0.02 to 0.25, mostly 0.07 to 0.12 millimeter, and thus of grade 2 (very fine). Minute black particles (probably graphite) occur throughout but are more plentiful in the dolomitic parts, which also contain very little pyrite and muscovite. The marble takes a high polish, but the dolomitic mottling projects in very minute relief.

A specimen of bed K (D, XIX, 148, c, rough) is a calcite marble of light bluish-gray color without mottling and of regular, even texture, with grain diameter of 0.05 to 0.87, mostly 0.12 to 0.5 millimeter, and thus also of grade 4 (medium) but a trifle coarser than that of bed A.

(See fig. 21.) The average grain diameter of the calcitic parts, determined by the Rosiwal method, is 0.1484 millimeter.

In general the marbles of these quarries are more bluish than those of the Proctor and Riverside quarries.

The beds strike N. 5° W. and dip 80° E. to 90°. Although the beds at a depth of 316 feet are still vertical, they will be found eventually to be underlain by the dolomite, which crops out east of the quarry. The character of the folds here is not clear. There are four sets of joints—set *a*, strike N. 80° E., vertical, spaced 2 to 5 feet for a distance of 50 feet between the two openings; set *b*, strike east to west, dip 10° N., few, spaced 3 to 20 feet; set *c*, same strike, dip 55° N., spaced 3 to 50 feet; set *d*, same strike, dip 10°–15° S. The quarry is at the east foot of a marble cliff 100 feet high. On the east side of the northern opening the marble at the surface is not over 5 feet thick. In drilling eastward at a depth of 75 feet the marble was found to extend but 25 feet. It is possible that the beds have suffered considerable erosion at this point.

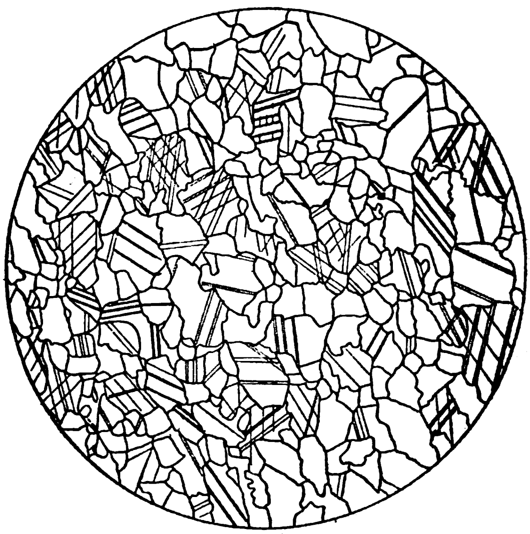


FIGURE 21.—Thin section of coarser part of light-gray clouded calcite marble from bed K, Hollister quarry, Pittsford. Enlarged 20 diameters.

Specimens: Champlain apartment house, Washington, D. C.; fourteen columns 29 feet 9 inches long and from 2 feet 10 inches to 3 feet 4 inches in diameter in Curtis Publishing Co.'s building, Philadelphia. These columns were cut parallel to the bed and show the small grayish plicated dolomitic beds. (See also Pl. VI, *B*.)

LANDON QUARRY.

The recently opened old prospect known as the Landon quarry is 1½ miles N. 10° W. from the Hollister quarries and close to the Brandon-Pittsford line, in Pittsford Township. (See Pl. I and map of Brandon quadrangle, U. S. Geol. Survey.) The opening measures 84 feet east to west by 50 feet across and 20 feet in depth.

Operator: Vermont Marble Co., Proctor, Vt.

The marble exposed consists of 80 feet of calcite marble. The upper part of the dolomite series is but a few hundred feet east of the quarry.

The marble, "Landon" (specimen D, XXXI, 18, a, b, rough), is a calcite marble of slightly bluish white color, with medium to dark gray, intricately plicated dolomitic beds up to 0.1 inch thick, which project slightly on the weathered face (specimen D, XXII, 240, a). Its texture is uneven, with grain diameter in the calcitic parts of 0.05 to 0.75, exceptionally 1.5, mostly 0.12 to 0.37, averaging 0.24 millimeter, and thus of grade 4 (medium), and in the dolomitic parts as much as 0.02 millimeter, but also with large cloudy plates 0.75 to 1.75 millimeters across having rhombic cleavage and rarely dolomitic twinning. These plates show under a 450 enlargement a peculiar granular texture. The marble contains very little quartz, some muscovite, pyrite, limonite, and sparse very minute black particles throughout. Its general texture is a little finer than that of the beds of the Hollister quarry and its little dolomitic beds are more numerous, producing more mottling.

The beds shown by the plications strike N. 20°–25° W. and dip 80° WSW. A close jointing or cleavage spaced in places 1 inch to 2 feet dips 30° E. One set of joints strikes N. 30° E. and a single vertical joint on the north wall runs east to west. The relation of the beds to the two dolomite series is not clear.

BRANDON.

There were but two active quarries in Brandon in 1910. The marbles of four idle ones which were visited in 1903 were examined microscopically. Two new prospects were opened in 1911.

QUARRY 238.

The abandoned quarry at locality No. 238 is a mile north of the Landon, a little east of the railroad, and about 2 miles S. 25° E. of Brandon station. (See Pl. I.)

The marble is a calcite marble of milk-white color, with little cloudy dolomitic and muscovitic beds. The calcitic parts are irregular in texture and have a grain diameter of 0.05 to 0.75, mostly 0.12 to 0.38 millimeter, being thus of grade 4 (medium). The marble contains some pyrite and a little quartz.

The plicated bedding is vertical and is crossed by low eastward-dipping cleavage ("reeds").

BRANDON ITALIAN QUARRY.

The Brandon Italian quarry is half a mile south of Brandon station and 0.7 mile west of the west boundary of the basal dolomite. (See Pl. I and map of Brandon quadrangle, U. S. Geol. Survey.) The quarry measures about 600 feet north to south by 60 feet across and 75 feet in depth.

Operator since 1909, Vermont Marble Co., Proctor, Vt.

The marble is of uncertain thickness owing to close folding, as explained below. The character of the marble is regarded by the operators as identical with that of the Hollister quarries.

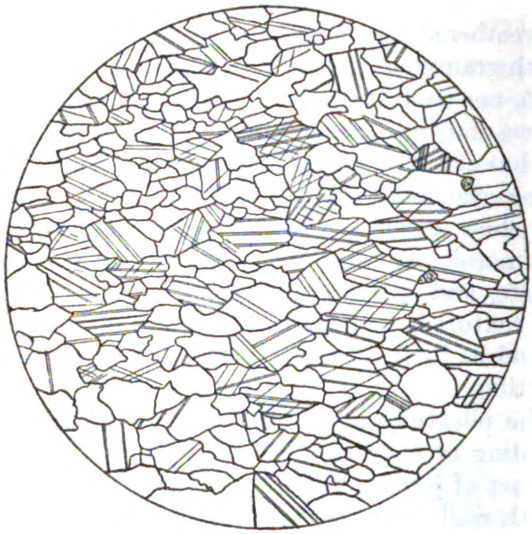


FIGURE 22.—Thin section of calcitic part of clouded calcite marble from the Brandon Italian quarry, showing irregular grain form and elongate texture. Dotted particles are quartz. Enlarged 20 diameters.

The marble, "Brandon Italian" (specimens D, XXII, 250, a, b, rough) is a calcite marble of light bluish-gray color crossed by small dark-gray graphitic dolomitic beds which on the bed face produce an irregular mottling. Its texture is uneven and somewhat elongated, with grain diameter in the calcitic parts of 0.05 to 0.87, mostly 0.17 to 0.5 millimeter, and it is thus of grade 4 (medium). The grain form and texture are shown in figure 22. An estimate of the average grain diameter by the Rosiwal method yields 0.155 millimeter. The section did not cross any of the dolomitic beds. Quartz grains, somewhat plentiful, measure 0.05 to 0.07 millimeter. A little pyrite and rarely muscovite are also present.

The beds strike N. 20°–25° W. and on the east side dip steeply to the east at the south end but stand vertical at the north end. In the center of the quarry they zigzag in a horizontal direction, indicating a synclinal or anticlinal structure. A repetition of the beds on either side of the synclinal axis is therefore to be expected. Core drilling at a point 200 feet east of the quarry shows continuous marble. In breaking the blocks an obscure vertical cleavage parallel to the bedding on the

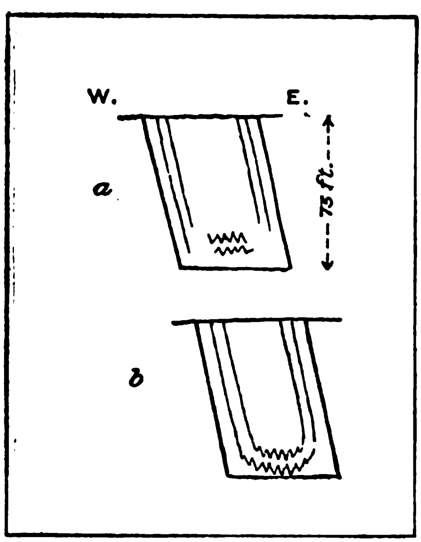


FIGURE 23.—Structure at Brandon Italian quarry. a, Actual; b, an interpretation.

east side of the quarry is utilized. The possible synclinal structure is shown in figure 23, *b*. The marble in 1903 was reported as affording evidence of compressive strain.

Specimen: Roman Catholic Church at Middlebury.

BRANDON ITALIAN HIGH STREET QUARRY.

The Brandon Italian High Street quarry is 0.6 mile northeast of the Brandon Italian quarry and half a mile east-southeast of Brandon station. (See Pl. I.)

