Prospecting for Gold and Silver in North America

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PROSPECTING

FOR

GOLD AND SILVER

IN NORTH AMERICA

BY

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"GEOLOGY OF COLORADO AND WESTERN ORE DEPOSITS"
"GEOLOGY OF COLORADO COAL DEPOSITS"
"PLACER MINING," ETC.

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PREFACE TO FIRST EDITION

In preparing this little work the author has felt the difficulty which arises in a theoretical dissertation on so eminently practical a subject as prospecting. It seems like giving rules and prescriptions for hunting or fishing or any other natural or practical pursuit. Though theory and practice are not at variance when happily combined, yet either without the other proves very unsatisfactory. Thus, the reader of this book, should he start out armed only with its theory, will find himself for some time pretty much "at sea" when he comes to actual practice in the field. As, however, he gradually obtains some practical experience, he may find this little work of use to him. So, also, the seasoned prospector, who has hitherto trusted to luck, keenness of observation, intuition, and experience, may find himself in the future much better equipped by acquiring a little of the theory.

While we have endeavored to give the prospector all assistance in our power, as to the best means of educating himself, describing his outfit, etc., we have devoted special attention to the description of such geological and other phenomena as he is likely to meet with in connection with his work, so that he may have an intelligent idea of them when he encounters them.

We have selected just as much material as we think would be most interesting and useful to him, saving him the time and trouble of wading through heavy tomes and laboriously picking out, from a vast amount of, for his purpose, superfluous matter, that which he will most require.

The work is intended to be a popular one, addressed to the average student, prospector, and miner, and to the general public.

JANUARY 1, 1895. ARTHUR LAKES.

PREFACE TO SECOND EDITION

The kind reception given to "Prospecting for Gold and Silver" by the mining and prospecting fraternity, as well as the general public, has made necessary a second edition. In this we have added to the text sketches of some of the principal prospecting regions of North America, which, besides illustrating the principles presented in the work, will, with their maps and illustrations, prove useful guides to prospectors who may venture into those districts. Having extended the scope of the work, we have accordingly given it a more general title, namely: "Prospecting for Gold and Silver in North America."

Respectfully,

ARTHUR LAKES.

BOSTON BUILDING, DENVER, COLO.,
OCTOBER 1, 1896.

PREFACE TO THIRD EDITION

The hearty and cordial reception that was given to "Prospecting for Gold and Silver in North America," has already exhausted two large editions and has rendered necessary a third. In this new edition the general plan and scope of the book are unchanged, but the text has been revised throughout and brought entirely up to date. The illustrations used are almost entirely new, while the size of the book has been increased and its typography greatly improved. An appendix has been added upon "Testing Gold Ores for Treatment by Concentration and Amalgamation," by H. Van F. Furman, which gives concisely a number of simple laboratory tests for determining upon the proper method for extracting the value from an ore. By these simple tests it is possible, through the use of simple and inexpensive appliances, to find out the probable mill value of an ore without submitting it to an expensive mill run.

JUNE 1, 1899. ARTHUR LAKES.

CONTENTS

PROSPECTING FOR GOLD AND SILVER

IN NORTH AMERICA

CHAPTER I

ON PROSPECTING—PREPARATION AND OUTFIT FOR WORK

THE regular prospector, as a rule, has at some time of his checkered career had some actual experience in the mines themselves, from which he has learned by observation the appearance of different ores, their different values, how the veins appear on the surface, how to open a vein, and the uses of pick, shovel, and blasting powder. In a word, he is a miner who has become too restless to stick to steady work, and so follows the more uncertain and precarious livelihood of seeking for new and undiscovered veins, many of which, even in an old mining district, may yet be discovered, covered up by brush or débris, while a new district offers a most enticing field. These mineral veins or ledges may make him in a moment a comparatively rich man, and if he finds them, they will cost him nothing, only a simple compliance with the inexpensive regulations of the law. So the life of a prospector offers many attractions to one who is restless and loves to roam, and loves to find something new, and is not afraid of considerable hardship. To save a vast amount of time and labor, he should acquire knowledge. Thus, for instance, if he were prospecting for coal he would be wasting his time in hunting for it in granite, or if he was hunting for the precious metals, he would lose time in looking for them among the unaltered sedimentary strata of the prairie. This is merely for example, but an infinite variety of knowledge is necessary for him in his vocation, besides even that of the simpler elements of geology, such as the knowledge of different kinds of minerals, and their value, the kind of places and peculiar rocks they are associated with their appearance on the surface, etc., together with some knowledge of assaying, or blowpiping, or panning.

In a newly discovered camp men will rush in for a few weeks, work a little in the different mines, sufficient to give them an idea of the kind of ores and rocks and other circumstances in the locality, and then will strike out on their own account and prospect around the camp for new veins or extensions of those already discovered. An extension, by the way, of a very rich discovered lode is not always to be relied on. Nature seems often to concentrate her riches at one point, and leave the extension barren, as in the case of the Comstock, of Nevada, where but little wealth has been found outside of the great lode and mine itself.

The best education is in the mines themselves; so a novice on arriving at a mining region had better spend as much time as possible in practical work in and around the various mines before he launches out prospecting. A prospector can rarely carry about much assaying or other apparatus with him for determining the character or value of ores he may find; hence, it is well for him to accustom himself to these ores in the mines themselves. Also he should acquaint himself with the peculiar ores of each particular district, before he attempts to prospect in its vicinity, for an ore such as coarse-grained galena in one district may be generally rich, while in another it is remarkably poor in silver.

The best previous education for a prospector would be a course at a school of mines, where he will learn the elements of geology, mineralogy, assaying, etc., and next to that, practical work in the mines themselves, and lastly the prospecting field. A little knowledge of blowpiping may also help him, which he may acquire at his school.

Having left his school, he should learn the practical use of the pick, drill, and blasting powder. By working around a concentrator he will learn the difference between ore and gangue rock; and "picking" or "sorting" ores will teach him at sight the values of ores. The prospector should know how to open his vein or ledge, when he finds it, with pick, shovel, and blasting apparatus. A little carpentry will teach him how to make a hand winch, and a few lessons in blacksmithing will teach him how to sharpen and temper his tools, for there will probably be no carpenter or blacksmith shop within miles of where he may go. Other prospectors will teach him how to use his pan or iron spoon for testing ores, and various other dodges and makeshifts. An important point is to learn how to average approximately the quantity of ore in and the value of a ledge when he has found one. Valuable ore on a ledge lies in pockets, strings, bunches, irregularly distributed through the quartz or other material of the vein; he should learn to tell at sight the relative proportion of ore and gangue. He would do well to study the result of working ores in a mill or furnace, such as trying to estimate the yield of bullion from the ores which are mined, taking them in weekly or monthly lots. With some such preliminary knowledge, he is ready for the field.

HIS OUTFIT

The following list of necessaries, by Mr. A. Balch, in his "Treatise on Mining," is as full as can be given by any one, and is more than the average prospector generally needs. As a rule, we would say take as little as you possibly can, and do not overburden yourself with impedimenta.

A PROSPECTOR AND HIS OUTFIT.

"*First.* Two pairs of heavy blankets, weighing about 8 pounds each.

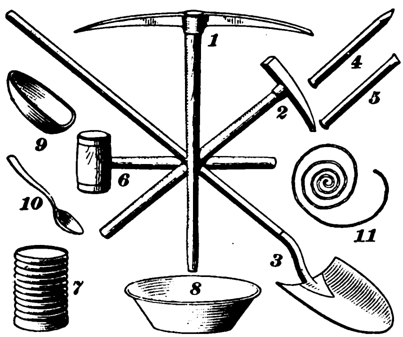
"*Second.* A buffalo robe or blanket-lined poncho.

"*Third.* Suit of strong gray woolen clothes, pair of brown jean trousers, a change of woolen underclothing, woolen socks, pair of heavy boots, soft felt hat, three or four large colored handkerchiefs, a pair of buckskin gauntlets, toilet articles, etc. All should go into a strong canvas bag.

"*Fourth.* A breach-loading rifle or shotgun and a revolver. Around his waist a strong sash to carry his holster and knife, in a sheath. His ammunition, if his revolver is a large bore, may conveniently fit both his rifle and revolver. Pipe and tobacco.

"*Fifth.* A sure-footed native or mountain pony. A Mexican saddle with its saddle horn, straps, etc., to tie on various things, such as his pack, bags, water canteen, etc. The left stirrup may be fitted with a leather tube, in which the rifle barrel may be placed. A strap around the saddle horn will secure the gun stock. The long lariat or stake rope for tethering his horse should be coiled up and tied by a strap to the saddle horn.

"*Sixth.* For prospecting, a 'poll' pick, an iron prospecting pan, and a horn spoon should be carried. The pan besides being useful for washing out sand serves also as a dish or bathing vessel. A large iron spoon for melting certain metals is likewise to be carried, and in some cases a small portable Battersea assaying furnace.



A PROSPECTOR'S TOOLS.

1, 2. Picks.
3. Long-handled Shovel.
4, 5. Drills.
6. Heavy Hammer.
7. Blasting Powder.
8. Pan.
9. Horn Spoon.
10. Iron Spoon.
11. Fuse.

"*Seventh.* A frying pan 8 inches diameter, of wrought iron, a coffee pot, tin cup, spoon and fork, and matches in tin box, pocket compass, a spy glass, or pair of field glasses.

"*Eighth. Provisions:* bacon, flour, beans, coffee or tea, pepper, salt, and box of yeast powder, all packed in strong bags, to go into a canvas sack. A few lessons in the kitchen on cooking will be advantageous before starting.

"*Ninth.* Packing the broncho: Place a folded blanket on the horse's back; on this lay the saddle. The saddle bags contain small things. The bags with provisions are placed behind the cantle of the saddle; on top of this the bag of clothing. The pick goes on top, tied by a thong. Coffee pot and frying pan are lashed on the bags."

Sometimes a prospector takes a horse to ride on and another as a pack animal, or a donkey only. For grass and water for his horse he must trust to the country, and he will fix his temporary camp in some suitable location, where these are to be found, and thence, as from headquarters, prospect daily the adjacent country, returning nightly, it may be, to his camp.

BRIEF SKETCH OF PROSPECTING

We may divide the prospecting for the precious metals into two general classes: (1) hunting for gold in gold placers;

PANNING GOLD AT CRIPPLE CREEK, COLORADO.

(2) hunting for gold- and silver-bearing ledges or veins or deposits.

"Placers" are places where gold, having been torn from the ledges and rocks by denudation, by water and ice, is swept down by these agencies till it finally finds a resting place. Gold, being heavier than quartz or country rock, sinks to the bottom first. If the stream is violent, it will carry the gold on, if fine, till it comes to an eddy or pool, where the waters are more quiet, and there it will sink. The water carries the clay and lighter stones still farther on. In this way millions of tons of rocks containing more or less gold disseminated through them may have been reduced and the gold set free, or the gold may have been derived from a few individual gold-bearing ledges or veins.

The prospector takes his pick, shovel, and pan, and his horn spoon, and finds perhaps an old dry river bed, where the water has ages ago receded. At some point the sides of this old river course widen out suddenly, forming a basin. "Here," says the prospector, "there must have been an eddy," and he prospects it accordingly; at another point he finds a place where the water must have run over a rock and made a waterfall; at the bottom he digs again.

He loosens the soil with his pick, and shovels it out; at a certain depth, which may be from 5 to 20 feet or more, he strikes "bed rock," which may be granite, shale, sandstone, or some other rock. Here he looks for nuggets, and with his knife digs into all the little crevices of the rock, to hunt for them and for scales and wires of gold.

Also while sinking his shaft, he pans the gravel carefully at various depths, especially where there are streaks of clay or "black sand." The latter are grains or little pebbles of magnetic-iron ore, a common accompaniment of gold, altered relics of the iron pyrites in which the gold was originally contained.

He fills his pan half full of water, throws into it a shovelful of dirt, first picking out the pebbles, stirs the mass with his fingers till the water is fully charged with the clay, and gradually winnows out all the clay. Filling the pan again with water, he gives it a peculiar circular motion, and each little wave of sand passes off till the whole is winnowed away, and at last he sees specks of gold shining free in the bottom of the pan. Then it is not difficult to estimate approximately the amount of gold to the bushel or cubic foot of earth of the placer, and thus to estimate the approximate value of the placer. He then locates or stakes out his placer claim, which, according to the regulations of the United States Government, cannot exceed twenty acres for a single individual.

The second class of prospectors are those who try to discover ore deposits, ledges, or veins "in place," that is, in the hard rocks of the hills.

The prospector's first effort is to find "float." A vein outcropping on the surface becomes oxidized and crumbles by action of the atmosphere, rain, etc.; pieces break off and fall down hill. Some of this float is barren quartz or country rock, and some may be mineralized. Commonly, float is a rusty, spongy mass of rock, showing, besides iron, often some copper stains, and in it there may be grains of galena, pyrite, or some other

FINDING THE FLOAT.

ore. He tries to trace this float to its home in the ledge whence it came. Of one thing he is certain, the float must have rolled *down* and not *up* hill. If the float is fairly scattered over the lower zone of the hill, and no float is found above that zone, on the top of that zone he will hunt for his ledge. If the float is all over the hill, he assumes the ledge is on the top.

If he finds his float at the mouth of a cañon or watercourse, he walks up that watercourse, noticing not only the float, and its diminishing or increasing, but also any peculiar rocky pebbles, such as a peculiar porphyry, perhaps, which he may by chance recognize again further up, in place, and give him a hint as to whence the stream derived most of its material of pebbles. He notices whether the float fragments increase as he proceeds, and if they suddenly cease at a certain point, at that point he hunts for the ledge on either side of the cañon, and breaks off any pieces that may look likely.

Having found the ledge and traced its croppings, he tries to find out its approximate value. This he does by breaking off at intervals along it likely looking fragments of the rock, grinding them up to about the size of peas. He mixes these well, takes half of them, and reducing this half to fine powder, which is again halved, till of the whole ledge he can carry away an average sample of a few ounces. He may wash this in his pan to see if there is any free gold in it; other ores he will recognize at sight. These samples he will have assayed and the returns will show the approximate value. He measures the length and thickness of the vein, and examines the wall enclosing it.

He then proceeds to locate or stake it out by measuring off a parallelogram 1,500 by 600 feet. At the corners of this he places piles of stones, and in one or more of them places a stake of wood on which he writes his name, a description of his claim, and the date. At the nearest recorder's office he files a copy of this document. He must do a certain amount of improvement work on this annually, such as digging a ten-foot hole or putting up a cabin or some work equivalent to the value of $100, so as to hold it. He may also claim a mill site on non-mineral land adjacent, not exceeding five acres. Now the property is his, to do as he likes with it.

THE GEOLOGICAL TRAINING OF A PROSPECTOR

One of the first things for a prospector for gold and silver to acquaint himself with is the elements of geology. He can read this up theoretically in many excellent treatises and manuals, such as LeConte, Dana, and Shaler's Manuals, and Geikie's Handbook of Field Geology, etc., and become learned in the names of eras and epochs, and the jargon of scientific names of fossils and minerals, and varieties of rocks; but let him not imagine at the end of this process that he "*knows* geology."