Operator since 1909, Vermont Marble Co., Proctor, Vt.

The marble beds consist of 107 feet of light bluish-gray marbles situated very near the underlying dolomite. The marble closely resembles that of the Brandon Italian quarry.

The marble beds strike about north and dip 50° W. The knoll east of the quarry consists of the bluish-gray basal dolomite, striking N. 25° W. and dipping 90°. The first dolomite west of the quarry should be the intermediate dolomite.

GOODELL QUARRY.

The Goodell quarry is at the foot of the north end of the Taconic Range about 2½ miles southwest of Brandon station. (See Pl. I.) It is a small opening abandoned soon after it was made owing to the smallness of the marble bed.

The beds include 15 feet of fine white marble, apparently both underlain and overlain by a dark gray graphitic quartzose dolomite. Some of the marble is in thin beds and the whole was reported as running out or covered along the strike. It probably belongs toward the upper graphitic series.

The marble (specimen N. D, I, 9, b) is a calcite marble of milk-white color and of regular, even texture, with grain diameter of 0.02 to 0.37, mostly 0.07 to 0.25 millimeter, and thus of grade 2 (very fine). It takes a high polish.

The marble bed and the dolomitic rock on both sides of it strike N. 30° E. and dip 35° S. 60° E. Of the overlying dolomite a thickness of 15 feet is exposed. It is uncertain whether the two dolomitic beds are one bed doubled over or two distinct beds. The rock in thin section has a grain diameter of 0.009 to 0.094, mostly 0.02 to 0.04 millimeter. Its character as dolomite is not shown by twinning. It contains sparse grains of quartz and rarely one of plagioclase (feldspar). A very graphitic and quartzose bed a millimeter thick and another of twinned calcite particles with quartz grains appear in the section.

W. T. Schaller, of the Geological Survey, who examined the rock qualitatively, reports that "calcite and dolomite together form a large part of it, but dolomite itself does not form the chief constituent."

A railing with balusters of this marble can be seen at the side of the pulpit in the Congregational Church at Brandon.

CONNELL QUARRY.

The Connell quarry is about 1,800 feet ENE. of the Goodell quarry and 4¼ miles southwest of the bench mark in Brandon village. (See Pl. I.) Operator, Brandon Marble Co., Brandon, Vt.

The quarry measures 60 by 30 feet and is 24 feet deep; there is a second opening 175 feet to the north.

The beds here consist of 30 feet of marble, both overlain and underlain by graphitic dolomite. The stratigraphic position is like that of the Goodell quarry. The thickness of 30 feet includes a 7-foot bed of fine white statuary, 13 feet of mottled, and 10 feet of gray marble.

The white marble (specimens D, XXXI, 88, a, rough; b, polished) is a calcite marble of very faint ivory tint and of regular, even texture, with grain diameter of 0.05 to 0.45, mostly 0.1 to 0.24 millimeter. A Rosiwal measurement of a thin section shows an average grain diameter of 0.1 millimeter. It therefore belongs to grade 2 (very fine), as does also the "statuary Rutland." It contains rare quartz grains and sparse minute black specks. It takes a high polish.

The beds are on the strike of the beds in the Goodell quarry (N. 30° E.) and dip 40° S. 60° E. The excavations have not proceeded far enough to show the relations of the two dolomite beds to one another.

ROYCE QUARRY.

The long idle Royce quarry is three-fourths of a mile northwest of Brandon station at the west foot of a ridge 100 feet high. (See Pl. I.) The quarry measures about 150 feet along the strike. The marble exposed measures about 70 feet, underlying (really overlying in consequence of overturned folds) grayish dolomite which may be the intermediate dolomite.

The marble is of two kinds. One (specimen D, XXII, 218, a) is a calcite marble of very light bluish-gray color, with inconspicuous medium-gray dolomitic (?) mottling (beds), and of even texture, with grain diameter in the calcitic part of 0.02 to 0.37, mostly 0.1 to 0.25 millimeter, and thus of grade 3 (fine). It contains some small quartz grains and some pyrite. There is a rough parallelism of the twinning planes of different particles. The other (specimen D, XXII, 218, b) is a calcite marble of milk-white color, with little grayish micaceous dolomitic beds. The calcitic part has a grain diameter of 0.02 to 0.5, mostly 0.1 to 0.25 millimeter, and is thus also of grade 3. It contains small sparse quartz grains and very minute black particles of uncertain nature.

The marble and the dolomite east of it strike N. 15°–20° W. and dip steeply to the east. The upper marble beds are crossed by joints dipping 30° W.

PROSPECT 255.

Prospect 255 is 2¼ miles north of Brandon station, just west of the boundary of the basal dolomite east of the road to Leicester. (See Pl. I.)

The marble is white and light bluish gray. A specimen of the latter (D, XXII, 255, a) shows small medium gray dolomitic bands up to 0.1 inch wide. The calcitic part is of irregular texture and has a grain diameter of 0.05 to 0.75, mostly 0.12 to 0.5 millimeter, being thus of about grade 4 (medium). It contains minute quartz grains and some pyrite. A large plate of untwinned dolomite, 1.12 millimeters across, with rhombic cleavage, is crowded with graphite. This marble is coarser than that of the Royce quarry.

The beds strike N. 10° E. and dip 35° E. Dolomite lies east of the marble with like dip, both forming part of an overturned fold. The marble thus belongs at base of the marble series.

VERMONT ITALIAN MARBLE CO.'S QUARRY.

The quarry of the Vermont Italian Marble Co., of Brandon, is 1½ miles N. 20° W. of the bench mark in Brandon village. (See Pl. I.) It was opened in 1911.

The marble is reported as practically identical with that of the Brandon Italian quarry, 2 miles to the south, and is said to measure 600 feet in width, without reference, of course, to any duplication in folding. The beds dip about 18° roughly eastward. One or more of them attain a thickness of 8 feet.

SUDBURY.

SUDBURY BRECCIA PROSPECT.

A reddish hematitic dolomite resembling some of the fragments in the breccia of the Dyer quarry, in Manchester (p. 97), occurs at a point 4 miles WSW. of Brandon, in Sudbury Township, along a brook flowing north into Otter Creek. It is about half a mile northwest of the site of the Cool farmhouse.

The bed from its location appears to be very near the top of the marble. The rock is brecciated in places and coarsely cemented with flesh-colored and colorless calcite.

MIDDLEBURY.

MIDDLEBURY MARBLE CO.'S QUARRY.

The abandoned quarry of the Middlebury Marble Co. is 2 miles east-southeast of Middlebury, a little west of the west limit of the basal dolomite and about 1,100 feet east of the road to East Middlebury, in Middlebury Township. (See map of Middlebury quadrangle, U. S. Geol. Survey.) This quarry has been idle for over 28 years. It measures about 100 feet east to west.

The following section is exposed, beginning on the west:

Section of marble beds at Middlebury Marble Co.'s quarry.

	Feet.
Calcite marble, bluish	6
milk-white	9
white, translucent	14
fine grained, faintly pink	17
white (like 14-foot bed)	22
	68

The marble of the 9-foot bed (specimens D, XXII, 410, a and c, from a prospect 250 feet farther south) is a calcite marble of milk-white color and of regular texture, with grain diameter of 0.02 to 0.37, mostly 0.12 to 0.25 millimeter, and thus of grade 3 (fine). It contains rare quartz grains and spherules of pyrite. The texture of this rock is that of a normal marble and very different both in grade and in grain arrangement from the section obtained of Brandon Italian, as will be noticed by comparing figures 24 and 22. An estimate by the Rosiwal method shows its average grain diameter to be 0.11 millimeter.

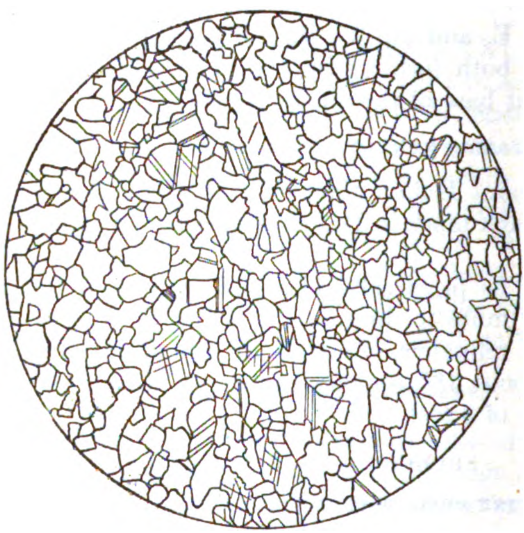


FIGURE 24.—Thin section of white calcite marble from abandoned quarry of Middlebury Marble Co. Enlarged 20 diameters.

The structural relations are not clear. The marble, however, probably belongs not far from either the dolomite series or the intermediate dolomite. The dip on the west side of the quarry is 40°-50° W. About 600 feet east of the quarry a whitish dolomite and very quartzose beds strike N. 10° W. and dip about 72° E. At an old disused quarry a mile north marble about 40 feet thick strikes north and dips 45° E.; and at another opening a quarter of a mile west of this one white marble about 70 feet thick, with muscovitic streaks, strikes N. 10° E. and dips 90°.

MARBLE LEDGE QUARRY.

The long disused Marble Ledge quarry is about 3¼ miles N. 25° E. of Middlebury and 1¾ miles east of Beldens. (See map of Middlebury quadrangle, U. S. Geol. Survey.)

A body of white marble about 60 feet thick is exposed, striking north and dipping 50° E. Muddy Branch here flows through a small gorge along the strike and there seems to be a syncline between the stream and the quarry.

MONKTON AND BRISTOL.

The dolomite of Monkton has been described on page 45. It belongs apparently to the dolomite which underlies the calcite marbles. The only quarry operated in recent years was idle in 1910.

VERMONT MARBLE CO.'S MONKTON QUARRY.

The Monkton quarry of the Vermont Marble Co. is at the west foot of the so-called Hogback Mountains, really the west flank of the Green Mountain range, about 1½ miles north-northeast of East Monkton and 6 miles N. 10° W. of Bristol, in Monkton Township, Addison County. (See map of Middlebury quadrangle, U. S. Geol. Survey.) The opening is 30 by 15 feet and 5 feet deep. The quarry is not now used, the company having withdrawn the marble from the market.

The beds exposed consist of about 270 feet of dolomite. The marble, "Ruvaro" (specimens D, XXXI, 63, a fresh; d, weathered), is a mottled pink and white quartzose hematitic dolomite marble. It contains thin beds of sericite and quartz (specimens D, XXXI, 63, b, c). Descriptions of these will be found on page 45.

The dolomite strikes N. 25°–30° W., dips 30°–40° W., and is crossed by slip cleavage dipping 40° E. and in places by close east-west joints dipping steeply to the north. About 315 feet east of the dolomite is an outcrop of quartzite, slightly calcareous in places, striking N. 15° W. and dipping at a steep angle to the west, crossed by cleavage dipping 60° E. A little farther south, at the head of a brook flowing southward, dolomite and quartzite are in contact, both rocks for the depth of a foot dipping steeply to the east, whether by faulting or minor overturned folding is not evident.

This marble was polished by the company and sold for decorative use.

COLUMBIAN MARBLE CO.'S MONKTON QUARRY.

The Monkton quarry of the Columbian Marble Co. is 0.6 mile S. 32° W. of the Vermont Marble Co.'s quarry, on the south side of the east-west crossroads in the same township. The opening is about 20 feet square and 5 to 10 feet deep and has been long disused.

The marble is identical with that of the Vermont Marble Co.'s quarry. The weathered parts have a muddy gray color. The beds strike north, dip 45° E., and show many minor fractures along the bedding.

CHAPIN PROSPECT.

The same dolomite marbles crop out between the two quarries last described, on the farm of L. O. Chapin, of Bristol, Vt.

JIMMO PROSPECT.

The Jimmo prospect is in Bristol Township 1¼ miles west-southwest of the Bristol bench mark. (See map of Middlebury quadrangle, U. S. Geol. Survey.) Owner, Harry Jimmo, Bristol, Vt.

The marble (specimen D, XXXI, 67, a) is a quartzose hematitic dolomite marble of deep-pink color, differing from that of the Monkton quarries and prospects by its less conspicuous mottling and deeper shade. It also has films of sericite. The thickness exposed is 8 feet.

SWANTON.

The dolomite marbles of Swanton have already been described in a general way on page 43. The quarries, opened about 1870, are about a mile S. 65° E. from Swanton, on a ridge on the south bank of Missisquoi River and rising to 165 feet above it, in Franklin County. Five openings situated at different elevations and on different beds are now in occasional use. They have working faces on the east ranging from 15 to 40 feet in height and from 50 to 100 feet or more in length. Operator, Barney Marble Co., Swanton, Vt.

The marble beds are about 150 feet thick. The character of the beds is shown in the descriptive sections given below. Some of the beds are uniformly reddish brown and recur at irregular intervals. Others, near the top, are uniformly bluish gray. Some at the base are greenish gray, with brecciated dolomitic lenses or beds and distorted corals. Others have a reddish or purplish matrix with similar brecciated beds and corals.

The marbles are known commercially as "Champlain marbles." There are five more marked varieties described in the following paragraphs.

"Royal red" (specimens D, XXXI, 3, a, polished; e, rough with chloritic veinlets) is a quartzose hematitic untwinned dolomite marble of dark reddish-brown color, with irregular, slightly lighter clouds and some whitish streaks. It consists, in descending order of abundance, of (*a*) dolomite plates of irregular form, tending to rhombic outline, and of some rhombs with grain diameter of 0.02 to 0.3, mostly 0.02 to 0.12 millimeter, averaging 0.07 and thus of grade 1 (extra fine); (*b*) interstitial reddish-brown hematitic (kaolin), in places more abundant, forming streaks along the bedding; (*c*) plentiful angular quartz grains, 0.02 to 0.15 but mostly under 0.07 millimeter with rare grains of feldspar (plagioclase); (*d*) a few opaque particles (magnetite?); and (*e*) rare muscovite flakes. The dolomite plates have very minute reddish specks. The quartz grains have cavities with moving vacuoles. This marble is very sonorous, emits an argillaceous odor, effervesces very slightly with acid test, and takes a high polish. A thin section of it is shown in figure 8, page 44.

"Jasper" (specimens D, XXXI, 3, g, rough; and c, polished) is a quartzose hematitic untwinned dolomite marble of bright-reddish ground containing pinkish and white irregular lenticular objects from 0.1 to 0.7 inch in width and from an inch or less to 8 inches in length, generally with the long axis parallel to bedding but in places at all angles. The white ones are highly crystalline and effervesce as little as does the ground under acid test, and some have a nucleus of milky quartz. The ground has the same composition as the "royal red" but contains magnetite grains, giving rise to hematite stain. The corals are in part coarsely crystalline twinned dolomite and in part granular dolomite. In sonorousness, effervescence, and polish this marble is like the "royal red." A photograph of a specimen of this marble is reproduced in Plate VIII, *A*, *c*, and blocks of it are shown in Plate V, *B*.

"Lyonnaise" (specimen D, XXXI, 3, b, polished) is a quartzose hematitic untwinned dolomite marble of brownish-red ground or of merging forms of roundish cylindrical or irregular outline in brownish red with the interspaces filled with whitish crystalline dolomite. One of these forms has crystalline quartz in the center. The ground is of the same composition and texture as the "royal red." Some of the white twinned dolomite incloses granular dolomite. In sonorousness and effervescence of ground this marble is like the "jasper" and the "royal red." The polished face shows some dull (kaolinic?) streaks.

"Oriental" (specimens D, XXXI, 3, h, rough; d, polished) is a quartzose hematitic and magnetitic untwinned dolomite marble with ground of dark reddish brown inclosing dark purplish-gray areas of very irregular curving outline and concentrically banded, also with some irregular spots of white calcite having a nucleus of crystalline quartz. The ground is like that of "royal red" in texture and composition. The dark purplish-gray parts abound in magnetite grains, more or less oxidized to hematite, and contain rare minute scales of biotite. The coarsely crystalline white parts appear to be part calcite and part dolomite. There are veinlets of white twinned dolomite. The sonorousness, effervescence of ground, and polish of this marble are like those of "royal red."

"Olive" (specimens D, XXXI, 3, k, l, rough; and m, polished) is a quartzose untwinned dolomite marble of light, faintly greenish-gray ground, inclosing very irregular lenses or elongated cones, more or less parallel, some of them brecciated, of light pinkish-gray color. Some of these lenses have a nucleus of white twinned dolomite surrounding crystalline quartz; most of them have a dark-brownish rim of limonite from the oxidation of pyrite. The dolomite plates of the ground carry minute dark grains. The ground also contains pyrite and grains of magnetite, mostly not oxidized to hematite. There are rare muscovite scales in the finer parts. This marble is also very sonorous, emits an argillaceous odor, and effervesces very slightly with acid test. The polish is fair but shows some dull (kaolinic?) streaks.

The dolomite marble beds of Swanton are underlain on the west by a calcareous bed containing the brachiopod Kutorgina, of Lower Cambrian age, and are overlain on the east by the Lower Cambrian shales of St. Albans.[1] The following sections were taken at the quarries:

1. At the top of the hill, strike N. 30° E., dip 10° S. 60° E.: Beginning at the top, 17 feet of mottled red and white dolomite marble, 3 feet of bluish-gray dolomite, 2 feet of plain red ("royal red"), 16 feet of mottled red and white. A joint face is coated with salmon-colored calcite. The bluish-gray dolomite (specimen D, XXXI, 3, i) has a marked argillaceous odor and weathers light ocher color; its effervescence is slight. In thin section this is a quartzose untwinned dolomite with a few grains of magnetite, passing into hematite, and some light-yellow grains, probably from oxidized pyrite. Interspersed among the quartz grains are a few of feldspar (orthoclase and microcline).

2. At the next quarry down: 12 feet of mixed dolomite beds, overlying 7 feet of hematitic and magnetitic dolomites with purplish spots ("oriental"). Some joints strike N. 35° E., stand vertical, and are spaced 5 to 18 feet; others strike N. 50° W., are vertical to steep, and are spaced 5 to 20 feet. Some diagonal fractures are coated with chlorite and salmon-colored calcite.

3. At a disused quarry next below: Beginning at the top, 8 feet of alternating mixed dolomite marbles, 2 feet of plain red ("royal"), 8 to 10 feet with white lenses or corals, discolored, and 2 to 3 feet plain red ("royal"). On some of the weathered surfaces the red argillaceous hematitic cement projects above the white lenses. The brecciation of the lenses is distinct.