Geology can no more be learned by means of a book, without field work and actual personal contact with nature and rocks, than chemistry or assaying can be acquired without ever using a test tube or a cupel. The student may, perhaps, be unfavorably situated for this practical field work. There may be no mountains or upheavals of strata, or deep natural ravines, within available distance, to study. He is located, perhaps, on the great, monotonous, flat prairie. Very well, then, let him study what lies nearest him. This same flat, monotonous prairie has an interesting and wonderful history. Let him read up what he can find about this in his books, then go out and examine what he can of the few feet of horizontal strata exposed in some shallow watercourse or dry ravine; examine minutely, both with eyes and microscope, the minerals composing these strata. Let him classify and collect and note the different kinds of pebbles scattered over the surface, or in the bed of a brook. Let him speculate as to the cause of the undulations of the surface, the deposition and peculiar character of the clays forming the soil. Let him study thoroughly the geology of his native village, his immediate surroundings, *first.* The knowledge and practical habit of observation so acquired will lead later to more extensive studies in wider fields. A student may be shut up in a big city; let him study the paving stones of the streets and visit the stone yards of the masons. It will pay him better to take a trip to some distant mountain region than to buy another expensive book on geology after he has mastered the first bare elements. There is nothing like field work, eye practice, and hammer practice. The student should endeavor, whenever he possibly can, to verify by actual vision and personal experience whatever he reads in his books. When traveling, let him always carry a geological hammer with him, and at any station the train may stop for a few moments step out and try to get a specimen of the country rock; at the same time let him study all he can of the geology of the country he is passing through, from the windows of the train, aided perhaps by a geological map. The genuine prospector is always looking about him, is everlastingly cracking stones, has always his eye wide open for "something kind o' curious."

If he is near some mountain region, where, as in Colorado, the whole strata of the earth's crust is upheaved and exposed, along the mountain flanks, in the depths of the cañons or on the summits of the peaks, after studying his manual, let the student get, if he can, some published geological report on such a country, such as those of the United States Geological Survey, abounding in illustrations and geological sections. Let him take this book in hand and go to the very place described and pictured as a geological section, and with his hammer study each member of the section closely. This will make him familiar with the different geological periods, formations, rocks, minerals, and fossils, *as they actually appear in nature* rather than as his *imagination has supposed* them to be from his study of the textbooks: book geology and field geology are not always in perfect harmony.

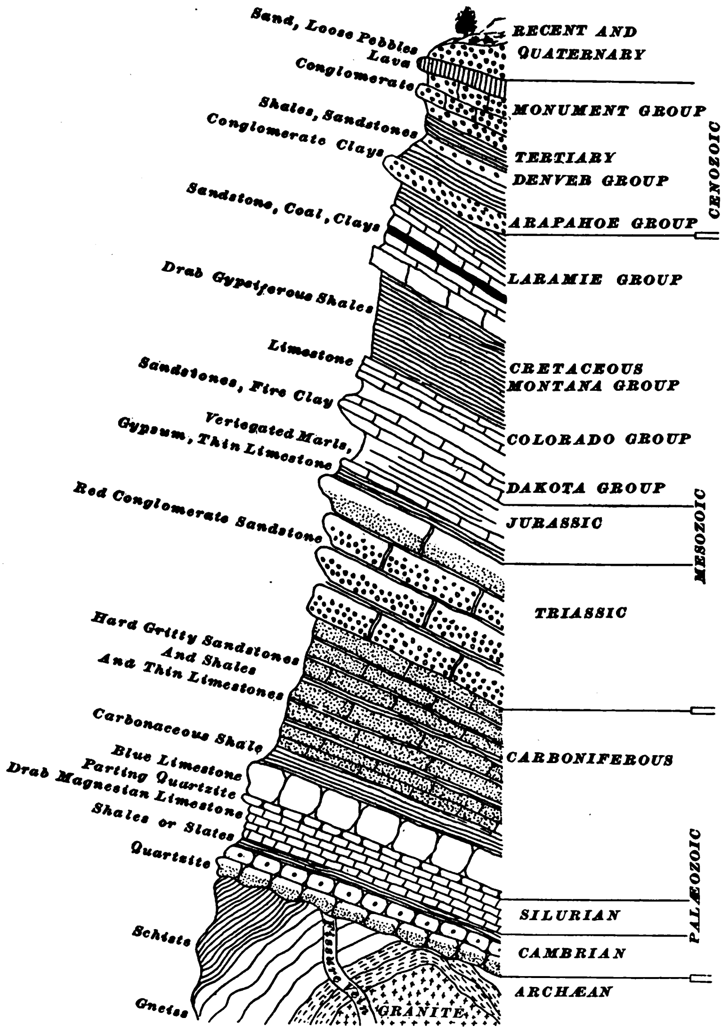
Having studied and learned one local section well, such as that cut by a stream along the foothills of a mountain range, let him repeat the course at the other and more distant points. He will find at each locality, though the main features are the same, that there is always an interesting variety, such as new fossils, peculiar minerals, changes of dip, faults, or other structural peculiarities.

Along the flanks of a mountain range, a prospective prospector cannot study too many of these geological sections. Having become familiar with these foothill sections, he is prepared to plunge into the heart of the range itself. At first, and for long distances perhaps, he will encounter only granitic rocks forming the axis and core of the range. These are well worthy of study and full of variety. Later the cañon may open into some mountain valley or park, where the strata he studied on the foothills or prairie border are again repeated and he finds himself again at home. Seizing upon some well-defined and familiar representative of a geological horizon, from this as a standpoint he soon reads off the succession of the rest. Here, however, the appearance and texture of the rocks will probably be different to what they were in the foothills. Heat has so changed or metamorphosed the sandstones and shales that they are scarcely recognizable as the same rocks as those of the foothills. Yet even here a highly silicified fossil shell, or a leaf impression on shales, or sandstone changed into slates or quartzite, will give the prospector his clue and his desired and definite geological horizon, and he will have little difficulty in again arranging and grouping correctly the rocky series. But a prospector has a "practical end" in view. He is "after the precious metal," gold and silver, not after "pure science" or "fossils or sich." What practical use is there, he may ask, in this same careful study of geological sections, where probably there is not a speck of gold or silver? Simply that minerals and metals of economic value, such as gold and silver, are more frequently found in the rocks of certain geological periods than in others. Locally, this is especially true. For instance, nearly all the silver-lead deposits of Colorado are found in a certain bed of limestone not over 200 feet thick, to be found only in one geological period out of many others, viz., the lower division of the Carboniferous. It would naturally, then, be advisable for a Colorado prospector to be able to surely identify this limestone, as well as the geological horizon in which it occurs, among the various other limestones of various other periods and ages in the mountains.

Again, gold is mainly confined to crystalline rocks of the Archæan age, or to porphyries associated with these. A prospector should be familiar with these rocks and their varieties. Gold is also found in the placers, derived largely from the breaking up of these rocks, and the ability to distinguish the different pebbles may lead to the source whence the gold was derived. Familiarity with rocks of all kinds is necessary to a prospector's education.

GEOLOGICAL SECTIONS OF COLORADO

In illustration of what we have said, let us take the two accompanying generalized sections showing the crust of the earth as exposed in Colorado. The vertical section of an ideal cliff shows all the members of the various periods in a stupendous cliff resting on fundamental Archæan granite at the bottom of a cañon. The generalized section represents the same rocks and succession of strata, displayed in upturned "hogbacks" along the flanks of the mountains and foothills on the border of mountain and prairie. Both of these are ideal sections, "generalized" or "made up" of actual partial typical sections found in different localities in Colorado; the vertical one in detached and sometimes widely separated districts in the heart of the mountains; the other at similarly distinct and different localities along the banks of the various rivers issuing from these cañons in the mountains,



A VERTICAL SECTION OF THE EARTH'S CRUST IN COLORADO.

cutting their way through the upturned strata of the flanking foothills and debouching on the prairie.

It is very rare to find at one locality anywhere in the world a complete section of the earth's crust exposed. The nearest approach to this in Colorado is the remarkable section between Colorado Springs and Manitou, which shows along the wagon road the succession of strata from Archæan to Quaternary.

One of the most remarkable *vertical* sections in the world is in the grand cañon of the Colorado River, where the stupendous cliffs show, in one face, a thickness of some 6,000 to 7,000 feet of strata, representing several geological periods, but by no means a complete section of all that is known of the earth's crust.

To show how difficult and rare it is to get a complete section of all the periods in the earth's crust, we may state that sometimes the rocks of a single geological period are from 10,000 to 20,000 feet thick. A cañon might thus be cut to a depth of 5,000 feet, and yet be in only part of a single earth period.

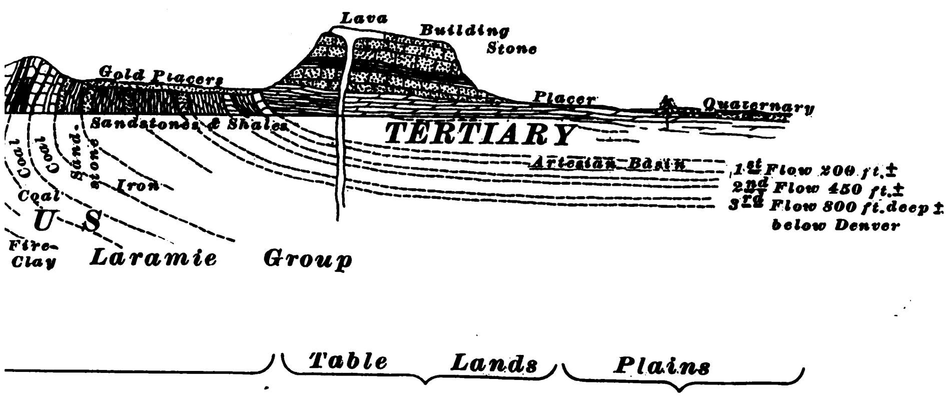
By far the most extensive and available sections are, like those represented in the engraving, along the courses of streams on the flanks of a mountain range. It would be a formidable task to scale a cliff 5,000 feet high and examine minutely, in ascending, each of its geological divisions, while, on the other hand, in the foothill regions, a prospector may walk over and mark and study as much as 10,000 to 40,000 feet of strata along the banks of a river in a single afternoon. In the Weber Cañon, in Utah, as much as 40,000 feet of strata, composing the flanks of the Wahsatch Range, can be seen by the traveler from the windows, as he glides through in the railway car, and the inquiring prospector or geologist can examine and study this vast section leisurely, on his mule or on foot, and on a good road, without doing any climbing. Smaller partial sections can be similarly studied along many of the streams issuing from the Rocky Mountains among the foothills of Colorado. Such, for example, as at Boulder Creek, Clear Creek, Bear Creek, the Platte River, and, most complete of all, the one along Fountain Creek, near Colorado Springs, which we have already mentioned. Similar sections can be found in most mountain regions, such as, in America, the Adirondacks in the East, and the Sierra Nevada and Coast Range in the West. We emphasize again that the close study of these is the best preliminary step we know of in a prospector's geological education.

Let us now examine our ideal generalized Colorado section, which we will suppose to be all exposed along the banks or cañon of a single river. We will start from the Archæan granite in the cañon, thus giving us a sure, a known, and the lowest possible geological horizon to begin with.

THE ARCHÆAN

This Archæan we find to be composed, towards its core, of solid, shapeless (amorphous) crystalline granite, which seems to have been fused out of all shape by fire and water, or aqueo-igneous fusion. With this, but more characteristic of the upper and outer edge of the Archæan, the granite assumes a more stratified and bedded character, which we designate as "gneiss," and interbedded with it at intervals are distinctly laminated or finely leafed strata, called schist. All these varieties are composed of the same minerals in different arrangement and quantity, viz., mica, quartz, hornblende, and feldspar. As these rocks are semi-igneous or metamorphic, we find no fossils in them. Traversing all these Archæan rocks, and cutting them at all sorts of angles, we may notice some eruptive dikes of porphyry, which were once certainly molten and which ascended in that state through fissures opened in the rocks from depths and sources unknown. As we approach the edge of the granite we may even see some of these molten rocks, insinuating once fiery tongues among the weak places and bedding planes of the overlying sedimentary strata, as represented in the diagram, where one dike is shown to have sent out so thick an intrusive sheet of porphyry (see Fig. 2) between the overlying limestones, that where subsequent erosion took place, this thick sheet, by its superior hardness, was left to form the highest cap of the mountain, as on many of our prominent mountain peaks, such as Mt. Lincoln and others in South Park.

Besides these rocks, the prospector will observe numbers of quartz and pink feldspar veins of all sizes, some mere streaks, and occupying incipient fissures or weak places (veins of segregation), others occupying large, well-defined fissures or jointing planes (so-called true fissure veins). Some of these may or may not carry metal, gold or silver, lead or copper; at any rate,


Lava
Building Stone
Gold Placers
Placer
Quaternary
Sandstones & Shales
TERTIARY
Artesian Basin
1st Flow 200 ft.±
2nd Flow 450 ft.±
3rd Flow 800 ft. deep ±
below Denver
Coal
Coal
Sand-stone
Coal
Iron
U S
Fire-Clay
Laramie Group
Table Lands
Plains

S AND STRATA.

special attention will be paid them, particularly if any of them look at all decomposed or rusty, or are in close proximity to an eruptive porphyry dike.

THE CAMBRIAN

Now the prospector emerges from the Archæan granite and finds the first true sedimentary water-formed rocks, lying where the ancient seas placed them on the eroded upturned edges of the granitic series.

If this section should be near the plains or foothills, this first sedimentary rock will be a sandstone, pure and simple, or a conglomerate of little pebbles; but in the parks and center of the mountains, where these ancient strata are most conspicuous, the first rock lying on the granite is a hard white semi-crystalline quartzite or metamorphosed sandstone. He may possibly find some obscure signs of ancient fossil shells in this series, which is called the Cambrian now, though formerly it was held to be only a lower division of the Silurian. In Colorado these Cambrian rocks rarely exceed 200 or 300 feet in thickness, but in other regions they are often very much thicker. In this series the prospector may look for precious ore, more especially gold. He will carefully look, also, for intrusions of eruptive porphyry in this series, as at the junction of this with the quartzite ore is most likely to be found. He will also observe any rusty signs in the filling of cracks as good indications of gold-bearing ore. Silver also may be found associated with lead or zinc.

SILURIAN

Walking along, he next comes to some 200 or 300 feet of drab-yellowish or light-gray thin-bedded limestone of a dolomitic character, characterized by numbers of little white flints or (rarely in Colorado) by some fossil shells, which, by reference to the engravings in his manual, he finds to be Silurian, and so recognizes the series. Here he may find indications of lead, silver, or other ores, but not much gold, as a rule.