4. Below the disused quarry and near the gateway, strike N. 50° E., dip 10°–15° S. 40° E.: Beginning at the top, 10 feet of hematitic dolomite with light lenses and corals, rather short and mostly

[1] See Hitchcock, Edward, and Hager, A. D., Geology of Vermont, vol. 2, 1861, pp. 773–775. Edson, G. E., Geology of the town of Swanton: Sixth Rept. Vermont State Geologist for 1907, 1908, pp. 210–220, fig. 5. Perkins, G. H., Preliminary report on the geology of Chittenden County: Idem, pp. 224–245, Pl. XXXIX (a slab of marble from Swanton with a number of pteropods, *Salterella pulchella*).

parallel to bed, 3 feet of plain red ("royal," measuring 5 to 6 feet at a disused opening a little east), and 10 feet of hematitic dolomite ("jasper"), with long, narrow white corals on bright-reddish ground, the corals at all angles, some vertical, but in places mostly parallel to bed. Joints strike N. 60° W., dip 70° N. 30° E. to 90°, and are spaced 6 to 10 feet. Joints in the "royal" bed strike N. 30°–35° W. and dip 25°–30° E. or W.; some are coated with chlorite.

5. At the west foot of the hill near the river and 60 feet above it, lower than section 4, the following series dips 15° about southeast, beginning at the top: Uncertain thickness of hematitic dolomite with white lenses, etc., 1 foot of plain red rock, 5 feet like upper bed, and 14 feet of finely laminated grayish dolomite with lenses and corals ("olive").

The marbles of Swanton are used for columns, wainscoting, and tiling. Their attractive and unusual coloring makes them as desirable for interior decoration as does their hardness for floor wear. This hardness is due to their dolomitic and quartzose composition and to their texture. Specimens: Columns and wainscoting in Detroit post office; columns and panels of "royal red" in numismatic room, United States Mint, Philadelphia; wainscoting and counter, Southern California Savings Bank, Los Angeles; wainscoting in Auditorium, Chicago; "olive" wainscoting in Columbus Despatch Building, Columbus, Ohio; tiling in city hall, Indianapolis, Ind. The length of columns is limited by the joint spacing to 10 feet.

ISLE LA MOTTE.

FISK QUARRY.

The Fisk quarry, first opened (for lime burning) in 1664 and furnishing building stone in 1788, is on the west side of the south end of Isle la Motte, in Lake Champlain, 11½ miles south of the Canada line, in Grand Isle County. The western edge of the quarry is only 100 feet from the shore. The quarry covers several acres and has a depth of 20 feet. Operator, N. W. Fisk, Fisk, Vt.

The series consists in natural order of the following beds which are of Chazy age:

Section of marble beds at Fisk quarry.

	Feet.
Black unmetamorphic calcite marble	20
Dark-gray crinoidal calcite marble	4–6
Dark-gray and black alternating calcite marble	12
	36–38

The marbles, "Fisk black" and "Fisk gray" (specimens D, XXXI, 1, a, black, fresh; g, polished; e, f, weathered; b, gray, crinoidal; d, gray with Maclurea), have already been described in detail on pages 47–48. (See also fig. 9.) They are slightly dolomitic carbonaceous fossiliferous calcite marbles of unmetamorphic origin and of very dark gray shade and are susceptible of high polish. The weathered surface of the black is dark bluish gray in places, with irregular brownish-gray dolomitic bands. The polished surface is almost black, with here and there sections of Macluréas in white calcite. The stone, except the dolomite bands, effervesces freely with acid and is very sonorous. Certain tests and analyses of these marbles made for the architect of the Bennington Monument and the Buffalo Pan-American Exposition, are in Mr. Fisk's possession.

The beds dip 5° to 7° NE. and had a glaciated surface in places, with polished grooves protected by 2 to 4 feet of sand and clay, carrying a few bowlders.[1] The black beds are subdivided into beds half an inch to 2 inches thick by dolomitic films or bands as thick as half an inch.

The polished product is supplied to the market by the Barney Marble Co., of Swanton. The black has long been used for tiling all over the United States. In the post office at Worcester, Mass., it has been combined with marble from Swanton in wainscoting. The waste of the quarry is sold as crushed stone.

LIME MARBLES.

IRA AND LEICESTER.

The lime marbles of Ira and Leicester are included here because of their geologic and petrographic relation to the constructional and monumental marbles already described.

DAY QUARRY.

The Day quarry is 3½ miles south-southwest of West Rutland, 1½ miles southeast of the top of Mount Herrick, in the Taconic Range, on the 1,300-foot level, in the town of Ira, Rutland County. (See Pl. I and map of Castleton quadrangle, U. S. Geol. Survey.) The quarry is reported as having been in operation in Revolutionary times. Operator in 1900, D. D. Day, of Ira, Vt.

The marble belongs either to the upper graphitic beds close to the base of the schist formation, or else within the schist.

The marble is a graphitic calcite marble with fine black and grayish bands, and of very uneven texture, with grain diameter of 0.02 to 0.37, rarely 2, mostly 0.07 to 0.25 millimeter, and thus of grade 3 (fine). It contains some quartz and feldspar grains, pyrite, and

[1] See Sixth Rept. Vermont State Geologist for 1907, 1908, Pl. VI, for photograph of one of the glacial grooves.

much graphite in bands. In places it abounds in sections of a large gastropod, resembling Maclurea.[1]

The marble area is about 300 feet east to west by 800 feet northeast to southwest, and is surrounded by the Berkshire schist of the range. It either protrudes through the overlying schist in consequence of erosion, or else forms a lens within it. On the west side of the quarry a tongue of graphitic sericite schist is dovetailed in the marble and the strike of the marble appears to be nearly east to west and the dip 10°–20° S. The strike of the schist mass east of the marble, however, is N. 30° E. and the dip 20° N. 60° W.; west of the marble the schist strikes east and west and dips at a low angle to the north. The marble seems to occur at the intersection of a minor transverse fold with the usual folds of the Taconic Range. A synclinal axis passes between the quarry and the top of Mount Herrick. The schist next the marble is slickensided, the grooves running N. 5° W. and dipping 45° E. The marble is much jointed, fractured, and veined with calcite and quartz. Vertical joints strike N. 20° E. and are coated with felty asbestos, "mountain leather" (specimen D, XIX, 259, e), indicating metamorphism subsequent to jointing.

HUNTLEY QUARRY.

The Huntley quarry is about 800 feet west of Leicester Junction, 5½ miles northwest of Brandon station, in Leicester Township, Addison County. (See Pl. I and map of Brandon quadrangle, U. S. Geol. Survey.) Operator, Brandon Lime & Marble Co., Leicester Junction, Vt.

The stratigraphic position of the marble beds of this quarry can hardly be determined, owing to the scarcity of outcrops and the distance of the quarry from the basal dolomite on the east and the schist on the west, 2 miles in each case. Marble more than 20 feet thick is exposed in beds which are doubled over on themselves two or three times.

The marble (specimen D, XX, 217, a) is of translucent but dull aspect, light buff-pinkish color, and uneven parallel elongate texture, as shown in figure 25, with alternate irregular tiers of large and small grains. The larger grains, whose longer axes are parallel, have a diameter of 0.04 to 0.2, mostly 0.04 to 0.09 millimeter, and are thus of grade 1 (extra fine); the smaller grains are more roundish, with a tendency to rhombic form, and have a grain diameter of 0.009 to 0.03, averaging possibly about 0.02 millimeter, finer than grade 1. The larger grains show rhombic cleavage and twinning

[1] This locality is referred to by Hitchcock and Hager (Geology of Vermont, vol. 1, 1861, p. 432), also by Wing (Dana, J. D., Am. Jour. Sci., 3d ser., vol. 13, 1877, p. 339). In February, 1901, Dr. C. D. Walcott expressed the opinion in a letter to the writer that there was no reason why the fossils of this locality, which resemble those occurring more or less abundantly to the north in the upper part of the Chazy or lower part of the Trenton, should not occur well up in the Trenton.

parallel to that cleavage, and are presumably calcite; the smaller ones, with neither cleavage nor twinning, may be dolomite, or else calcite crushed along its cleavage. (See p. 19.) The stone effervesces with acid more freely than dolomite. The marble of these quarries seems to be referred to by Hitchcock and Hager.[1]

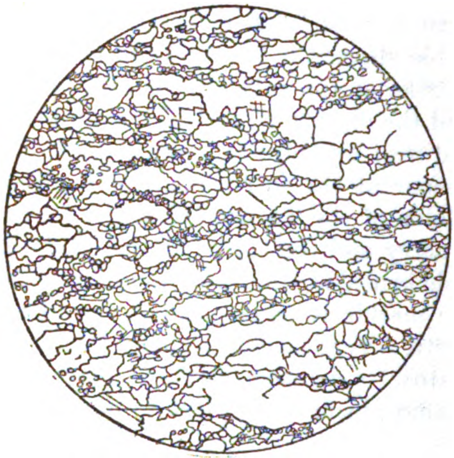


FIGURE 25.—Thin section of marble from Huntley quarry, Leicester Junction, showing elongate alternate grain texture. Enlarged 77 diameters.

The strike of the beds is N. 15° E. Beginning on the east there are within a width of 60 feet three synclines, two anticlines, and part of a third, with their axial planes inclined 45°–55° E. From the manner in which the rock breaks from the mass it is evidently still under compressive or tensional strain. It is also rather sonorous. Some of these folds are shown in Perkins's last report.[2]

SWIMMINGTON QUARRY.

About 0.7 mile southeast of the Huntley quarry is the Swimmington quarry of the Leicester Marble Lime Co., not visited by the writer but described by Perkins,[3] in which a dark-gray (graphitic) marble forms a completely compressed (isoclinal) fold with an almost horizontal axial plane. The fold is about 7½ feet in diameter and 100 feet long.

The structure at both of these quarries indicates that Leicester Junction marks the location of a north-south zone or axis of intense crustal compression similar to that which passes near the Owls Head, in Dorset. (See p. 93.)