CARBONIFEROUS

The next series of this should, according to the textbooks, be the Devonian, characterized by fossil fishes and "Old Red" sandstones; but the rocks of this epoch for some reason are missing in Colorado. Instead of this, resting on the Silurian, he finds a thick bed of heavy-bedded, massive "blue-gray" limestone, characterized by black flints, and at rare intervals by fossil shells and corals, which again, by reference to his book, he finds to be characteristic of the Lower Carboniferous. This limestone, when traversed by sheets of eruptive porphyry, has yielded at Leadville and at Aspen and in New Mexico and Arizona some of the largest silver-lead deposits in the West. In fact, throughout the West it may be considered as the main silver-lead horizon. This limestone is generally between 200 and 300 feet in thickness, and is readily recognized by its position relative to the Silurian below it, by the massiveness of the strata and by their dark-gray color. It is commonly called the "Blue Limestone" in Colorado.

MIDDLE CARBONIFEROUS

Above the Lower Carboniferous is a bed of dark black shales, in which thin seams are sometimes found, and fossil plants like those in the coal strata of Pennsylvania, which is sufficient to show that it, too, belongs to the Carboniferous. These shales are followed by some 2,000 or more feet of "grits"—rough, hard, gritty sandstones, partially changing into quartzite, akin to the "mill-stone grits" of the Eastern States. A few limestones occur in this thick Middle Carboniferous series, which locally and when capped by porphyry produce silver-lead deposits, but generally speaking, the "grits" are unproductive in Colorado.

The Upper Carboniferous consists of beds of gypsiferous shale and heavy brownish-red conglomerate sandstones.

TRIASSIC "RED-BEDS"

From these we pass into a series of heavy-bedded, coarse conglomerate sandstones of a brick-red color, commonly known as the "Red-Beds" in Colorado; little indications of ore are to be expected in this series. The prevailing redness of the series makes it an easily recognized geological horizon in Colorado and elsewhere. The thickness in Colorado varies from 1,000 to 2,000 feet.

JURASSIC

The prospector next comes to a softer and more variegated series, consisting largely of pink, green, red, or maroon marls and clays, with some thin limestones and red sandstones. This is the Jurassic series, in which some remarkable lizard remains, called Dinosaurs, have been found, proving the correctness of its Jurassic name. This is not a likely mineral horizon, generally speaking, in Colorado.

CRETACEOUS

These softer beds are capped by a hard massive sandstone, about 200 feet thick, forming by reason of its superior hardness a prominent hogback in the prairie or foothill region. Fossil remains of leaves show it to be a land and fresh-water group, which is called the Dakota group.

This group in Colorado forms the base of the great Cretaceous system; lying on it is an enormous thickness of drab shales, with a few limestones characterized by fossil sea shells, showing the group to be the marine Cretaceous, likewise a poor prospecting ground. Toward the upper portion, these shales pass gradually into heavy-bedded sandstones, containing several seams of coal and many impressions of tropical foliage. This is the Laramie group of the Cretaceous, evidently of fresh-water origin, and noted as the main coal-producing horizon in the West.

TERTIARY

On this, at a somewhat gentler angle, even to horizontality, rest thick beds of shale and clay and conglomerate, composed of volcanic detritus and pebbles, showing that at the time these Tertiary beds were being laid down by large fresh-water lakes and marshes surrounded by tropical foliage, volcanic eruptions on a grand scale repeatedly occurred. Hence it is that many of the Tertiary beds are preserved from erosion by being capped with volcanic rocks, such as basalt, andesite, or rhyolite, as at the Table Mountains at Golden, on the Divide near Colorado Springs, and elsewhere in Colorado. One of these lava-capped "mesas" is represented in the section. Fossil leaves and coal seams are found in this period.

QUATERNARY

Lastly, strewn indiscriminately over all the formations, is the "Quaternary drift," composed of loose pebbles and sands and clays, the material derived from rocks of all the periods through the agency of glaciers and streams.

Here the prospector will pan for his gold placer, and in his search may possibly come across the teeth or tusks of the great mammoth or fossil elephant, together with the first indications of the presence of primitive man. The pebbles by their variety will form a fertile subject of study to determine to what class of rocks they belong.

This ends the prospector's first preliminary lesson in Colorado geology, but, taking this section as a type, he may, to his great advantage, similarly study other sections remote from Colorado.

In Colorado, if he knows this section by heart, he has the key to nearly all our mountain structure, and will be at home wherever he goes. He will be struck, too, to see to how small a portion of this great section the precious metals are more or less confined—principally to the Archæan and Paleozoic rocks.

CHAPTER II

THE PROSPECTOR'S HISTORICAL GEOLOGY

In Chapter I we gave some hints to the prospector how to commence his geological studies, and gave him an example of a geological section of the foothills and mountains of Colorado, and how to study it in detail practically. Having completed this study, if a thoughtful man, he will like to know more of the natural history of all this section of the earth's crust: what is the natural history of the Archæan, the Cambrian, Silurian, etc.; why some of these strata contain sea shells, and others land plants, why some are evidently of marine and others of fresh-water origin, and particularly why some are especially metalliferous, and others not so much so. We propose, therefore, in this chapter to give him a brief sketch of the earth's history as exemplified in the generalized sections.

HYPOTHETICAL ORIGIN OF THE EARTH

The world was not "spoken into existence ready-made" in the state we now find it. It has attained this condition through a multitude of gradual changes and revolutions which have taken millions of years to accomplish. The remote history of the earth's origin is a matter of hypothesis and speculation. There are reasons for supposing that at one time its elements were in a gaseous condition, and that this planet was an incandescent luminous cloud, revolving through space, and gradually consolidating into a molten ball, surrounded still by an atmosphere of gases—a condition perhaps not very unlike that of the sun, whose interior by some is supposed to be passing into the molten state, while its exterior consists of various incandescent gases arranged more or less according to their specific gravities. The spectroscope has detected the elements of some of our earth metals and minerals in the sun in a state of vapor. The ultimate source of the precious metals is also a matter of speculation, like the nebular hypothesis we have alluded to, by which the earth is supposed to have arrived at its present condition as the result of the gradual cooling of an incandescent mass. As the specific gravity of the crust is much less than that of the whole mass of the earth, it has been inferred that the heavy metals must be in much larger proportion in the interior of the earth than in the rocky crust, though this greater interior specific gravity might be also accounted for by the rocks of the interior being much more tightly packed by enormous pressure than those near the surface. Volcanic emanations and hot springs contain metallic minerals; so also do the waters of the ocean, but we know not from what depth the former came, nor from what source the latter derived them. As circulating waters take up and throw down their metallic contents under varying conditions, the same material may have been deposited more than once, and in more than one form, since it reached the rocky crust.

Upon the cooling of the ball, a crust formed like that on molten iron, crumpled and corrugated by contraction into an uneven surface, with comparatively slight elevations and depressions, and doubtless broken through here and there by great fissures and volcanic craters, through which the molten flood beneath poured out in volumes, adding to the thickness of the congealing crust.

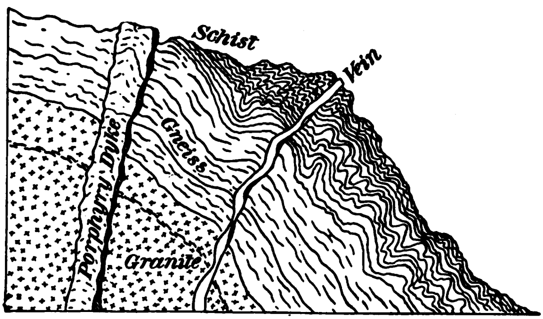
Upon such a surface the gaseous atmosphere, gradually cooling and condensing, descended as hot chemical rain, and filled the troughs of the crumpled surface with a hot, chemical, steamy ocean. Whatever land of primitive lava rose above this ocean was battered by the waves, reduced to sediment, and deposited as the first sedimentary strata in the bed of that primeval ocean, the eruptions from below the thin crust doubtless contributing largely to the same material.

ARCHÆAN AGE

Thus, perhaps, were formed the first stratified rocks of the world that we have an opportunity of actually seeing and studying, viz.: the granitic series, with its varieties of gneiss, schist, syenite, etc., and as this is the beginning age, so far as we know, we call it the *Archæan*, the Greek word for beginning. It would seem probable, however, that these granitic rocks forming the axes of our mountains may not have been the very first rocks of the crust, for we observe some of them, such as the gneisses and schists, to be stratified, and to show elements in them that seemingly have been derived from other and still older rocks, which latter may or may not have belonged to the original cooling crust. Some geologists claim that the Archæan is the first cooled crust, and attribute it to a molten origin. This may be true in the case of the seemingly fused massive amorphous granites (though these may be but the result of aqueo-igneous fusion of sediment or extreme metamorphic action), but scarcely for the stratified gneisses and schists, though it is to be noted that a sort of stratified or schistose structure is sometimes observed in truly igneous rocks and may be induced by peculiar arrangement of minerals, pressure, and cleavage, instead of water lamination. The subject is a difficult one and too abstruse for the limits of this work.

In the scale of geological periods in the textbooks, we sometimes find this great Archæan divided into two or more groups, such as the Laurentian, Huronian, and of late the Algonkian.

The Laurentian is the oldest and may be called the Archæan proper, while the Huronian and Algonkian may be grouped generally as Pre-Cambrian, or series of rocks laid down after the Laurentian and before the Cambrian. All the rocks are of a highly crystalline order and have a peculiar and distinct general appearance, different, as a rule, from those of any subsequent geological periods, and so not easily mistaken for them, consisting in the lower division mainly of granite, gneiss, and schists, and in the upper divisions of gneisses, schists, quartzites, slates, some marble, serpentine, etc. The upper or Pre-Cambrian series is not nearly so universally found as the Laurentian or Archæan proper. In Colorado we find the Pre-Cambrian represented



ARCHÆAN ROCKS.

locally in South Boulder and Coal Creek cañons, along the foothills, near Salida in the Arkansas valley, in the Quartzite range, and on the road between Ironton and Ouray in the San Juan Mountains. The new Kootenai silver-mining district of British Columbia seems to be largely in these Pre-Cambrian rocks. This Pre-Cambrian is usually very thick, numbering many thousands of feet. It is distinct from the Archæan proper or Laurentian by lying on the latter at a different angle, in other words "unconformable." The rocks, too, do not contain so much of the heavy massive granites and heavy-bedded gneisses as the Laurentian, but are more characterized by quartzites, by conglomeratic gneisses and schists, and show clearly that, though highly metamorphosed and crystalline, they are of true fragmental and aqueous origin, for the pebbles in the gneiss are often very distinct, and ripple marks are not uncommon on the quartzites and slates and schists. The material was doubtless deposited by water, and was derived from the underlying and older Laurentian. The whole Archæan series, however, has evidently passed through an ordeal of heat, such as is called aqueo-igneous heat, and all its elements are in a highly crystalline condition. Its strata are intensely folded and crumpled as shown.

Signs of life, such as graphite and possibly corals, even in the upper series, are exceedingly obscure and doubtful. Great iron beds also occur, and are indirect proofs, perhaps, of the previous existence of life.

We have been thus particular with this Archæan age because its rocks are of great importance to the prospector, being the main repositories of gold, silver, and the precious metals throughout the world. Moreover, many of the other and newer rocks containing gold and silver have been made from the detritus of this, and the gold placer beds came largely from the detritus of the rocks and porphyries found in this age. Thus the Archæan may be considered as the parent of nearly all the other rocks. When later we have studied the origin of ore deposits, we shall see how eminently the Archæan age, with its attendant heat, chemical reactions, fissuring, metamorphism, and volcanic eruptions, was favorable to the diffusion and concentration of precious ores in its rocks.

CAMBRIAN AND SILURIAN AGES

Cooling and consequent contractions still progressing in the globe, fresh and greater wrinkles and corrugations were caused on the surface of its crust, and some of these granite sea-bottom strata were crumpled up till the crumples arose above the then universal ocean, as low islands or reefs. The ocean had by this time cooled sufficiently to support low forms of marine life, and so along the flanks of these gigantic islands corals formed reefs, shell fish swarmed, and seaweeds grew. Sands formed by the waves from the material of the granite were laid down as shoreline beaches, often mixed with shells; and in deeper water corals were forming limestones as at the present day, both, by time and pressure, consolidating into hard rock, eventually, it may be, metamorphosed by heat into a semicrystalline hardness, as in the case of the Cambrian quartzite and Silurian limestones, the latter sometimes changed to marble. If these Cambrian quartzites were formed from the detritus of the granite, and the granitic series is the source of gold, it is not surprising that we find the Cambrian quartzites locally rich in gold, as they were the auriferous sea beaches (like those of today in California which are gold-bearing) of that period, later consolidated into hard rock. In Colorado the Cambrian quartzites are only locally prolific in gold, as at Red Cliff, but as they have hitherto been much overlooked by prospectors, they are worthy of closer attention by the gold seekers. The limestone not being of a true fragmental origin, but formed by the slow work of corals, could not be expected on consolidation to be a recipient of gold, but later, by its peculiar chemical composition, of which we will speak hereafter, and by its cavernous nature, it furnished a more convenient receptacle for silver and lead ores.

So, then, in Colorado and in other regions, we find first the upheaved crumpled granite of the old Archæan island, and on these the Cambrian sandstone or quartzite beach of "golden sands," with some fossil shells, and upon this again Silurian limestone with relics of fossil corals and shells. So we call these ages the Cambrian and Silurian, because the fossil shells and corals are peculiar to those ages and distinct from those of later periods or the present day.

North America at Close of Archæan.

North America at the beginning of these periods was barely outlined by a few granite islands congregating mainly in the region now occupied by Canada, while one or two reefs or scattered chains of islands marked the site of the Eastern ranges of mountains, and a few parallel granite islands outlined the site of the principal uplifts of future great ranges of the Western Cordilleras. All else was ocean, and that ocean was depositing its Cambrian beaches and Silurian coral limestones against or near these granite islands, destined in time to grow into lofty mountain ranges and to become the backbone of the American Continent.

DEVONIAN

The Devonian, which should come next in order in the geological tree, appears to be absent in Colorado, but is well shown at the Eureka Mines in Nevada. The rocks appear to be mostly marine limestone, full of corals and shells and a few remains of gigantic fishes, for which this age was celebrated. Land plants and some coal are found in it in the East. Lead-silver ores may be expected in the limestones of this age, and the Cornwall (England) Devonian slates, traversed by quartz porphyries, are the main rocks carrying tin ore, an ore very scarce at present in North America.

These ages we are speaking of are separated or distinguishable from one another by decided and characteristic changes in their

SECTION SHOWING UNCONFORMITY OF GEOLOGICAL ERAS.

fossil, animal, and vegetable life; also in some countries by marked unconformability of the rocks, i. e., the rocks of one age lying at a different angle upon the upturned rocks of a previous age, marking great oscillations between sea and land.

In America, however, these oscillations between sea and land seem to have been less than in Europe, and we find a general uniform rise of the continent from the primitive oceans, and an orderly succession of strata lying against the flanks of the ever-rising granite nucleus of both mountains and continent. Hence, to distinguish the different ages we are driven more to the study of fossils and lithological peculiarities than deriving any help from observed marked unconformability. In the figure the strata of the different eras lie upon one another at different angles, and the glacial and Quaternary drift pebbles and clays are strewn unconformably also over the tops of the uptilted and eroded strata of all the eras beneath.

CARBONIFEROUS

As the eastern portion of the American continent gradually rose from the sea, and as to the granite islands were added a Cambrian, Silurian, and Devonian shore, with further unequal elevation a kind of wide trough or synclinal fold or depression appears to have been formed between the middle and eastern part of America, which was at first occupied by a wide arm of the sea, later, by continued elevation, by a great body of fresh water, and later by low marshes and low marshy islands barely above sea level. Upon these low-lying lands grew a dense vegetation, unlike any of the present day, but resembling somewhat the tree ferns of our southern semitropical states. This low-lying region was subject to freshets and inundations from the surrounding higher regions, periodically deluging the swamps and swamp vegetation with river and flood deposits of pebbles and sand, under pressure of which the peat gradually turned into coal. Successive coal seams were formed by successive growths of vegetation between the intervals of periodic inundation or of subsidence, and possibly at times of upheavals, for these low lands, as sediments accumulated, appear at times to have sunk below the sea and again to have been either built up above it by fresh supplies of sediment, or to have been temporarily raised up by upheaving forces.

Finally, by a grand revolution which closed the Carboniferous age in America, the coal swamps with their coal beds and strata were crumpled up to form the present great Appalachian Chain.

Similar movements no doubt took place about the same time in the Rocky Mountain and western region. But here the marine condition seems to have predominated over the fresh water one, for we find the Carboniferous in Colorado more represented by marine fossiliferous limestones and sandstones than by those of fresh-water origin, though the Weber grits may have had a fresh-water origin, as in a few rare instances we find fossil plants like those in Pennsylvania, together with a few insignificant small seams of coal. But in the West it is evident that the circumstances from one cause or another were not favorable for the production and growth of extensive coal beds, as in the Eastern States. The coal-forming time was reserved in the West for a much later period, viz., the Laramie or Upper Cretaceous. The Lower Carboniferous in Colorado, however, contains in its limestones much of our silver-lead wealth, as at Leadville and Aspen.

The Cambrian, Silurian, Devonian, and Carboniferous ages have been grouped together by geologists into one great era, the Paleozoic, owing to a general family likeness in the fossil fauna and flora of these ages.

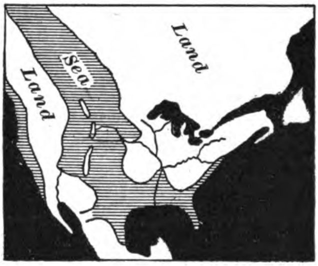
To the Archæan and Paleozoic rocks the bulk of our veins and deposits of gold and silver are mainly confined, though both in Colorado and elsewhere, as will appear later, if certain peculiar conditions are present, the rocks of the later and newer periods may also in some regions produce precious ores. But the prospector should give his closest attention to these older rocks; hence we have devoted extra space to their description and history.

TRIASSIC AND JURASSIC, OR JURA-TRIAS

After the Carboniferous, followed the Triassic and Jurassic. Sometimes in America, owing to the difficulty of positively separating the two periods, they are combined under one name, the Jura-Trias, and in Colorado are locally called the "Red-Beds," owing to their prevailing red and variegated colors. The series is well represented in the celebrated Garden of the Gods, near Colorado Springs. The red conglomerate sandstone of the Trias proper has so far yielded no determinative fossils, but the variegated clays in the upper Jurassic, at Morrison and elsewhere, have yielded some remarkable Saurian remains of land lizards. It is probable from the presence of salt and gypsum in these red-beds, and the prevailing redness of the rocks, due to iron which was not leached out through the agency of organic life, and the general absence of fossil remains, that the lower portion of these rocks was laid down in land-locked salt seas, or salt lakes, shunned by both vegetable and animal life. The upper portions, however, show evidence of the existence of land of a low marshy character, with fresh water and probably large estuaries, as we find the remains of turtles, crocodiles, fresh-water shells, and Dinosaurs, or land lizards. The rocks of these periods are not generally prolific in ores. The Silver Reef sandstone of Utah is an exception, which contains chloride of silver disseminated through it. When pierced by eruptive rocks, however, ore should be looked for in this series as elsewhere.

CRETACEOUS PERIOD

Upon this followed the Cretaceous, a series of very thick formations, numbering several thousands of feet in Colorado, consisting in its middle portion of limestones, and thick beds of drab shale. These are mostly marine, as shown by the sea shells in them, but at the base is what is called the Dakota group, or Cretaceous No. 1, a prominent sandstone hogback in which the fossil impressions of leaves very like, but not identical with, those of the present day, show that land and fresh water existed at the time. The limestones and clays of the middle, or Colorado, group contain quantities of fossil marine shells, such as the Nautilus, Ammonite, Baculite, and Inoceramus.



NORTH AMERICA IN THE CRETACEOUS.

The Laramie forms the upper group of the Cretaceous, and contains our principal western coal fields and abounds in fossil remains of tropical foliage.

This Laramie group marks an important era in our Rocky Mountain region, for it shows the beginning of the great Rocky Mountain revolution, by which the granite islands before mentioned, against which all the previous sediments had been forming, mainly beneath the sea, were elevated 10,000 feet or more into continental or mountainous masses, dragging up with them portions of the sea bottom and exposing it as land surface, draining off the shallow Cretaceous sea which had hitherto divided the Eastern half of the American continent from the Western, bringing on a land and continental condition, which was completed in the following Tertiary age and has continued to the present.

The Jurassic, Triassic, and Cretaceous are grouped into one main division, called the Mesozoic or middle-life era of the world's history. None of the rocks of this age in Colorado are celebrated for ore deposits, except locally, under local conditions.

In California and portions of the extreme West where these rocks have been highly metamorphosed by heat and penetrated by igneous rocks, some of the leading ore deposits of gold and silver are found. The same remark applies also to the succeeding Tertiary in those regions, particularly in the Sierra Nevada and Coast ranges.

TERTIARY

The Tertiary age seems, in the Rocky Mountains, to mark an era of comparative rest in mountain elevation, for the strata forming some of the divisions of this age lie almost horizontally upon the tops of the earlier upturned periods.

These beds were formed by fresh-water lakes in Colorado, surrounded by tropical vegetation. In the Coast ranges of Califorinia the Tertiary is upturned into mountain forms and metamorphosed, and, from the presence of sea shells, is clearly of marine origin. The Tertiary in Colorado is best seen in outlying table lands. In Wyoming the Tertiary lake formed the Green River beds and Bad Lands, abounding in fossil mammals, leaves, fishes, and insects. The Tertiary was the world's tropical summer, a period of beautiful lakes of semitropical foliage and a warm climate. In certain regions it was disturbed by gigantic revolutions which upheaved the Himalayas and the Alps. Such revolutions as occurred in our Western Cordillera system were marked by enormous ebullitions of lavas of various kinds, issuing from fissures deluging Idaho, Nevada, part of Oregon, and Washington. Remnants of this same disturbance are seen in the form of basaltic overflows capping Tertiary strata in Colorado and New Mexico; and the vast volcanic region of San Juan, in southern Colorado, is covered with successive lava overflows of the same period.

The Tertiary rocks in Colorado are not generally good prospecting ground. The lavas, however, are (with the exception of the basalt, which for some reason is generally sterile) locally productive, as for instance the entire San Juan region, also Cripple Creek mining camps and Silver Cliff. So the prospector, while he need not waste time among the sedimentary beds, will do well to examine any eruptive rocks of this period for gold especially, and also for silver. The varieties of lava are principally andesite, rhyolite, trachyte, and basalt. In the Coast Range of California, where the Tertiary beds have been metamorphosed by heat into slates, gold and cinnabar are found.

GLACIAL EPOCH AND QUATERNARY AGE

The Tertiary Summer was closed by the world's Great Winter. The ice from the north pole, for some reason we will not discuss, extended its domain far south, to latitude 40. All the northern temperate regions of the world were ice-sheeted and the sheet extended itself as by long fingers down the, by that time, highly developed mountains, filling the ravines with glaciers. By the downward destructive grinding motion of the glaciers, the ravines, commenced by water, were deepened and widened by ice. Fissure-veins were thus exposed, both of gold and silver. The débris from their progress the glaciers carried on their backs and dumped at the outlet of the cañons; and when the temperature finally became warmer and the glaciers melted, all the long lines of traveling boulders scattered upon their backs, many of them containing gold robbed from the veins, were left as banks or "moraines," forming our gold-placer grounds along the sides of our streams and cañons, or sometimes a thousand feet above the present river bed, marking the original height or thickness the great ice bodies once attained.

So were our cañons largely formed, and so did our gold placers originate. After the Glacial epoch, a warmer period set in, called the Quaternary. The ice melted. Vast bodies of fresh water were distributed in wide streams and monstrous lakes over large portions of this hemisphere. The rough morainal dumps of the glaciers were "sorted" or modified by water, rolled into pebbles and sand, and redistributed along the banks of streams or carried out into beds of lakes. In the pebbles and sand was much of the precious metal mined and robbed from the veins. The gold, by its insolubility, remains to this day in our placer beds and "drift" or "wash," and is collected by hydraulic mining. That the prospector for gold should closely study these Glacial and Quaternary deposits is evident.

So ends the history of our section. Still the agencies of nature are at work as of old. Continents are gradually rising or sinking. Mountains are being imperceptibly elevated. Water is still sculpturing them with cañons. Rivers are carrying down fragments robbed from the land and depositing them in the ocean, to form strata for future continents.

The fires of the earth are not yet dead, for volcanoes still vomit lava. The earth, however, is still continuing to lose internal heat. Its crust is still contracting and wrinkling itself upwards, for we find modern sea beaches raised high on our seaboard cliffs. Shocks of earthquakes from time to time prove that motion of some kind is going on beneath us, and doubtless our mountains are still rising imperceptibly, as they appear to have done in ages past, giving additional lifts and elevation to old uplifted strata, and slowly elevating newer strata that since the Tertiary have lain apparently undisturbed. We say apparently, for not only are the Tertiary beds uplifted from five to ten degrees, but even the more recent Quaternary deposits, showing that movement has been going on comparatively recently and may still be progressing imperceptibly.

CHAPTER III

THE PROSPECTOR'S PALEONTOLOGY, OR STUDY OF FOSSILS

A PROSPECTOR in his roaming among the rocks is likely from time to time to come across a good many fossils or petrified remains of life that once existed on this planet. He will feel curious to know what these are, what class of animal or vegetable they may represent, to what geological era, epoch, or subdivision they may belong.

Fossils to a geologist are the labels of the rocks; show a geologist a fossil, and he will probably be able to tell at a glance whether the fossil came from a series of Paleozoic, Mesozoic, or Cenozoic rocks; whether it belonged to a very ancient geological period, down near the primitive granite, or to a comparatively recent one, near the modern soil, high up in the geological scale and nearer to the life of the present day. He may be able to tell not merely whether it belongs to one of the great divisions, to the great eras, but also to the subdivisions of these eras—whether to the Silurian or Carboniferous, the Jurassic, or the Cretaceous, or even to minor divisions of these, called groups; whether, for example, it belongs to the Dakota group of the Cretaceous, or to the Laramie group of the same period.

PRACTICAL USE OF FOSSILS

The practical use of a general knowledge of fossils is obvious. A prospector finds in certain strata a fernleaf of the Carboniferous; this tells him he must be on the coal strata, and forthwith he hunts for coal. Or he finds a Paleozoic shell or coral, which points to the fact that he is probably in the neighborhood of the precious ore-bearing rocks.

Later, perhaps, he finds a shell or coral characteristic of the Lower Carboniferous blue limestone, the celebrated lead-silver bearing formation of Colorado and the West, and he is encouraged to look for these ores. The limestone by itself is but a poor guide, for there are many limestones not unlike it in the different series of rocks, but this particular shell labels this as *the* blue limestone, and no other. Hence, a characteristic fossil may help considerably in following up in its extension an ore-bearing rock, and not only that locally, but in regions very far apart. Soon after the celebrated ore deposits of Aspen were discovered, and the mines were in their infancy, some fossils were discovered that showed the deposits to be in the same limestone as that at Leadville, which had proved there so productive. This gave an additional impetus to the camp—"a second Leadville," so it was said.

Again, though a prospector may not find at once the particular geological stratum or period he is looking for, if he finds a characteristic fossil anywhere, in some other period, he knows from it whether the period he is after lies geologically below or above where he is looking.

Thus, if a prospector finds a Silurian shell, he knows that the Carboniferous blue limestone must be close above this

Silurian, or if he finds a marine Cretaceous shell, he knows that the Laramie coal-bearing group lies above. On finding a

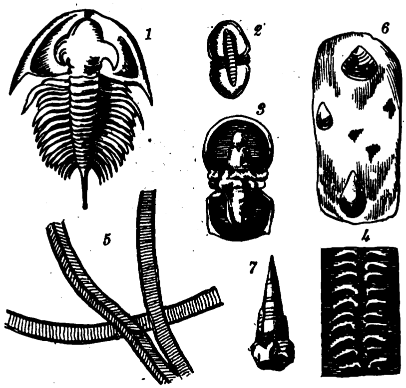
Era	Period	Characteristic Rocks.	Minerals, Metals &c.	Fossils.
Psychozoic	Recent	Soil, Clay, Pebbles	Some Gold	Man, Buffalo &c.
	Quaternary	Pebbles Sand, Clay	Placer Gold	Elephants teeth, Bones Man Bones, Tools
Cenozoic	Tertiary: Pliocene, Miocene, Eocene	Loosely Stratified Conglomerates, Sands Basalt Andesite Rhyolite Lavas Conglomerates Sandstones Shales & Clays Some of Volcanic detritus, others of Granitic detritus	Old Gold Placers in California Lava-Gold & Silverbearing Thin Lignite Coal Metamorphosed Sandstone Gold bearing in California also Asphalt in Colorado and California	Fossil Leaves Mammals in California Marine Shells
Mesozoic	Cretaceous: Laramie	Clay Coal Beds Sandstones	Coal	Leaves, Trees &c. Sea Shells
	Cretaceous: Colo.	Drab Shales Clays Limestone Dark Shales	Canon City Oil Horizon Flux Lime Clay, Iron, stone	Scaphites Baculites Sea Shells Inoceramus Oysters
	Cretaceous: Dakota	Conglomerate Sandstone	Fire Clay	Leaves of trees
	Jurassic	Variegated Clays Red marls, Sandstone Lime Stone	Gypsum Oil and Lime & Red Building Stone	Dinosaurs Colo. Sea Shells in Wyoming
	Triassic	Thin Lime stones Thick Red Conglomerate Sandstone	Copper Silica for Glass Silver, Reef Sandstone Some Red Building Stone	Footprints of Saurians
Paleozoic	Carboniferous	Gypsiferous Shales Reddish Conglomerate Eastern Coal Beds Shales Sandstones Grits & Shales	Eastern Coal of Pennsylvania	Land Plants Corals
	L. Carb	Blue Limestone	Silver, Lead	Sea Shells, Spirifers, etc.
	Devonian	Reddish Sandstone Lime stones	Eureka, Nevada Silver, Lead Deposits	Sea Shells Fish Corals
	Silurian	Drab Pale Limestone Dolomite	Marble Silver, Lead Iron	Sea Shells Crustacea Trilobites Corals
	Cambrian	Slates Quartzites	Gold	Sea Shells
Archæan	Pre Camb.	Quartzites, Conglomeritic Gneiss, Schist Slates, Marble	Gold, Silver Lead, Zinc, Copper &c. Iron	Few Positive Signs of Life
	Archæan	Granite, Gneiss Schist, Syenite		

PROSPECTORS' GEOLOGICAL TABLE OF WESTERN FORMATIONS, SHOWING PRINCIPAL CHARACTERISTIC ROCKS, MINERALS, AND FOSSILS TO BE FOUND IN THEM.