SERPENTINE.

ROXBURY.

The serpentine quarry, opened before 1858, is about half a mile south of Roxbury station, and about 600 feet west of the railroad, in Washington County. It measures at the surface 100 feet north to south by 35 feet across, but at the bottom, 70 to 75 feet down, 120 feet north to south by 48 to 50 feet across. A new opening, 500 feet south of the old one, was begun in 1910. Operator, Barney Marble Co., Swanton, Vt.

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[1] Geology of Vermont, vol. 2, 1861, p. 768.
[2] Perkins, G. H., Rept. Vermont State Geologist for 1909–10, Pl. LXIX.
[3] Idem, pp. 349–351, Pls. LII, LXXI.

The serpentine, "Vermont verde antique" (specimens D, XXXI, 2, c, rough; f, polished), and its geologic relations have been described on page 49.

The serpentine is finished at Swanton and is used for columns, wainscoting, counter tops, base, and tiling. A photograph of a small polished piece is reproduced in Plate VIII, *A*, *a*.

Specimens: Wainscoting, post office, Danville, Ill.; the Delaware Hotel, Fort Worth, Tex.; New St. Charles Hotel, New Orleans. Columns and panels (10 feet 6 inches by 4 feet 2 inches), Hall of Justice, San Francisco. Counter tops and base, Union Station, Washington, D. C. Base, First National Bank, Chicago. Tiling, city hall, Indianapolis, Ind. The length of columns is limited to 15 feet.

CLASSIFICATION OF VERMONT MARBLES.

ECONOMIC CLASSIFICATION.

In the following table an attempt has been made to classify for economic purposes all the Vermont marbles described. The grade of texture and the petrographic name of each marble are also given, with page reference to the fuller description.

As the same marble is sometimes used for different purposes the subdivisions are not rigid. Some of the graphitic monumental marbles are used for electric switchboards.

The number of varieties of interior decorative marbles is so large that only the more distinct and important ones are given.

Economic classification of western Vermont marbles.

Constructional.

Trade name.	Quarry.	Location.	Color.	Texture.	Grade.	Grain form.	Grain arrangement.	Petrographic name.	Described on page—
Dorset A	Norcross-West Valley	South Dorset	Cream to very light, faintly greenish smoke.	Coarse	5	Irregular	Normal	Calcite marble	98
Dorset B	Norcross Plateau	do	Light cream, clouded with light gray to smoke tinted.	do	5	do	do	do	100
	Dorset Mountain Marble Co., upper northwest quarry.	Owls Head, Dorset.	White and also clouded white	do	5	Regular	do	do	102
Dorset Mountain	Blue Ledge	Green Peak	Faintly bluish white, mottled with very light gray.	do	5	Irregular	Uneven	Calcite marble with dolomite lenses of grade 1.	104
Manchester blue	Freedley quarries	Dorset Mountain (Dorset).	Very light bluish gray	do	5	do	do	Calcite marble	106
Mahogany	do	do	Milk-white	do	5	Very irregular.	do	do	106
Cloud	do	do	Light bluish gray, with medium-gray bands up to 0.2 inch wide.	do	5	Irregular	do	Calcite marble with little dolomite beds and lenses of grade 1.	106
White Stone Brook	White Stone Brook	do	Faintly cream, tinted white, with fine yellow-grayish streaks and spots.	do	5	Very irregular.	Normal	Calcite marble	108
Danby	Imperial	Dorset Mountain (Danby).	do	do	5	Irregular	do	do	109
Clarendon Valley gray.	Clarendon Valley	Clarendon	Very light bluish gray, with fine, closely and acutely plicated dark-gray streaks.	do	5	do	Uneven	Calcite marble with little graphitic dolomite beds of grade 1.	110
Clarendon A	Clarendon	do	Bluish white, with bands 0.1 to 0.2 inch wide or rows of spots of medium gray.	do	5	Regular	do	do	111
Clarendon dark	do	do	Light to dark bluish-gray bands up to 0.2 inch wide alternating with dark-gray to black bands.	Medium	4	do	do	Graphitic calcite marble in alternating little beds more or less graphitic.	112
Albertson extra dark.	Albertson	West Rutland	Medium bluish gray, with minutely plicated black streaks and some whitish ones, both crossed at various angles by slightly undulating black streaks (cleavage planes).	do	4	do	Normal	Graphitic calcite marble, the graphite abundant along little plicated beds and also along cleavage planes across them.	123
True Blue	True Blue	do	do	do	4	do	do	do	124
Riverside	Riverside	Proctor	Slightly bluish white, with dark-gray bands and spots.	Coarse	5	do	Uneven	Calcite marble, with little lenses and beds of graphitic dolomite of grade 1.	126

Florence No. 2	Florence No. 2	Pittsford	Light bluish gray, with whitish and dark-gray streaks and spots.	Medium.	4	do	do	Calcite marble, with little lenses of graphitic dolomite of grade 2.	129
Unnamed	Prospect west of Florence No. 2.	do	Milk-white	do	4	Irregular	Normal	Calcite marble	130
Pittsford Italian	Turner	do	Slightly bluish white, with finely plicated streaks of medium gray.	do	4	Regular	Uneven	Calcite marble, with finely plicated beds of graphitic dolomite up to 0.1 inch thick of grade 2.	130
Florence No. 1	Florence No. 1	do	Light bluish gray, with fine dark-gray streaks.	Slightly coarser than above.	4	do	do	Calcite marble, with little lenses of graphitic dolomite of grade 2.	131
Pittsford Valley	Hollister quarries	do	Light bluish gray, with little medium to dark-gray plicated streaks which on bed surface appear as irregular mottling.	Medium.	4	do	do	Calcite marble, with little beds of graphitic dolomite of grade 2.	133
Bed K	do	do	Light bluish gray without mottling.	do	4	do	Even	Calcite marble	133
Landon	Landon	do	Slightly bluish white, with medium to dark, intricately plicated beds up to 0.1 inch wide, appearing on bed surface as irregular mottling.	do	4	do	Uneven.	Calcite marble, with little beds of graphitic dolomite of grade 1; also with dolomite plates up to 1.75 millimeters thick.	135
Brandon Italian	Brandon Italian	Brandon	Light bluish gray, with small dark-gray beds which on bed surface produce an irregular mottling.	do	4	Irregular	do	Calcite marble, with little beds of graphitic dolomite.	136
Interior decoration.									
Dorset green bed	Norcross-West Valley.	South Dorset	Faintly greenish to pale cream color, with very dark to light greenish-gray streaks, acutely plicated at intervals.	Coarse	5	Regular	Normal.	Actinolitic calcite marble, with little beds of fibrous actinolite, quartz, etc.	99
Eastman blue	Eastman	West Rutland	Medium bluish gray in angular plications in cross section.	Fine	3	Elongate	Even	Graphitic calcite, marble, with more or less graphitic laminæ, some dolomitic.	114
Kiel's green	do	do	Cream to flesh colored alternating with bright greenish-gray bands, both up to 1 inch thick and in acute folds up to 5 inches long.	Coarse (cream). Medium (gray).	5 4	Irregular Elongate	Uneven.	Calcite marble, interbedded with muscovitic and chloritic calcite marble.	114
Green-veined cream statuary.	do	do	Delicate cream-colored bands up to 2 inches thick, alternating with slightly plicated bands of yellow to pale-greenish tint up to 0.1 inch thick.	Fine	3	Regular	Even	Calcite marble, slightly limonitic from oxidation of pyrite in very minute grains.	114

Economic classification of western Vermont marbles—Continued.

Interior decoration—Continued.

Trade name.	Quarry.	Location.	Color.	Texture.	Grade.	Grain form.	Grain arrangement.	Petrographic name.	Described on page—
Cream statuary	Eastman	West Rutland	Delicate cream color, with very pale brown beds up to 0.1 inch thick.	Fine	3	Regular	Even	Calcite marble, slightly limonitic.	115
Solid green	do	do	Bright greenish gray	Extra fine.	1	Irregular, elongate.	Parallel.	Muscovitic quartzose calcite marble.	115
Light cipolin	do	do	Light greenish, with broad plications.	Medium	4	(?)	(?)	Muscovitic calcite marble.	115
Dark cipolin	do	do	Bright light greenish, with broad plications and alternations in amount of color.	do	4	(?)	(?)	Muscovitic calcite marble, with chlorite, epidote, and green tourmaline.	115
Bed M	do	do	Milk-white, with straight parallel bands of delicate green.	Fine	3	Regular	Even	Muscovitic (sericitic) calcite marble.	115
Brocadillo	Vermont Marble Co., West Rutland, east side.	do	Faintly greenish white ground, with fine greenish-gray plicated beds and straight streaks up to 0.2 inch wide.	Medium	4	Irregular, elongate.	Parallel.	Muscovitic (sericitic) calcite marble with epidote and chlorite.	120
Livido	do	do	Medium to delicate light bluish gray, with plicated dark-gray beds up to 0.1 inch wide.	Fine	3	Irregular	Uneven.	Slightly graphitic calcite marble, with little dolomitic lenses of grade 1.	120
Olivo	do	do	Light greenish gray and pale greenish to white undulating bands up to one-half inch wide.	Medium	4	Regular, elongate.	Parallel.	Muscovitic calcite marble, more micaceous than brocadillo.	120
American pavonazzo.	do	do	Milk-white ground, with thin dark blue-greenish plicated beds of irregular width and distribution.	Fine	3	(?)	(?)	Chloritic muscovitic calcite marble.	121
Rubio	do	do	Very delicate pinkish ground, with thin plicated greenish beds.	Very fine probably.	2 probably.	(?)	(?)	Very slightly muscovitic calcite marble.	120
Ruvaro	Monkton Vermont Marble Co.	Monkton	Mottled pink and white	Extra fine.	1	Plates and rhombs.	Uneven.	Hematitic untwinned dolomite.	141
Royal red	Barney	Swanton	Dark reddish brown, with irregular slightly lighter clouds and some whitish streaks.	do	1	do	do	Hematitic untwinned dolomite with quartz grains and kaolin.	142
Lyonnaise	do	do	Merging forms of brownish red, with interspaces filled with white.	do	1	do	do	Hematitic untwinned dolomite with interspaces of white twinned dolomite and quartz.	143