Cretaceous or Jurassic fossil, he knows that the Carboniferous and Paleozoic series must lie considerably below him.

In the geological table, on page 42, we have shown what rocks and what minerals and metals are likely to be found in the geological divisions and subdivisions; also, generally, what classes of fossil life are to be expected in each.

Then, in the diagrams of fossils, we have selected pictures of the fossils most commonly to be found in all the great divisions, so that if the prospector finds a fossil, he may, by comparing it with the pictures, find what its name is, and to what great geological division or subdivision it belongs; it is not so necessary for him to remember the scientific "jaw-breaking" names of these fossils, as it is for him to be able, at sight, to recognize whether it belongs to one or other of the great eras, or, better still, to one of the minor subdivisions of these; whether it is Paleozoic or Mesozoic, whether Silurian or Cretaceous, whether it belongs to the Colorado marine Cretaceous or to the Laramie fresh-water Cretaceous, etc. If the fossil is a very peculiar one and cannot be identified as belonging to any of the common ones we have pictured, he had better send it to the office of the United States Geological Survey at Washington, or to some good paleontologist. We frequently have fossils sent to us to know whether this or that fossil is a likely indication of the presence of coal or other mineral, and sometimes our identification is a material help to the prospector; but with the above table the prospector could save himself the trouble and postage stamps.



CAMBRIAN FOSSILS.

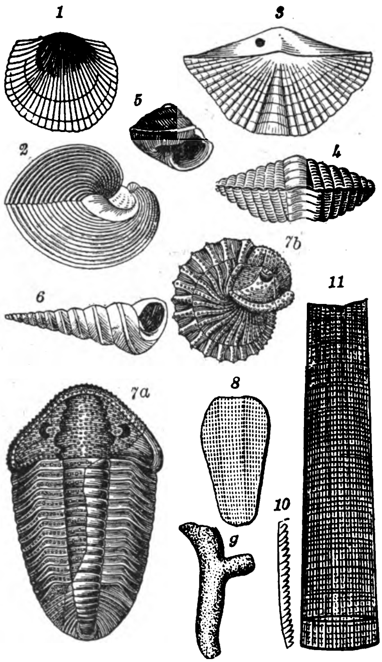
1, 2, 3, Trilobites; 4, Track of Crustacea; 5, Track of Worm; 6, 7, Sea Shells.

ARCHÆAN

Starting, then, from the Archæan as a sure and safe horizon, the prospector will find no fossils, and only some indirect probable evidences of past life, such as graphite, which may possibly represent ancient coal derived from some form of vegetation unknown to us. Limestone and marble are also indirect evidences of past organic life, most modern limestones being due to the remains of corals, etc. Whatever life may have existed in those primitive granitic rocks has been pretty well obliterated by excessive metamorphism and crystallization of the strata.

CAMBRIAN

Resting on the granite he finds the Primordial or Cambrian series, sometimes called the Potsdam Sandstone. If this series consists of unaltered sandstones, he may be fortunate enough to find some of the shells and other traces of life of those old beaches, as are shown on page 43; but, generally speaking, in Colorado and the West the Cambrian is so highly metamorphosed and altered into hard crystalline quartzites, that evidences of past fossil life are as scarce and indistinct as in the Archæan, and probably for the same reason. The forms he may find are a little crustacea called a Trilobite, something like a "sand crab;" also a few little shells and some marks of worms.



SILURIAN FOSSILS.

1, 2, Orthis; *3, 4,* Spirifer; *5,* Pleurotomaria; *6,* Murchisonia; *7a, 7b,* Trilobite (Calymene); *8,* Coral Fenestella; *9,* Coral Choetites; *10,* Graptolite; *11,* Orthoceratite.

SILURIAN

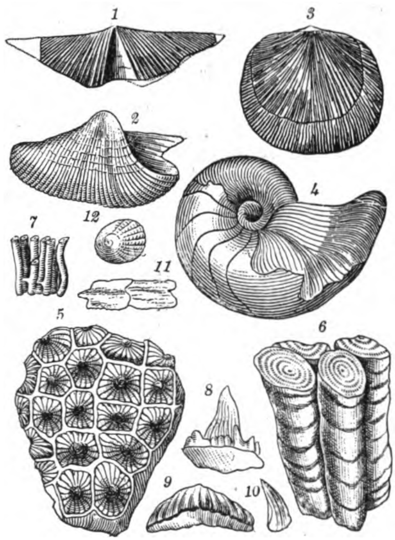
In the next series, the Silurian, he may be more fortunate. He may find remains of seaweeds, corals, and shells, and fragments of a sort of sea worm called a Crinoid, or sea lily. The little disks with a hole in the center, forming a little ring about the size of a pea, constituting the disks or rings of which the stems of the sea lily are composed, are sometimes very common in Silurian and Paleozoic rocks, though it is rare to find a complete Crinoid, and especially the beautiful comb-like flower or head of the sea lily. He is likely to find, also, a more advanced type of the Trilobite and various Spirifers and shells as pictured.

DEVONIAN

In the Devonian he may find the teeth or bones of fishes, and a few remains of peculiar land plants, neither of which are known in the Silurian below, also many corals.

CARBONIFEROUS

In the Lower Carboniferous blue limestone, corals and shells appear, especially Spirifers and Productus, together with Crinoids and a very simple curled shell, like a snake coiled up, a Goniatite, one of the earliest of the Ammonite class. At Aspen, associated with the ore deposits, we found in the blue limestone most of these, together with a kind of snail shell called Pleurotomaria. At Leadville, in the same formation, Spirifers and Productus are occasionally found. A very curious coral is one shaped much like a screw, called Archimedes, who was the inventor of the screw. Cup corals are quite common.



Devonian Fossils.

1, Spirifer; *2*, Comocardium; *3*, Orthis; *4*, Goniatites; *5*, *6*, *7*, Corals; *8*, *9*, *10*, Fish Teeth; *11*, *12*, Fish Scales.

In the Middle Carboniferous, associated with the coal seams, many curious remains of reeds, ferns, and other aquatic plants of that age are found, but these are scarce in Colorado and the West. The prospector will observe that there is a general family likeness between the fossils of each division of the Paleozoic and in the Paleozoic as a whole, and it may not always be easy for him to determine whether a shell is Silurian, Devonian, or Carboniferous, but of one thing he will be certain, that it is Paleozoic.

TRIASSIC

In the Trias throughout the West, he is not likely to find many fossils; the rocks are generally too coarse; but in the Eastern States, though he may not find any true remains, he may observe the tracks left by great Saurians as they walked on their hind feet, or on all fours, on the red sands of the beaches of those dreary salt Triassic seas, leaving "footprints on the sands of time" full of interest.

CARBONIFEROUS FOSSILS.

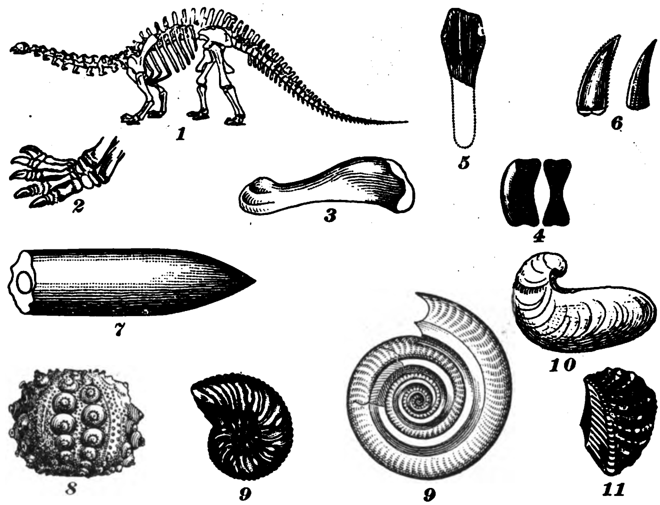
1a, 1b, 1c, Productus; *2, 2,* Spirifers; *3, 3, 3,* Rhynconella; *4,* Euomphalus; *5, 5,* Crinoids; *6,* Pleurotomaria; *7,* Bellerophon; *8,* Athyris Subtilita; *9,* Astartella; *10,* Goniatites; *11, 12,* Corals; *13, 14, 15, 16,* Plants; *17,* Spine of Echinus.

JURASSIC

In the Jurassic shales and limestones in Colorado, he may be equally unsuccessful, though in the upper Jurassic, just below the Dakota sandstone, he may light on the bones of gigantic Dinosaurs, or great land lizards, such as the author found in Colorado and Wyoming, monsters 60 to 80 feet in length and proportionally tall, standing from 20 to 25 feet in height. In the lower Jurassic, in Wyoming, he will find great numbers of sea shells and Ammonites, and a round shell, like a cigar, called a Belemnite, or spear head, the internal shell of an ancient cuttlefish.

CRETACEOUS

In the Cretaceous, beginning with the lowest group, the Dakota group, net-veined leaves of deciduous trees, such as the willow, oak, maple, etc., the earliest known leaves of those kinds of trees, may be expected in the sandstone and clays.

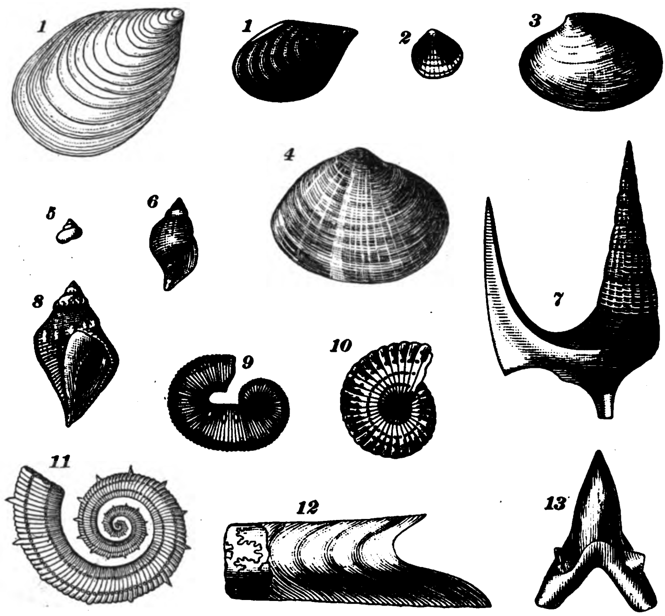


JURA-TRIAS FOSSILS.

1, Dinosaur Lizard; *2*, Foot; *3*, Shoulder Bone; *4*, Vertebra of Sea Saurian, Ichthyosaurus; *5*, *6*, Teeth of Saurians; *7*, Belemnite; *8*, Echinus; *9*, *9*, Ammonites; *10*, Exogyra; *11*, Trigonia Shell.

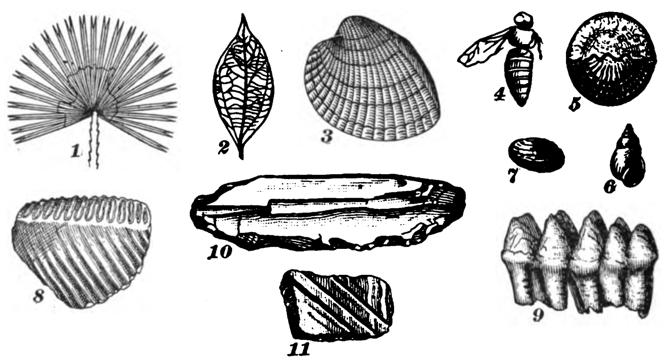
In the Colorado group of the Cretaceous, above the Dakota, abundance of oyster shells and large clam shells (Inoceramus) are sure to be found in the limestones and marine shales. In the Montana group of the Cretaceous, above this, consisting mainly of drab shales and some sandstones, great quantities of sea shells are found, among them various peculiar forms of the Ammonite, allied to the modern nautilus, and called Scaphites, resembling snakes or worms uncoiling, together with shark's teeth and bones of sea Saurians.

In the sandstones of the Laramie Cretaceous, remains of seaweeds are found; in the sandstones immediately below the coal beds, and in those associated with or above the coal, are found great varieties of semitropical leaves, such as those of the



CRETACEOUS FOSSILS.

1, 1, Inoceramus; *2,* Cardium; *3,* Corbula; *4,* Mactra; *5,* Margarita; *6,* Fasciolaria *7,* Anchura; *8,* Pyrifusus; *9, 10,* Scaphites; *11,* Crioceras; *12,* Baculites; *13,* Shark's Tooth.



TERTIARY FOSSILS.

1, Palmetto; *2,* Cinnamon Leaf; *3,* Cardium; *4,* Insect; *5,* Nummulite Shell *6, 7,* Fresh-Water Shells.

QUATERNARY FOSSILS.

8, Mammoth Elephant's Tooth; *9,* Mastodon's Tooth; *10,* Flint Implement; *11,* Stone Grooved by Glacier.

palmetto, fig, beech, elm, magnolia, sassafras, etc. The presence of these leaves is a pretty sure indication of coal.

TERTIARY

In the Tertiary fresh-water beds, similar leaves and thin beds of poor lignite coal are found, together with fossil insects and remains of mammals. In the marine Tertiary are sea shells.

QUATERNARY

In the Quaternary drift, among the pebbles, sands, and "wash" characteristic of gold-placer beds, an occasional tooth, tusk, or bone of the great hairy Mammoth elephant or the Mastodon elephant may be discovered, together with the stone implements or bones of prehistoric man, and pebbles grooved by glaciers.