Jasper	do	do	Bright reddish ground, with pinkish and white irregular lenticular objects up to 0.7 inch wide and 9 inches long.	do	1	do	do	Ground like that of royal red, with magnetite, corals of coarsely twinned and of granular dolomite, some with nucleus of quartz.	143
Oriental	do	do	Dark reddish-brown ground, with irregular areas of dark purplish gray and some white spots.	do	1	do	do	Ground like that of royal red; purplish parts of magnetite more or less oxidized; white parts of calcite and dolomite.	143
Olive	do	do	Light, faintly greenish gray ground, with lenses more or less parallel or brecciated of light pinkish gray, some with white nucleus.	do	1	do	do	Ground of untwinned dolomite with quartz grains and kaolin. The lenses contain twinned dolomite and have border of oxidized pyrite.	143
Vermont verde antique.	Roxbury	Roxbury	Dark purplish-greenish ground, black when polished, with network of intersecting white and light-greenish veins and black metallic particles.					Serpentine of fibrous and radial texture, with veins of magnesite and talc and large particles of magnetite.	49
Chrome mica schist.	Foley	Shrewsbury	Verdigris-green to faintly greenish gray, but when polished brilliant dark emerald-green.	Fine to medium.		Fibrous	Parallel schistose.	Chrome mica (fuchsite) schist, with chlorite, quartz, tourmaline, and magnetite.	50
Manchester breccia.	Dyer	Manchester	Bright brick-reddish cement inclosing fragments of cream-colored, bluish-gray, and deep-reddish marble.	Fine. Medium. Extra fine.	3 4 1	Elongated Regular do	Parallel. Normal. do	Calcite and dolomite marble breccia and hematitic calcitic cement.	97
Fisk black	Fisk	Isle la Motte	Extremely dark gray ("black") almost jet-black when polished, with here and there sections of large white marine gastropod shells.		4 1	Irregular	Uneven.	Carbonaceous, slightly dolomitic fossiliferous, calcite marble of unmetamorphic origin.	145

Monumental.

Blanc clair	**Eastman**	**West Rutland**	**Milk-white, in places faintly clouded.**	Fine	3	Regular	Normal.	Calcite marble	115
Brandon statuary	**Connell, Brandon Marble Co.**	**Brandon**	**Faintly ivory-tinted**	Very fine	2	do	do	do	138
Statuary Rutland	**Vermont Marble Co., West Rutland, east side.**	**West Rutland**	**Milk-white**	do	2	do	do	do	118
Second statuary Rutland.	do	do	**Milk-white, with faint grayish to yellowish clouds.**	Fine	3	Somewhat irregular.	do	do	119
Rutland Italian	do	do	**Faintly bluish white, with faint irregular grayish and yellow-brownish mottling.**	Medium	4	do	do	do	119

Economic classification of western Vermont marbles—Continued.

Monumental—Continued.

Trade name.	Quarry.	Location.	Color.	Texture.	Grade.	Grain form.	Grain arrangement.	Petrographic name.	Described on page—
Dark-blue Rutland.	Vermont Marble Co., West Rutland, east side.	West Rutland	Dark bluish gray, mottled with white and fine black streaks (Maclureas).	Fine	3	Irregular	Normal	Graphitic calcite marble	119
True Blue	True Blue	do	Medium gray, with more or less finely plicated black streaks crossed at various angles by slightly flexed ones.	Medium.	4	Regular	do	do	124
Florentine blue	Florentine	Pittsford	Dark bluish gray, with fine very dark and light gray straight bands.	Fine	3	do	do	do	132
Middlebury	Middlebury Marble Co.	Middlebury	White, translucent	do	3	do	do	Calcite marble	140
			Floor.						
Royal red	Barney	Swanton	Dark reddish brown, with irregular slightly lighter clouds and some whitish streaks.	Extra fine.	1	Plates and rhombs.	Uneven.	Hematitic untwinned dolomite, with quartz grains and kaolin.	142
Lyonnaise	do	do	Merging forms of brownish red, with interspaces filled with white.	do	1	do	do	Hematitic untwinned dolomite, with interspaces of white twinned dolomite and quartz.	143
Vermont verde antique.	Roxbury	Roxbury	Dark purplish-greenish ground, black when polished, with network of intersecting white and light-greenish veins and black metallic particles.					Serpentine of fibrous radial texture, with veins of magnesite and talc and large particles of magnetite.	49
Fisk black	Fisk	Isle la Motte	Extremely dark gray ("black"), almost jet-black when polished with here and there sections of large white marine gastropod shells.		1, with some 4.	Irregular	Uneven.	Carbonaceous, slightly dolomitic fossiliferous calcite marble of unmetamorphic origin.	47

SCIENTIFIC CLASSIFICATION.

The marbles of western Vermont fall naturally into the following 12 petrographic groups:

Scientific classification of western Vermont marbles.

1. Calcite marbles	Statuary Rutland. Light Rutland Italian. Middlebury.
2. Graphitic calcite marbles	True Blue. Florentine. Dark-blue Rutland.
3. Muscovitic calcite marbles	Brocadillo. Solid green (Eastman).
4. Chloritic and muscovitic calcite marbles	American pavonazzo. Dark cipolin.
5. Actinolitic calcite marbles	Dorset green bed.
6. Calcite marbles with minute dolomitic lenses and beds, usually graphitic.	Hollister. Pittsford Italian. Brandon Italian.
7. Brecciated calcite and dolomite marble, with hematitic cement	Manchester.
8. Carbonaceous slightly dolomitic unmetamorphic calcite marble	Fisk black.
9. Graphitic dolomite marble	Parker & Pinckney.
10. Hematitic untwinned dolomite marble with quartz grains	Swanton.
11. Serpentine	Vermont verde antique.
12. Chrome mica (fuchsite) schist	Foley quarry, Shrewsbury.

Some of the calcite marbles of groups 1, 5, and 6 are tinted cream color, probably by oxidized pyrite or bluish by graphite, both in grains of infinitesimal size. Group 3 contains a very little chlorite and in some marbles epidote.

RELATIVE VALUES OF VERMONT MARBLES.

To assist the reader in getting a correct idea of the relative qualities and abundance of these marbles, the prices current in 1910 of a few of them are given. These prices are all f. o. b. at the nearest railroad for blocks of ordinary sizes in the rough.

Prices per cubic foot of Vermont marbles, 1910.

Dorset A and Dorset green bed	$2.00
Dorset Mountain quarries, for exteriors	1.00
Pittsford Valley and Riverside	2.75
Common Rutland blue	2.00
Other "blue" marbles	2.75–4.00
Statuary Rutland	11.50
Other Rutland fine white marbles	4.00–8.50
Colored Rutland marbles (Vermont Marble Co.) for interiors	2.00–6.50
Eastman colored marbles for interiors	2.75–4.50

MARBLE MACHINERY.

No attempt has been made to list the machines in use at the quarries. The purpose of this publication will, however, be served by a brief reference to the most improved marble machinery and by designating the quarries and works where it has been introduced.

The channeler and gadder for vertical and horizontal cutting are in general use. The recent improvements consist in the substitution of electricity for steam in these operations and in the introduction of carborundum wheels in the finishing department.

The Vermont Marble Co. is using in its West Rutland tunnels channeling and drilling machines driven by air compressed by electricity at each machine. It also has an electric railroad 1,300 feet long at a depth of 240 feet connecting several of its West Rutland quarries.

The most improved marble mill is that erected by the Rutland-Florence Marble Co. at Fowler, which in May, 1911, passed into the hands of the Vermont Marble Co. This mill has a capacity for 60 gangs of marble saws, 43 of which are installed. A derrick car running on a central track the entire length of the building delivers the blocks to transverse tracks running under the gangs of saws on either side.

The Vermont Marble Co. uses a vertical diamond saw one-sixteenth of an inch thick and 7 feet in diameter and the Norcross-West Marble Co. one 5 feet in diameter. The diamonds are about 1 inch apart.

The Manchester Marble Co. and the Barney Marble Co. use a carborundum coper and molder.

The Norcross-West Marble Co. uses a coring machine for monolithic circular columns up to 7 feet long and 3 feet 6 inches in diameter. The same firm has lathes for columns 22 feet long and 4 feet in diameter and the Vermont Marble Co. one for columns 29 feet 9 inches long and 3 feet 4 inches in diameter. The most systematic storage yard is that of the Vermont Marble Co. at West Rutland, with its great traveling crane for the distribution of blocks.

ADAPTATIONS OF THE MARBLES OF WESTERN VERMONT.

The table on pages 150–154 shows the general adaptations of the marbles of western Vermont for construction, interior decoration, monuments, statuary, and flooring. The constructional marbles range from the coarse whitish ones of South Dorset and the milk-white and cream-tinted ones of Dorset Mountain to the mottled ones of Green Peak, Pittsford, Proctor, and Brandon and the medium bluish gray of the Albertson, Florentine, and True Blue quarries. These graphitic marbles are particularly well suited for rock-faced construction in the soot-laden atmosphere of cities, where white marbles become streaked in a very few years. They are also much in demand for electric switchboards, on account of their content of graphite and their lack of magnetite.