CHAPTER IV

THE PROSPECTOR'S LITHOLOGY, OR STUDY OF ROCKS

A PROSPECTOR wants to know a great deal about rocks. They are his constant companions in the field. His business is among rocks. He wants to be able to recognize them at sight, when he picks up a loose pebble or confronts a mighty cliff. When traveling over the mountains, as he surveys the grand panorama from the top, he wants, by the peculiar forms and patterns each variety of rock is apt to take as the result of erosion and weathering owing to different degrees of hardness, to be able to make a shrewd guess, from a long distance, as to whether one mountain is made of granite, or another of limestone, or a third of porphyry. This habit of forming rough guesses as to the character of distant rocks decides him as to choosing his course for prospecting. "In those sharp granite-looking peaks," he says, "perhaps I will find fissure veins. Yonder cones, like the spires and minarets of a Gothic cathedral, must be porphyry or igneous rock, another likely locality, and mark where they break through the sedimentary strata, and tip them up all around them; at the junction of these sedimentaries with the igneous rock there may be limestone, and a 'contact blanket' deposit. Yon smooth grassy slopes are probably underlaid by sandstone or limestone, and the rolling valley beneath by soft shales. The latter are unpromising for precious ores." Or, again descending from his perch into the cañon below, he recognizes the granite basis, and on top of it a series of sedimentary rocks. The lowest of these, by its rusty-white, masonry-like structure, he judges to be Cambrian quartzite; the thin-bedded strata above, Silurian limestones, and the heavy massive beds above these, Lower Carboniferous blue limestone; while a dark greenish-gray rock, running in and out irregularly among the strata, sometimes between the

CHARACTERISTIC APPEARANCE OF ROCKS IN THE FIELD.

A, Sedimentary Rocks Tipped up Against Intrusive Porphyry Laccolite; *B, C*, Basalt Capping Soft Shales; *D, D*, Distant Granite.

stratification planes, at others cutting across them, he judges to be an intrusive sheet of porphyry, and looks again for "contact" deposits. A rock running up like a low wall from the bottom of the cañon to the top may be either a quartz fissure vein or a porphyry dike, and well worth examining. There are many ways of studying rocks, one by hand specimens, finding out all the minerals composing them, and then naming the rocks from which they came; another by observing the appearance of large masses of rocks in the field, and noting their mode of occurrence; and lastly, if we wish to be very accurate, making thin microscopic sections and a chemical analysis, but for the average prospector these last will be rarely necessary.

If a prospector bought a manual to study rocks for practical purposes, he would find himself among a sea of names of varieties of rocks, nine-tenths of which it is safe to say he would never meet with in his field experience.

To save him the trouble of wading through such books, we select just about as much as a prospector is liable to meet with in the field or find practically useful, saying little about such common rocks which are familiar to every one.

SAN JUAN VOLCANIC PLATEAU MOUNTAINS.
Composed of a Succession of Lava Sheets Resting on Granite.

Those that need most definition and are of most importance in the mining field, are the crystalline rocks belonging to the class called metamorphic and igneous; the last especially needs careful determination.

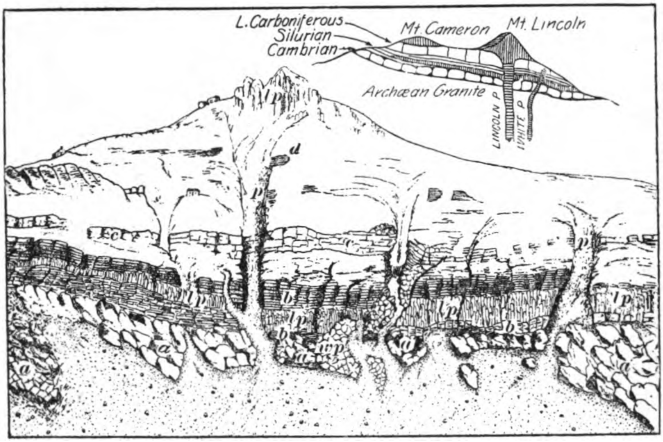
Nearly all sedimentary rocks (limestone excepted) are derived from fragments of igneous and metamorphic rocks. Probably nine-tenths of the sedimentary rocks are derived from granite alone, the remainder from the igneous rocks, such as porphyry, basalt, etc. By describing the parent rock, the derivative one is more easily made out.

ROCK-MAKING MINERALS

Crystalline rocks are made up of certain distinct minerals, most of them of quartz, feldspar, and mica, with sometimes, also, hornblende and augite. Other minerals may locally occur as occasional elements.

Quartz is too well known to need special description. The hexagonal prism of this crystal is too hard to be scratched with a knife, and will scratch glass. This distinguishes it from calcspar and barite, for which it might be mistaken in the field; moreover, it will not effervesce with acids.

The *feldspars* are nearly as hard as quartz. Their colors are white, grayish, and flesh color. They are rarely as transparent as quartz, being generally opaque. Their form of crystallization is different from quartz, and in a vein they show one smooth face of their crystal, while the quartz is more like crushed loaf sugar. In a porphyry the feldspar crystals are very distinct,



SUMMIT AND SECTION OF MT. LINCOLN AND NORTH WALL OF CAMERON AMPHITHEATER.

a, Archæan Granite; *b*, Cambrian Quartzite; *c*, Silurian Limestone; *d*, Lower Carboniferous Limestone; *l p*, Lincoln Porphyry; *w p*, White Porphyry.

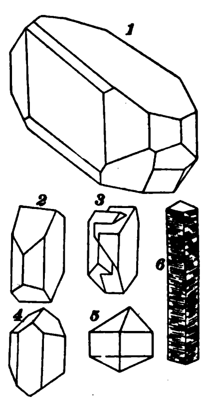
and give a characteristic spotted appearance to the rock. Two varieties of feldspar are characteristic of the crystalline rocks, one called orthoclase, or common feldspar, a potash feldspar, the other called oligoclase, a soda-lime feldspar. The former is very characteristic of granitic rocks as well as of igneous porphyries; the latter is rather more characteristic of more recently erupted igneous rocks, such as diorite, basalt, andesite, etc.

Orthoclase is generally in large crystals, oligoclase in small. When the crystals are very small, it may take a microscopic examination to determine to which variety of feldspars they may belong. The oligoclase and plagioclase crystals in igneous rocks are commonly but little white dots.

To determine accurately, microscopic slides and chemical tests must be made, but this is scarcely within the scope of the prospector, who wants to guess roughly at sight as to the name and character of a rock.

Mica, both black and white, needs no description.

Hornblende differs from mica in being of a duller luster and of a different form of crystallization, as shown in the plate. The color is a greenish black; the greenish tint is distinct when the crystal is struck by a hammer.



FELDSPAR, HORNBLENDE, AND PYROXENE CRYSTALS.

1, Triclinic Oligoclase Feldspar; 2, Monoclinic Orthoclase Feldspar; 3, Carlsbad Twins Feldspar; 4, Augite or Pyroxene; 5 and 6, Hornblende.

Augite or *pyroxene* is scarcely distinguishable from hornblende. In Colorado, augite is mainly confined to two kinds of rock, basalt or dolerite and andesite, both of comparatively recent volcanic origin. Hornblende and mica are common to nearly all the metamorphic and igneous rocks.

Talc among miners means almost any soft, sticky, or slippery, decomposed rock; but strictly, talc is a pale-green soft mineral like mica, and is a silicate of magnesia. Steatite or soapstone is massive talc. Miners often wrongly call any soft clay or rock soapstone also.

Chlorite is another magnesian mineral, of a green and soft character. Chlorite is again a name given to almost any greenish rock of a schistose and soft decomposed character.

Calcite is carbonate of lime crystal, the element of limestone, and is distinguished by softness and effervescing in acids.

Dolomite, or carbonate of lime and magnesia, is very like calcite, and is the element of dolomitic or magnesian limestone. Dolomite effervesces with much greater difficulty than true limestone. To effervesce, the dolomite should be powdered and the acid heated.

Gypsum, or sulphate of lime, can be distinguished by its extreme softness, being scratched by the finger nail; it does not effervesce like lime.

Barite, or "heavy spar," occurs in some veins, but not as a constituent of rocks. It looks like calcspar, but is heavier and will not effervesce with acids.

Fluorspar occasionally occurs in veins, in cubes or massive. It is easily scratched with a knife; its colors are green, purple, yellow, blue, or white.

Garnets, green epidote, black tourmaline, and other minerals or gems may occur, but not as important constituents of the rocks.

CRYSTALLINE METAMORPHIC ROCKS

Granite.—Beginning with the granite series of the Archæan age, granite proper is massive, shapeless, or amorphous, and shows no bedding planes or other signs of former stratification. It is thoroughly crystalline, like lump sugar. By some it is considered a true igneous rock, one that has been thoroughly fused by heat, as much as the lavas or molten iron; by others its crystalline amorphous condition is supposed to be the result of extreme metamorphism of originally sedimentary bedded

GRANITE.

PEGMATITE.

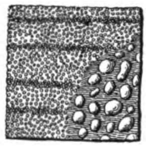
SYENITE.

rocks, such as gneiss or schist, the two latter being sometimes traced down through a gradual change into granite. The composition of granite is mica, quartz, and feldspar, with sometimes a little hornblende. The micas may be white mica (muscovite) or black mica (biotite). Both orthoclase and oligoclase feldspar may be present, but more commonly the former, which is often a pinkish flesh color. Granite, in its crystalline texture, differs both in character and appearance from porphyries and other igneous rocks, in the fact that its crystals are all jumbled up and crushed together like loaf sugar, and none of the crystals are set like plums in a pudding, distinctly in a backing or paste of very small crystals of amorphous or glassy material, as in the porphyries or igneous rocks. Granite is probably the oldest and deepest rock known. It is often traversed by sparry veins, both great and small, which consist of quartz or feldspar, or both, in a more sparry condition than when diffused through the parent rock.

These so-called "quartz veins" are often called "granulite," or "pegmatite," or "graphic granite." The quartz and feldspar are often arranged in parallel plates, giving on cross-section curious marks, like Hebrew characters; hence the word graphic. The bulk of our so-called quartz fissure veins in the granite mountains may be called pegmatitic veins. The colors of

GNEISS.

CONTORTED MICA SCHIST.



QUARTZITE (Part Magnified).

granite vary from reddish to gray, or nearly white to black, according to the preponderance and colors of the micas and feldspars in them.

Syenite is little more than granite without quartz, being composed of orthoclase feldspar and hornblende or mica, or both. It might be called a quartzless granite.

Gneiss may be called "bedded granite," showing a bedded appearance. Gneiss is often curiously and prettily banded or streaked by seams of mica dovetailing into each other. If mica preponderates, it is called "mica-gneiss;" if hornblende, "hornblendic gneiss."

Schist may be called laminated gneiss, or granite, being finely divided into lamina or leaves. This foliated structure is due to the arrangement of the flat-lying crystals of mica or hornblende largely composing it. It may be a mica-schist or a hornblende-schist.

Slate is shale altered by heat into a hard crystalline structure.

Quartzite was originally a sandstone composed of quartz grains, which by heat have been partially fused together at the edges, resembling granules of tapioca in a tapioca pudding. Quartzite differs from quartz in being a rock made out of pieces of quartz, and not the original mineral itself. Quartzite may be white like sugar, gray, brown, or rusty. It shows a true stratified structure.

Marble is limestone similarly changed to a more crystalline condition.

Serpentine is a green magnesian rock, sometimes found with marble and igneous rocks, and is formed by alteration of certain minerals in the latter.

CRYSTALLINE IGNEOUS, OR ERUPTIVE ROCKS

These are rocks which are supposed to have been thoroughly fused or melted in the bowels of the earth. Some reach the surface by fissures or volcanic vents, others have never attained to the surface or overflowed it, but have intruded themselves between the weak places in the underlying strata, or have congealed and cooled deep down below the surface, in great molten reservoirs called "laccolites," or lakes of stone. When these have been subsequently uncovered by erosion, they may present the forms of considerable mountain masses like the Elk Mountains, Henry Mountains, and Spanish Peaks. Geologists distinguish those rocks which have poured out on the surface from craters and volcanic vents as volcanic rocks, while those cooling below are called Plutonic.

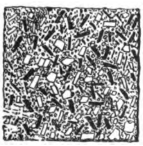
INTRUSIVE PLUTONIC ROCKS

The component minerals of these intrusive Plutonic rocks, such as are commonly called porphyries, are principally quartz and feldspar, with mica or hornblende. In color these rocks are some shade of gray, green, or maroon, or even white, but their most striking characteristic is a general *spotted* appearance. This arises from more or less large, distinct, perfectly formed crystals of feldspar or quartz, set in a finer-grained, crystalline paste or background, standing out distinctly from it. This base or background may be comparatively coarsely crystalline, finely crystalline, or so finely crystalline that the crystals can be discovered only by a microscope, while the larger crystals seem set in the paste, like plums in a pudding. In the depths of a mine, the porphyry is commonly much decomposed by water action or mineral solutions, and even passes into a clay or gouge. The characteristic spotty appearance, from the presence of individual crystals of feldspar, may even then identify the rock, or by chemical analysis the very aluminous character of the decomposed rock may determine its character. When feldspar is the main constituent, it is called a felsite porphyry; when a certain amount of quartz is present, a quartz porphyry.

Diorite, whose crystals are sometimes porphyritic in character, hence called porphyritic diorite or porphyrite, belongs also to this intrusive or Plutonian class, differing only from the others in the fact that its feldspar is of the triclinic plagioclase kind, rather than orthoclase. Hornblende is a prominent constituent of this rock, and gives it, more or less, its dark olive-green tint. In appearance it resembles a dark syenite, but its occurrence as an eruptive, intrusive rock distinguishes it, as syenite is generally a metamorphic rock. The peaks of the Elk Mountains are, many of them, of diorite. Diorite or porphyrite is the so-called porphyry of Aspen, above the ore deposits.

QUARTZ PORPHYRIES, OR PORPHYRITES

These are the commonest, and may be said to be the prevailing eruptive rocks associated with our ore deposits in Colorado, as for instance at Leadville, felsite porphyries as well as quartz porphyries occur in the granite rocks in the Central and Georgetown mining districts. All these rocks are common through



PORPHYRITIC DIORITE. (Porphyrite.)

FELSITE PORPHYRY.

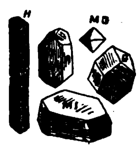
MT. LINCOLN QUARTZ PORPHYRY.

the West, and quartz porphyries are the most common eruptive rocks the prospector is likely to meet with in his search for ore deposits. We will describe in detail one or two typical species, though it must be observed that these porphyries are of endless varieties and shades of appearance.

Quartz Porphyry.—A quartz porphyry is a porphyry that contains quartz crystals large or small, in addition, usually, to large orthoclase feldspar crystals, generally of a vitreous glassy variety called sanidin, together with small crystals of hornblende or mica. As a typical example we take that which forms the dike composing the peak of Mt. Lincoln, Colorado, called Mt. Lincoln quartz porphyry. This porphyry and varieties of it are common in the western mining sections of Colorado.

In appearance it is a gray rock, spotted with large and small crystals of orthoclase sanidin feldspar, which sometimes show an oblong face 2 inches long by 1 inch wide; at other times, a shape like the gable end of a house, according to whichever part of the crystal happens to be exposed. Sometimes two crystals are seen locked together, forming what are called

LEADVILLE WHITE QUARTZ PORPHYRY.



HORNBLENDE, AUGITE, MICA, MAGNETITE, GARNET.

Carlsbad twins. When the rock is decomposed, these crystals not infrequently drop out and lie as pebbles on the ground. With these may be also seen rounded ends of bluish crystals like broken glass. These are portions of perfect quartz crystals, which when extracted show a six-sided pyramid at either end. These larger crystals are set in a crystalline ground mass of much smaller crystals of the same kind, together with many little black cubes of shining mica, or duller-lustered, longer, rectangular, oblong crystals of hornblende. This porphyry is eruptive and intrusive, occurring in dikes, intrusive sheets, and laccolites.

Leadville White Porphyry.—At Leadville there is a quartz porphyry known as the Leadville white porphyry, or "block porphyry" by the miners, which needs description, as it is the one that more especially is associated with the rich ore deposits. It is a white, compact, homogeneous looking rock, not unlike a shaly white sandstone or quartzite. It consists of feldspar, quartz, and a little mica. Its porphyritic or spotted character is so indistinct that one would be inclined to call it a felsite at sight rather than a true porphyry, but the microscope reveals perfect double pyramids of quartz and individual crystals of feldspar, set in a paste of the same minerals. It is often stained by concentric rings of iron oxide and marked with wonderful imitations of trees. The latter have earned for it the title of "photographic rock" or "dendritic porphyry." These markings are only the crystallization forms of oxide of iron, or manganese, something like fern frost on a window pane. The porphyry is very shaly, and breaks up in thin slabs; hence called, also, "block porphyry." It is common at Leadville and is also found elsewhere. In the same region there are many other varieties of quartz porphyry, such as the gray porphyry, the Sacramento, and the pyritiferous porphyry. The latter is often gold bearing.

YOUNGER EFFUSIVE VOLCANIC ROCKS

These intrusive plutonic porphyries and diorites are generally older than the other class, which reached the surface and poured over it, and which may be called, for distinction, "*effusive*" volcanic rocks.

Typical of these we may cite the dark basalts and dolerites that quite often cap the table lands of the prairie region and overlie our coal beds. A pinkish or dove-colored rhyolite also caps some of the mesas, and in certain of the districts, an andesite lava.

Dolerite and Basalt.—The latter being scarcely more than a fine-grained variety of the former, are very dark rocks, consisting of dark, heavy minerals, such as augite, magnetite, and a plagioclase feldspar called labradorite. Such minerals are said to be basic, and the rock composing them also basic.

Andesite is very like dolerite in appearance, though generally a lighter gray or pink. Both augite and hornblende may occur in it, more especially hornblende, sometimes mica also. The feldspar is called andesite feldspar, from the Andes Mountains. It often has a spotted, pepper-and-salt appearance.

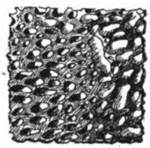
Rhyolite, under the microscope, shows a peculiar flowing structure, hence its name from *rheo*, "to flow." The lighter rocks in Colorado and the West are generally rhyolites rather than true trachytes. Their colors are pale gray, white, pink, or sometimes dark.

Rhyolite consists of a fluent, vitreous, ground mass or paste, usually containing crystals of sanidin feldspar, or even of quartz. When these crystals are conspicuous so as to give the rock a porphyritic appearance it is called "liparite."

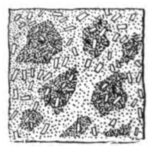
In some cases it may have even a granite-like appearance, the crystals of quartz, mica, and feldspar being more or less intermixed; then it is called nevadite. It is an acidic rock, consisting of acid minerals mainly.

Trachyte, from *trachus*, "rough," is a light-colored rock, with a peculiar, characteristic, rough feel, due to microscopic vesicularity. It consists of a ground mass of sanidin feldspar and

RHYOLITE LAVA.



AMYGDALOIDAL SCORIA.



ANDESITIC BRECCIA.

augite, containing crystals of the latter. In ninety-nine cases out of a hundred, in Colorado at least, also in the West, rocks which are popularly called "trachytes" are rhyolites or porphyries.

Basalts and some of the other extrusive volcanic rocks assume a columnar form on cooling. Also, on the surface of the flow the lava becomes minutely honeycombed like sponge from the escape of steam. This is called *scoria*, and when these holes are filled with almond-shaped white crystals, *amygdaloid*. At other times the rock is a *volcanic breccia;* that is, angular blocks of lava, great or small, are cemented together by lava. This probably was caused, when the lava was pouring out of the fissure slowly, by some portions congealing and being broken up by the onward flow, and becoming again involved in the molten mass without being remelted. Enormous masses of volcanic breccia cover the San Juan region. Sometimes, by steam, the lava is blown into dust, and descending with water, is worked up into a volcanic sandstone known as volcanic "tufa" or "tuff."

Obsidian is vitrified lava, or volcanic glass.

CHAPTER V

THE PROSPECTOR'S MINERALOGY

THERE are two classes of minerals in which the prospector is interested: one may be called the "earthy" minerals, such as quartz, calcspar, etc., associated with the precious ores; the other, the metallic minerals, constituting the ores themselves.

Both of these he wants to know at sight, or to determine with the simplest appliances. Generally speaking, his eyesight, his pocket knife, his ore glass and a little acid will be all he needs, nor need he concern himself about a great number of minerals, if he only knows the commoner ones well. The earthy minerals form the gangue or veinstone of the vein in which the precious ores are distributed.

EARTHY GANGUE MINERALS

These are principally quartz, calcite, or limespar, dolomite, fluorspar, and baryte, all of which we have already described among rock-forming minerals. These crystals are nearly always to be found in the adjacent rock as elements of that rock, and their more sparry condition in the gangue of the vein is derived by solution from the enclosing country rock. Thus, a vein running through granite will contain mainly quartz, though calcite and fluorspar may be associated with it in small quantities. A vein passing through limestone naturally carries calcite or limespar. Sometimes baryte is associated with the calcite, especially if near the limestone ore deposit there are porphyries.

Baryte has been detected as an element of some porphyries which are probably ore-bearing, and when prospecting, we have found baryte to be generally an indication of ore near by, while calcspar, or quartz, alone may or may not be barren. The float, or loose surface indications of ore deposits, at Aspen, is commonly made up of calcspar and baryte.

Fluorspar in Colorado is generally confined to veins in the granitic rocks and in some of the eruptive rocks. Its presence is a good sign of ore.

Oxides of Iron and Manganese.—These, often mixed together, form a large element in the gangue matter of a vein or ore deposit. Manganese can be recognized by its deep-black color. A beautiful rose-colored carbonate of manganese called *Rhodocrosite* is occasionally met with, associated with quartz and metal in some veins.

SPATHIC IRON.

Carbonate of copper is often associated with this gangue matter. It is readily distinguished by its bright-green or azure-blue color. "Float" is commonly rusty with iron oxide, and streaked with stains of copper carbonate.

Spathic iron, or *iron carbonate*, or *siderite*, occurs here and there in the gangue of fissure veins. It is very like brown feldspar, but heavier. These few common minerals cover nearly all that are generally met with as indications of, or in important connection with, ore deposits.

As a rule, most of these minerals occur in a massive state rather than as individual crystals in a vein.

METALLIFEROUS MINERALS

Through these gangues of various characters the precious metals are distributed in long, narrow patches or strings, or in large crystalline masses, or in scattered crystals, or in decomposed masses. The gangue matter is generally in the majority in a vein, and the ore thinly, sparingly, and irregularly distributed in it. When a vein is said to be 10 or more feet wide, it is not to be supposed that 10 feet of solid ore is meant, but that this is the width of the gangue between walls. The ore body may be only a few inches wide. The streak or main body of ore, called the "pay streak," has a tendency to keep near one wall or the other, or at times to cross from wall to wall.

HIGH- AND LOW-GRADE ORES

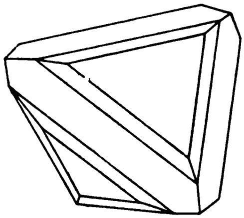
In gold veins, flakes or wires of "free" or "native" gold occur in the decomposed gangue, and sometimes in the pure, undecomposed quartz; "native" silver is found in much the same way, but more as specimens than as continuous bodies. Isolated patches of rare or valuable minerals, such as ruby silver, horn silver, silver glance, etc., occur locally in parts of the vein, sometimes coating stalactites or crystals of a "vug" or cavity lined with quartz or other crystals. An assay from such picked specimens would give a very unfair average of a mine or prospect.

The bulk of the profits of a mine come from the commoner minerals, such as galena, pyrite, or lead carbonate, and from the average grade of the mine. In California gold mines the average yield of gold to the ton is $16. In Dakota, $6. In the silver-lead mines of Leadville, $40 a ton is the average, and the ores are mostly low grade. A few mines of extraordinary high grade may yield from $75 to $100 a ton, but these are exceptional. Quantity of ore, facility for milling, cost of freight, the size of the vein, and its facility for working and nearness to market, give the offset.

DECOMPOSED MINERALS

Sometimes the gangue matter contains a variety of decomposed ore, in rich secondary combination, intimately mixed through its mass and rarely discernible by the eye. Thus, yellow mud from a mine may assay high, from the presence of invisible chlorides or sulphurets of silver. No accurate estimate of the value of a mine, or even of a piece of ore, can be found without an assay or mill run. The reason for such richness in decomposed surface products is that nature has been for ages leaching out, concentrating, and combining in richer forms the essence, so to speak, of the upper part of the vein.

Gray copper (*Tetrahedrite*).—Besides the ordinary galena and pyrites common in most mines, we sometimes find considerable bodies of gray copper in mines, or intermingled with other ores. This is generally a rich silver-bearing ore, running from sixty to some thousands of ounces to the ton. It generally occurs massive, rarely showing its pyramidal "tetrahedrite" crystals. In appearance it is not unlike a freshly broken piece of bronze. It is more common in fissure veins in granite and eruptive rocks than in limestone. In Halls Valley, Colorado, it is associated with baryte in a vein in the gneiss. It occurs in the Georgetown veins in granite. In the San Juan district it occurs also associated with baryte in the Bonanza mine; and an ore not identical with it in composition, but very like it in appearance, called bismuthinite, consisting of bismuth, antimony, copper, and silver, is characteristic of that region and is rich in silver. *Bismuthinite* has a more shiny, tin-like appearance than gray copper, and the red color which bismuth gives to charcoal under the blowpipe readily distinguishes it from gray copper. Gray copper has but little value as a copper-bearing ore.



GRAY COPPER (TETRAHEDRITE).

LOCAL VARIATIONS IN VALUE OF ORES

There are locally in different mining districts considerable differences in the value of certain minerals and ores. In one district gray copper may rarely exceed 60 ounces of silver; in another it is invariably over 100 ounces.

A coarse galena is generally poor in silver, while fine-grained "steel" galena is generally rich in silver; but the reverse may also be the case. In some of the mines at Aspen, fine-grained galena, especially near the surface, is quite poor in silver, while in other mines in the same district it is exceedingly rich. Localities occur, also, where coarse-grained galena runs well in silver and is richer than fine-grained galena. This is the case at the Colonel Sellers mine at Leadville. So one mining district or even one mine is not a rule for another.

Pyrites.—Iron pyrites and copper pyrites, common in most of our quartz veins in granite and in the eruptive rocks, may yield both gold and silver, but usually the former. There are certain districts more characterized by pyrites than others, such as the Central City district. These are generally gold-producing districts. Some of the mines at Breckenridge and South Park have strong pyritiferous veins in eruptive dikes, such as the Jumbo mine. These have of late produced a great deal of gold. The same district, however, produces large argentiferous lead veins. Pyrites generally favors the granite, eruptive, and crystallized rocks. The quartzites of the Lower Silurian of South Park and Red Cliff are often pyritiferous and generally gold-bearing. In limestone the pyrites is rare or absent, its place being filled by some form of iron oxide. In the deeper mines of Leadville, however, this iron oxide is beginning to pass down into the iron sulphide or pyrite from which it was derived. Iron pyrites can generally be distinguished from copper pyrites by its paler, more brassy color, by its superior hardness, and by its crystallizing in cubes. Copper pyrites is much yellower and softer, and crystallizes in a more pyramidal form. A vein may glitter with showy iron pyrites and yet be quite valueless. It usually yields more gold in its decomposed, oxidized condition than in its unaltered state. In the one case the gold is free-milling, and in the other it must be smelted at much greater expense.

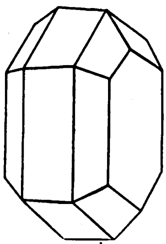
Sulphurets.—This term among miners is loosely used, and often means some decomposed ore whose ingredients cannot be determined at sight, but which somehow assays high in silver. True sulphuret or sulphide of silver is a name embracing a large family of rich silver ores, among which are stephanite or brittle silver, argentite or silver glance, sylvanite or graphic tellurium, and polybasite.

All these rich ores are compounds of sulphur and silver and other ingredients in varying proportions. They are somewhat alike in appearance and not always so easy to distinguish.

Argentite, silver glance, or sulphuret of silver, is of a blackish, lead-gray color, easily cut with a knife, and consists of an aggregate of minute crystals. Its composition in 100 parts is sulphur 12.9, silver 87.1. Under the blowpipe it gives off an odor of sulphur and yields a globule of silver.

Stephanite, or "brittle" or "black" silver is closely allied to argentite. Its composition is sulphur, antimony, and silver, silver being 68.5 per cent. The crystals are small. Under the blowpipe it gives off garlic fumes of antimony, and yields a dark globule from which, by adding soda, we get pure silver.

Polybasite, common at Georgetown and in some of the Aspen mines, such as the Regent or J. C. Johnson, on Smuggler Hill, is like the others, but of a more flaky, scaly, and graphitic appearance. It is not unlike very fine-grained galena, yielding 150 to 400 ounces of silver per ton.



STEPHANITE.

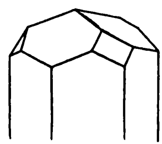
These sulphurets sometimes line little cavities in limestones with a dark sooty substance, which under the microscope proves to be crystals of one of the sulphurets of silver. Sometimes, also, a rock is stained all through a blackish gray by these sulphurets. Iron or manganese may produce much the same effect, but an assay will soon reveal the difference. Associated with such a rock we may see flakes or wires of native silver that have emerged from the sulphide state.

CHLORIDES

Chloride of Silver (*"Horn Silver,"* or *Cerargyrite*).—This is another result of secondary decomposition from a sulphide state (silver sulphide). It is a greenish or yellowish mineral, like wax, and easily cut with a knife. It is a very rich ore, running 75.3 per cent. silver, the remainder being chlorine. As a secondary product of decomposition it is generally found near the surface or in cavities, sometimes deposited on calcite or other crystals. In the mines at Leadville it is commonly associated with other decomposed ores, such as carbonates. In the Crysolite mine, a mass weighing several hundred pounds was found. Chloride, bromide, and iodide of silver are closely related, being compounds of chlorine, bromine, iodine, and silver. It is noticeable that these salts are the elements of sea water, and that these ores are often found in marine limestones. According to Mr. Emmons, the change at Leadville from sulphide to chloride was produced by surface waters; these waters are found to contain chlorine, which they have in all probability derived from passing through the dolomitic limestones which contain chlorine in their crystals, and these limestones perhaps originally derived it from the sea water in which they were deposited. Chloride of silver is found at Aspen and abundantly in the outcrop of mines in the territory of New Mexico and in Mexico.