The range of marbles suitable for interior decoration is very wide, including the variously tinted West Rutland marbles, the "Champlain marbles," the serpentine of Roxbury, and the dark emerald-green chrome mica schist of Shrewsbury. The prevalent use of large panels of polished banded marbles has brought about in recent years a considerable demand for these West Rutland marbles and for the actinolite marble of South Dorset. The supply of the finer grades of monumental marbles, particularly of the "statuary Rutland," is at present somewhat scanty, but there is reason to hope that as the marble belts are explored more scientifically it will be found to be much more ample.

The at present unused fine-grained dolomite marbles of Pittsford, which from their fine quartz veining and thin bedding can hardly be expected to furnish many large slabs, are yet very well adapted for mosaic work and terrazzo.

The lists of architectural specimens given after the description of each of the typical marbles, supplemented by Plates VII, XI, XIII, and XIV, illustrate their more important adaptations.

GENERAL OBSERVATIONS AND PROGNOSTICATIONS.

Upon careful inspection of the geologic map and of the stratigraphic and marble succession, as tabulated on pages 66, 96, it will be noticed that between Shaftsbury on the south and Middlebury on the north marble is to be expected chiefly along two geologic boundaries—that with the underlying dolomite series and that with the overlying schist series. It will also be observed from the symbols on the map that the portions of these boundaries along which marble has been or is being quarried constitute but a very small part of the entire boundaries.

The boundary with the dolomite, between Shaftsbury and Middlebury, actually measures 91 miles, to which should be added a few miles between Clarendon and Rutland. The boundary with the schist, between Shaftsbury and the north end of the Taconic Range in Brandon in the main valleys—that is, exclusive of the areas in Sandgate and the West Rutland Valley and the small marble area east of Biddie Knob in Pittsford—measures 93 miles. The boundary with the schist on both sides of the West Rutland anticlinal valley and in the small area east of Biddie Knob measures 15½ miles. The total length of these boundaries is 199½ miles

From these figures should be deducted those portions of the boundary already fully prospected or being worked. These amount to 8 miles in Pittsford, Proctor, Brandon, and Middlebury, along the lower boundary; 7 miles in Clarendon, Pittsford, and Proctor along the upper boundary; and 2 miles along the upper boundary in the West Rutland Valley—a total of 17 miles.

As large portions of the boundary are covered with a thick overburden of sand, gravel, or clay, the removal of which would be very costly, and as in many other places the marble is defective from much jointing, due to dikes or from reeds or irregular fractures, a considerable deduction should be made from the marble boundaries on this account. In order to err on the safe side, this unprofitable part is estimated at 75 per cent.

After making these deductions, the estimates of the unworked parts are as follows: Parts of marble belt contiguous to basal dolomite, 20 miles; parts contiguous to schist, 21 miles; parts in West Rutland Valley and in area east of Biddie Knob, 3½ miles. The unworked profitable portions of the marble boundaries thus probably aggregate 44½ linear miles.

The folded character of the structure should always be kept in mind. If good marbles occur on the east side of the schist mass which forms the southern part of Dorset Mountain, the same marbles should be expected on the west side of that ridge in Dorset Hollow. Similarly, the marble beds exposed on the east side of the West Rutland Valley, dipping east under the synclinal schist ridge, should be expected under normal geologic relations to recur on the east side of that ridge, about three-fourths of a mile west of Center Rutland.

The actual depth of the glacial and postglacial deposits upon the eroded marble surface can not be prognosticated. It must be determined by boring. If the aid of a geologic map and sections, even with all their uncertainties, is to be discarded, 10 feet of gravel or clay may be sufficient to conceal the presence of marble beds of as fine a quality as any now being worked.

In view of the great variety and value of the marble exposed on both sides of the West Rutland anticline, it would seem that, on scientific principles, the portion of the marble boundary which should first be explored is that on the west side of the West Rutland anticlinal valley and next that on the east side of the synclinal ridge east of that valley, or, more exactly, from the intersection of the West Rutland and Rutland town lines with the highway, about three-fourths of a mile southwest of Center Rutland, north and northwestward for a distance of 2 miles, to a point about a mile south of the Riverside quarry.

Finally, inasmuch as some members of the marble succession are absent between the basal dolomite and the schist ridge west of Proctor—possibly as shown in section H, Plate III, owing to faulting—and as the structural conditions appear to be much more favorable in Pittsford, the half-mile strip west of Fowler, between the railroad branches and the schist ridge on the west, ought to be carefully explored for these missing beds, and in like manner the territory between the Hollister quarry and the schist ridge.

SCIENTIFIC PROSPECTING FOR MARBLE.

While the practical judgment of a competent marble quarryman or marble cutter will always be required to determine whether a particular bed of a certain quality of marble is conveniently situated for quarrying and is also free from reeds or other blemishes, the scientific basis for marble prospecting in this region is afforded by the geologic maps (Pls. I and IV), the section (Pls. II and III), and the table of the marble series as given on page 96. With these and a careful reading of the paragraphs in the section entitled "Geologic principles governing the marble belt," pages 77–85, correct methods of prospecting will readily suggest themselves. The following hints may be helpful to some readers:

On the map the marble-schist boundary shows where the upper part of the marble series is to be expected and the dolomite-marble boundary where its lower part will probably be found. The first step is to determine the approximate position in the marble succession of the locality or beds to be prospected. This can be done by estimating their vertical distance from one of the determined stratigraphic levels, either the schist or the dolomite boundary, or from the intermediate dolomite, if its course has been traced. That vertical distance, of course, is the distance at right angles to the beds, but the prospector should make sure that these are not duplicated by folding. The same result may be obtained in some places by measuring the distance of the locality or bed from the line of strike of any quarried bed of known position. If the schist is near at hand, the beds to be expected in its vicinity are those of the upper graphitic marbles, except on Dorset Mountain. Where the upper graphitic marbles occur, if the white and muscovitic marbles are desired, they should be sought below the graphitic marbles. If the area lies between the basal dolomite and the intermediate dolomite, the lower clouded marble is, of course, to be expected in that position.

After the beds have been exposed by the usual cross trenching, their character should be carefully studied to determine the nature of the folding. If repetitions occur, then the arch or trough form of the fold and the degree of its pitch should be ascertained. In general, the part of a fold upon which a quarry is situated or is to be opened should be known and its remaining parts theoretically located, so that when quarrying operations are extended this may be done on rational principles.

If a quarry or proposed quarry lies immediately west of the intermediate or basal dolomite, the depth at which the dolomite underlies the marble at the turn of the trough should be determined by drilling.

Wherever the beds between two highly inclined parallel beds of dolomite show a tendency to form horizontal zigzags, the probability is that the beds on either side are continuous either below or above—that is, they constitute a compressed fold, anticline or syncline. Core drilling should then be done to determine whether the fold is a syncline and to ascertain its depth. In all core drilling the cores should be carefully inspected with a view to determining any duplication of beds—that is, evidence of folding—as it may have an important bearing on the operations of the quarry.

A wide margin should be given to dikes and reedy passages, and in opening quarries places with protective clay or till should be preferred.

TESTING OF MARBLE.

The more important tests of marble for economic uses are described below.

Chemical analysis.—This should have special reference to the content of iron sulphide or oxide.

Microscopic analysis.—For this purpose a number of thin sections should be made from cubes sawed, not hammered, from blocks taken at different heights in the same bed and horizontally far apart, and some sections should be cut transverse to the bed, others parallel to it.

The microscopic analysis should determine the grain form, the grain regularity, the average grain diameter by the Rosiwal method, the associated minerals and their relative abundance, and the presence of minute beds or lenses of dolomite and of divisional planes of bedding or cleavage.

Absorption.—Hirschwald[1] found that after Carrara marble was exposed on all the 23 rainy days of November and December, 1900, its maximum water absorption was 0.45 per cent and that the same marble when tested experimentally in the laboratory showed after one hour's immersion 0.49 per cent of absorption. He also found[2] that the water absorption of a coarse Tyrolese marble under slow immersion amounted to 0.74 per cent of the stone, in vacuum 0.82 per cent, and under pressure of 50 to 150 atmospheres 0.92 per cent, and that the water absorption of this stone thus tested amounted to 81.37 per cent of its total pore space, or in vacuum 90.01 per cent.

Porosity.—One of the simplest methods of determining porosity is to expose sawed blocks 2 by 1 by 1 inch for a few hours to a tempera-

[1] Hirschwald, J., Die Prüfung der natürlichen Bausteine auf ihre Wetterbeständigkeit, Berlin, 1908, p. 212.

[2] Idem, p. 156.

ture of about 104° F. and then to immerse them for 48 hours in a concentrated 4 per cent alcoholic solution of nigrosine, a deep-blue dye soluble in alcohol.[1] After drying for half an hour the blocks are to be broken squarely across with hammer and chisel. The degree of porosity will be indicated by the extent to which the dye has penetrated the blocks.

The importance of determining the porosity of marble and the disregard of it by some architects and builders is shown by the frequent combination of metals and marble on exposed faces. The metal inevitably oxidizes and the marble absorbs the oxide and becomes discolored. In the Forefathers' Monument at Plymouth one of the delicate bas-reliefs of white marble in the buttress of the base is stained bright vermilion. The stain appears to have been derived from red lead used in fastening the marble to the granite and to have been absorbed by the marble at the back of the slab and thus found its way to the carving on the front.

Compressive strength.—This should be tested on 6-inch sawed cubes with hydraulic compressor, as in the Watertown Arsenal tests. One set of blocks should be tested on the bed and another on edge.

Transverse strength.—This should be tested on sawed blocks between supports and both on bed and on edge.

Tensional strength or cohesion.—This should be tested by a method described by Hirschwald.[2] A sawed block of certain shape with lateral grooves in the center is fastened at each end into a steel frame provided with a hook. The tensional weight is applied to one of the hooks and the block is suspended by the other.

Magnetism.—A marble for use in electric switchboards should contain little or no magnetite. There is probably a slight difference in the amount of this mineral in different marbles, although the quantity in any one is exceedingly small. Its effect on an electric current should therefore be tested.

Translucence.—Marbles differ considerably in translucence, which can be tested by sawing very thin pieces of measured thickness and superposing them in order to determine the thickness traversed by light.

Polish.—A polished surface should be examined with a magnifier and the pits or protuberances noted.

Durability of color.—This can be determined by exposing a sand-rubbed and a polished surface to the south for three years and then comparing the surfaces with those of unexposed pieces prepared from the same block at the same time.

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[1] Made by Jäger at Barmen, Germany, and recommended by Hirschwald (op. cit., p. 163).
[2] Op. cit., pp. 171, 172.

Sonorousness.—This is an index of cohesion. It can be tested by hammering sawed slabs 2 inches thick, 4 to 6 inches wide, and 1 to 2 feet long.

Statuary test.—Renwick [1] makes this recommendation:

Marble for statuary purposes should never be selected in bright weather. Veinings and discolorations are more difficult of discovery at this time than at any other. A dull day with a good light is the best time for inspections; if after a shower of rain, so much the better. Provided no rain has fallen, the blocks should be soused with water; veins and stains can then be more readily perceived. If possible, have each block slung and struck with a hammer. If the sound of the blow is dull and heavy, look out for cracks. Should a hard, metallic tone be emitted the marble will be heavy in working; but if a soft, clear ring is heard, the material is sound and will both work and wear well.

GLOSSARY OF TECHNICAL TERMS.

Actinolite. A greenish mineral of the hornblende group, a silicate of lime, iron, and magnesia $(MgFe)_3CaSi_4O_{12}$.

Amygdule. A small globular cavity in an eruptive rock caused by steam or vapor at the time of its eruption, and generally lined afterwards with secondary minerals.

Anticline. The arch part of a wavelike bed of rock.

Bed. A continuous mass of material (sediment) deposited under water at about one time.

Biotite. A brownish to black mica containing a considerable percentage of iron and magnesia.

Brachiopod. A small marine animal, generally with a bivalve shell and provided with two ribbon-like respiratory organs near the mouth, which also serve to draw currents of water to the mouth.

Breccia. Rock made up of angular fragments produced by crushing due to a crustal movement and then recemented by infiltrating mineral solutions.

Calcite. The mineral consisting of lime carbonate ($CaCO_3$) which constitutes most of the commercial white marbles. (See p. 24.)

Cambrian. The lowest division of Paleozoic time. Marked by abundant marine invertebrate life. Preceded the Ordovician.

Cephalopoda. The most highly organized of the mollusks, represented by the modern nautilus, squid, and cuttlefish, but in early geologic periods by many species with coiled or straight shells having compartments for air or gas.

Chlorite. A soft bluish-green foliaceous mineral, a hydrous silicate of alumina, iron, and magnesia.

Cleavage. When applied to a mineral designates a structure consequent upon the geometric arrangement of its molecules at the time of its formation.

Conformity. When one bed overlies another in parallelism, without any disturbance of the crust having affected the lower one before the deposition of the second, they are said to be in conformity.

Crinoids. Marine animals related to starfishes and sea urchins but mostly with plantlike calcareous skeletons rooted and provided with an articulated stem bearing a cup containing the alimentary organs.

Cryptocrystalline. Applied to a rock whose crystalline texture is obscure.

Crystalline. When the molecules of a mineral are arranged in geometric order the mineral is said to be crystalline.

Dike. Natural molten material erupted through a narrow fissure in rock.

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[1] Renwick, W. G., Marble and marble working, London, 1909, p. 61.

Dip. The degree and the direction of the inclination of a bed, cleavage plane, joint, etc.

Drift. Sand and bowlders deposited by a glacier, continental or local.

Dolomite. A lime and magnesia carbonate. (See p. 27.)

Dolomitization. The process by which a limestone (lime carbonate) may be changed to a dolomite. (See p. 33.)

Epidote. A grass-greenish mineral, a silicate of alumina, iron, and lime—$Ca_2(AlOH)(AlFe)_2(SiO_4)_3$.

Erosion. The wear of a rock surface by natural, mechanical, or chemical agencies.

Fault. A fracture resulting in the dislocation of the bedding or cleavage of a rock or vein, one part sliding up or down or both changing positions along the fracture.

Formation. A group of beds possessing some common general characteristic or fossil forms differing from those of the beds above and below.

Galenite. A mineral composed of lead sulphide (PbS), the common ore of lead.

Gastropods. A group of mollusks including land, fresh-water, and marine snails

Gneiss. When the minerals of a granite or granite-like rock under powerful compression assume a certain parallelism it becomes a gneiss.

Hematite. An oxide of iron (Fe_2O_3) which when scratched or powdered gives a cherry-red color or "streak."

Kaolin. A hydrous silicate of alumina derived from the alteration of feldspar.

Limonite. A hydrous oxide of iron ($2Fe_2O_3.3H_2O$); a hydrated hematite, which, when scratched or powdered, gives a brownish rust color.

Maclurea. An extinct marine gastropod in which the whorls of the shell lie in one plane. Some of the Maclureas of the Lake Champlain region attain several inches in diameter.

Magnetite. A black metallic mineral (FeO and Fe_2O_3) known by its strong magnetism and its black streak. One of the principal ores of iron.

Matrix. The general mass of a rock which has isolated crystals or mineral particles, sometimes called the groundmass.

Metamorphism. The process, partly physical, partly chemical, by which a rock is altered in the molecular structure of its constituent minerals and frequently in the arrangement of its particles. If the cause of the process is a general crustal movement the metamorphism is said to be regional or dynamic, but if its cause is mainly the contact with a molten intrusive rock, it is called contact metamorphism.

Millimeter. French decimal linear measure, the thousandth part of a meter or the tenth part of a centimeter. It is equivalent to 0.03937 inch, the meter being 39.37 inches.

Monolith. A column or monument of one stone.

Muscovite. Potash mica, the most common of the micas, generally of whitish to greenish color. Mainly a silicate of alumina and potash.

Oolitic. Term applied to limestone and other rocks when they consist largely of minute spherules and resemble the roe of fishes.

Ordovician. One of the great divisions of Paleozoic time, formerly called "Lower Silurian."

Pelitomorphic. Literally, having clay or mud form. Applied to a rock of clay-like texture.

Pitch. The inclination of the axis of a fold of rock.

Plagioclase. A term applied to all those feldspars that are not potash feldspars.

Polarized light. Light whose vibrations, unlike those of ordinary light, which extend in all directions, are in only one plane. Polarized light is used to distinguish minerals, particularly colorless, transparent ones, under the microscope. Minerals, like calcite or dolomite, that polarize light are of crystalline texture, but these do not polarize light in the direction of their vertical crystal axis.

Porphyritic. A term applied to rock texture to designate the presence of isolated crystals in a general mass (matrix or groundmass) of finer material.

Pteropod. An order of gastropod mollusks living at or near the surface of the ocean and provided with a pair of fleshy appendages on either side of the mouth which serve as fins. Many of them have more or less conical shells which form extensive deposits on the ocean floor. Shells closely resembling those of pteropods abound in rocks of Cambrian age. (See p. 66.)

Pyrite. Iron disulphide (FeS_2), the common light brasslike metallic mineral, generally injurious to building stones.

Quartzite. A metamorphosed quartz sandstone in which the cement which unites the quartz grains is also quartz.

Rhizopods. Animals of very low order and organization, consisting mainly of transparent protoplasm. Some of them have a calcareous case. They abound in the ocean, and their remains form extensive oozes on the ocean floor.

Rhombohedron. A crystal form bounded by six faces of rhombic outline.

Schist. A crystalline rock made up of flattish particles arranged in rough parallelism, some or all of which have crystallized under pressure.

Sedimentation. The deposition of particles, usually under water. A sedimentary rock is one consisting of particles thus deposited.

Sericite. A ribbon-like or fibrous form of muscovite or potash mica.

Serpentine. A hydrous silicate of magnesia and iron. (See p. 49.)

Slickensides. The polished and grooved faces of a joint or bed caused by the motion and friction of adjacent rock masses.

Slip cleavage. A cleavage arising from slippage along fractured microscopic folds.

Specific gravity. The weight of a rock or mineral compared to that of a body of distilled water of the same bulk.

Strike. The direction at right angles to the inclination of a plane of bedding, joint, etc.

Syncline. The trough part of a wavelike sheet or bed of rock.

Trilobite. A crustacean with affinities to the horseshoe crab of the eastern coast and generally marked by the division of the back into three lobes lengthwise and crosswise. Trilobites were very abundant in early geologic time.

Twinning plane. In calcite and dolomite this is the plane which separates two adjacent crystals which have formed with the poles of their main axes in different directions.

Unconformity. When the lower one of two contiguous deposits affords evidence of having been exposed to atmospheric erosion before the deposition of the upper one, there is said to be an unconformity between them.

Vein. When correctly used, denotes a more or less irregular, sometimes ramifying mineral mass within a rock. It should never be confounded with a bed.

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