SULPHARSENITES

Ruby Silver (*Pyrargyrite and Proustite*).—This is composed of sulphur 17.7, antimony 22.5, silver 59.8 = 100. It crystallizes in rhombohedrons, is seen in spots or crystals on a mass of ore of a deep red or blackish tint. When scratched with a knife it shows a bright- or deep-red color. In some mines this very rich ore occurs only as specimens, but in others it is present in sufficient quantity to largely influence the value of the ore in bulk. In parts of the Granite Mountain Mine in Montana, it constitutes the principal ore, associated, however, with other minerals. It there occurs in large masses and accounts for the extraordinary richness of that celebrated mine. Proustite is much the same, only a lighter red, and consists of sulphur 19.4, arsenic 15.1, silver 65.5 = 100.



RUBY SILVER.

CARBONATES

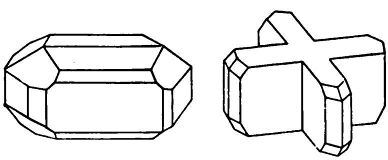
This term also embraces a large family, the commonest being carbonate of lead (cerussite) and carbonate of copper (malachite and azurite).

Copper carbonate can never be mistaken, owing to its brilliant-green and azure-blue color. Copper stains are among the common surface signs of a "lead." It is generally associated also with rusty stains. Both are the surface products from copper and iron pyrites forming a vein below ground which may or may not be profitable. Copper stains are common enough in many rocks, but do not always lead to bodies of ore. A very little copper will make a very wide green stain, enticing to the prospector but commonly deceptive. In South Park the red Triassic sandstones are so stained, but yield no ore. Along our foothills there is quite a stained belt from Golden to Morrison, and through Bergen Park. But few promising deposits of copper or other ores have been found, although handsome specimens of native copper have been discovered near Golden.

At the Malachite Mine, on Bear Creek, near Morrison, a prospect was at one time opened showing a good deal of silicate of copper (chrysocolla) and malachite, but for some reason it has not been worked since.

Copper in its native or uncombined state is rare in Colorado, and so far we have as yet no true profitable mine. A great deal of copper is found associated with other ores, and is extracted by some of the smelters. Carbonate of copper is not uncommon in the limestone districts, as might be expected from the carbonating influence of limestone upon minerals in it, or mineral solutions passing through it. Carbonate of iron (spathic iron, or siderite) constitutes part of the gangue matter in some of our veins, and may also be found associated with coal seams generally, in the latter case in an oxidized condition.

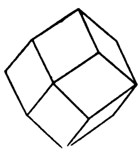
Cerussite (*Carbonate of Lead*).—This is mostly found in the limestone districts, such as Leadville. It is there known in two forms, one called "hard" carbonates, the other "soft" or "sand" carbonates. The crystals of this ore are small prisms, sometimes combined into a cross-shape, of a pale grayish white, and might be taken for some form of carbonate of lime or gypsum; their weight, however, soon shows the difference. They are a secondary product of decomposition, consisting of carbon dioxide and lead oxide; as a carbonate, they effervesce in nitric acid, and yield lead when heated. Cerussite is exceedingly rich in lead, carrying seventy-five per cent. The white lead of commerce has the same composition. In Leadville and elsewhere in Colorado it is silver-bearing also, and, though low in silver, the facility of its treatment at the smelter makes it a very desirable ore. As a rule it contains less silver than the unaltered galena, but is more easily treated than the latter. The process of change or derivation from a sulphide state (i. e., from galena) to a carbonate, is well shown sometimes in a piece of Leadville ore. A central kernel of galena is surrounded by a grayish-green ring of sulphide of lead or anglesite, and



SIMPLE AND COMPOUND CRYSTALS OF CARBONATE OF LEAD (CERUSSITE).

outside this may again occur crystals of lead carbonate. Thus the process is from a sulphide to a sulphate, then to a carbonate. The so-called hard carbonate is a brown mass, consisting of a hard, flinty combination of iron oxide and silica, impregnated with crystals of lead carbonate, with which are often silver chlorides also. The sand carbonates result from the decomposition and breaking up of the hard carbonates, or from a mass of pure crystals of carbonate of lead, which are, by nature, loose and incoherent. The Leadville mines are getting below these products of decomposition and entering upon the original sulphides of galena and iron. The yield in silver, however, is said to be equally good.

Zinc-Blende (*Sphalerite*) "*Black Jack*".—This is common in most mines, mixed with other ores. As it is a very refractory mineral in smelting, much of it is not desirable in a mine. It is easily recognized by its brown, resinous look, or, when very black, by its pearly luster. At Georgetown, near the surface, brown "rosin-zinc blende" carries silver, and is associated with rich ores, such as polybasite and gray copper. With depth the zinc blende becomes more abundant and blacker, and loses much of its silver properties. Zinc blende may run from nothing to twenty dollars silver, and rarely as high as $100 to the ton.



ZINC SULPHIDE (ZINC BLENDE).

In some mines in the San Juan, it occurs abundantly near the surface and fades out with depth. We have no true zinc mines in Colorado, the zinc being mixed with other ores. In some mines in Pitkin County the zinc predominates over all other ores, and though it runs high in silver, the smelters do not care to take it, on account of its refractory character. In the Eastern States, where zinc smelting is a specialty, such ore might be separated and both silver and zinc saved. In Missouri, zinc and lead are found together.

In Colorado there are no mines of one mineral alone, as in some other parts of the world. We have no true lead, zinc, or copper mines; these baser metals are either argentiferous or auriferous, and their baser qualities are sacrificed for their richer ones.

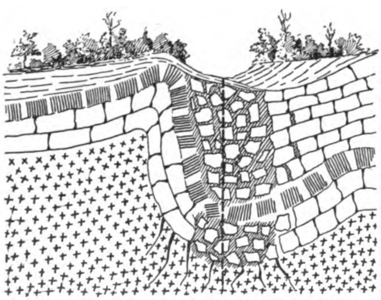
CHAPTER VI

ORE DEPOSITS

THEORIES REGARDING THE ORIGIN OF ORE DEPOSITS

A PROSPECTOR will find both a practical as well as a scientific interest in considering the origin of ore deposits. Where do the precious metals come from? What is their origin? How are mineral veins formed, and how do precious metals get into them?

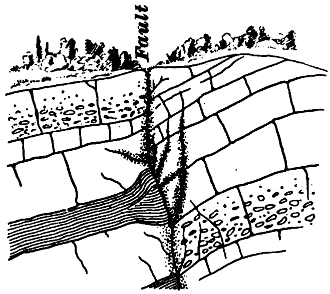
The remote origin of metals is a matter of speculation. They may have formed part of that gaseous mist from which, according to the nebular theory, our planetary system was evolved. As this passed into a molten condition, the metallic vapors may have separated into various combinations, and consolidated and been arranged in the general make-up of the world, accordin to their specific gravity. Some have thought that the interior of the earth may be more metalliferous than the surface crust, since the earth grows heavier towards the center. Volcanic rocks coming up from depths unknown contain a large per cent. of the heavier metals, particularly iron. But we turn from these speculations to theories of more practical interest to the prospector.



FOLD SHOWING BROKEN CHARACTER OF FISSURE AND ADJACENT ROCKS PRODUCING LATER A BRECCIATED VEIN AND "HORSES."

A prevalent theory, among miners and prospectors, is what may be called "the igneous theory," or the fiery origin of veins and metals. They are apt to attribute the fissures themselves to some violent volcanic outburst, and consider the quartz gangue or veinstone, together with the metals, as molten volcanic emanations, filling at one time a wide, gaping fissure.

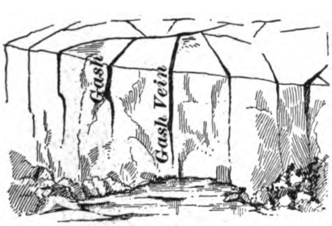
Others demand an intense heat, considering that the metals in the veins were reduced in the bowels of the earth by intense heat to a vaporous condition, which, ascending through the fissures, condensed and consolidated in a crystalline form in the upper and cooler portions of the fissures, as certain sublimed mineral vapors from a smelting furnace sometimes collect and recrystallize in the flues.



A TIGHT-FAULT CREVICE BEING ATTACKED BY SOLUTIONS PRODUCING FINALLY A NARROW FISSURE VEIN. (SMALL DOTS INDICATE ORE SOLUTIONS.)

By many prospectors every indication or surface appearance of a vein, or even a likely-looking rock, is called "a blow-out," a term suggestive, at least, of some sort of volcanic explosion at that point. With them, the "fire and brimstone" origin of ore deposits is as deep-seated as the veins in the rocks. These ideas contain a measure of truth, and were naturally suggested by observing that our ore deposits are so generally associated with volcanic rocks and evidences of past heat; and it cannot be denied but that the presence of these volcanic rocks had more or less to do with the ore deposits.

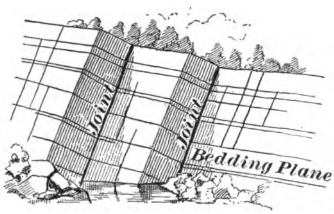
The modern study of ore deposits inclines to the belief that we need not draw directly upon the unknown profound supposed ignited regions of the earth's interior for the direct source of metals found in the veins, nor ascribe them entirely to violent explosive volcanic agencies, nor very intense heat, but rather that we may look nearer home for the immediate source of both metals and veinstone, namely, in the elements of the common country rock adjacent to the ore deposits; and for the medium of distribution and concentration of ore and veinstone nothing more violent or volcanic than water, more or less heated and alkaline. Nor is it so absolutely necessary to suppose that the filling of a vein fissure with quartz or metal must needs come *up* from profound depths, and from a foreign source; but quite



GASH-VEIN FISSURES IN JOINTED ERUPTIVE SHEET.

as likely from the adjacent sides of the fissure, or even from above the position later occupied by ore.

Veins of whatever kind are not vents for molten volcanic matter, but simply courses for water, more or less heated and alkaline, in fact, channels of mineral hot springs, carrying earthy minerals and metals in the same solution, and depositing them, partly by cooling and sometimes by chemical precipitation, and mainly by relief of pressure in such openings or weak places as may be found convenient.

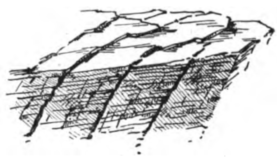


JOINTS AND BEDDING PLANES.

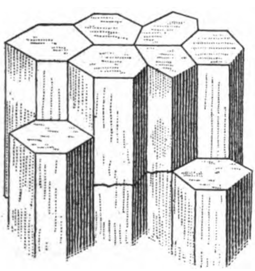
The origin of these openings and weak places in the earth's crust is various. The class of great fissures holding "fissure veins," cleaving our mountains from top to bottom to an unknown great depth, were caused by the fracturing and faulting of rocks, in the gradual process of folding upwards, and elevation of the mountain system, a process so slow and gradual that it may be even progressing now without one noticing it. The relief of extreme tension from folding results finally in faulting; though the fault fissure may extend to very great depths, it was probably not violent but gradual. From time to time, the shock produced by the grinding together of the walls of a fissure, in a slip or jerk of only a few inches, may have given rise to severe earthquakes on the surface.

JOINTED GRANITE.

A great fault fissure, too, was likely to be accompanied by minor adjacent faults, and also by small incipient fissures or loose fractures of the rocks, producing parallel fissures and zones of fissure veins. Other openings, occupied now by fissure veins, may be compared to those joints common to all rocks, the result of contraction and shrinkage of the granitic or volcanic rocks from a soft, semiplastic condition to one more solid and compact. But in no case, we think, were the fissures now occupied by veins 50 to 100 feet wide, originally wide open chasms, like that which swallowed up Korah, Dathan, and Abiram in Bible history, but rather cracks fitting very tightly together by enormous lateral pressure, such as we see in fault cracks of the present day, not yet occupied by veinstone or gangue or metal matter. These narrow cracks were worked upon by alkaline and by acid solutions and enlarged by the process, the rock gradually eaten into being replaced by gangue and metal matter, a process often further assisted by the shattered character of the rock commonly found adjacent to a great fault; this shattered cavity was sooner or later eaten out, so to speak, and replaced by mineral matter. Some of the broken rock, not being consumed in this way, was left, forming fragments in the vein, which when small are called "breccia" and when large, "horses." The great "gash" fissures, such as we find occupied by so-called fissure veins in volcanic sheets, such as those of the San Juan region, Colorado, appear to be due not so much to great earth movements, like the last, as to openings formed by cooling and contraction of the lava, somewhat as may be observed on the cooling of iron in a slag furnace. Ore deposits of lead and other minerals forming bedded deposits in limestones find their way in solution through the vertical joints common to all water-formed rocks, resulting from contraction in consolidating from a soft, muddy condition. Such fissures are short, but they act as channels to a more important line of weakness occupied by the main body of the blanket ore deposits, viz., the dividing line between one stratum and another. Another line of weakness for the attack of mineral solutions is at the juncture of a porphyry sheet or dike with some other rock. The interval between them is often occupied by a "contact" vein. The heat of the volcanic



JOINTED SLATE.

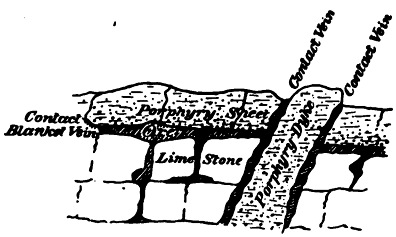


JOINTS IN COLUMNAR BASALT.

matter, together with steam, may have influenced the solutions, even if the porphyry did not actually supply the metallic element in the vein.

FOLDING AND FAULTING

In the many and great upheavals of the earth's crust, resulting in continents rising above the sea, and on those continents still greater and sharper upheavals forming mountain ranges, rocks have been much broken and fractured, from great fractures forming fissures miles in length and depth, down to little cracks of but a few inches. Much of this fracturing has been caused by the folding and crumpling upwards of strata into mountains, accompanied by great crushing and mashing together of the rocks. When this lateral tangential folding and compression of the rocks reaches its maximum intensity, the rocks break, and a fault or slip is the result, with its attendant fault fissure. This relieves the strain for a while, but the shock, doubtless at the time accompanied by earthquakes on the surface, resulted in a general breaking up of the adjacent country into many parallel and smaller faults and cross-faults, besides a general shattering of the ground intermediate to the faults. A region thus faulted and shattered is just in the desired condition for forming a future mineral belt or mining region, when the cracks and scars thus made have been healed and filled up by mineral matter, brought in through the agency of watery solutions more or less alkaline or heated.



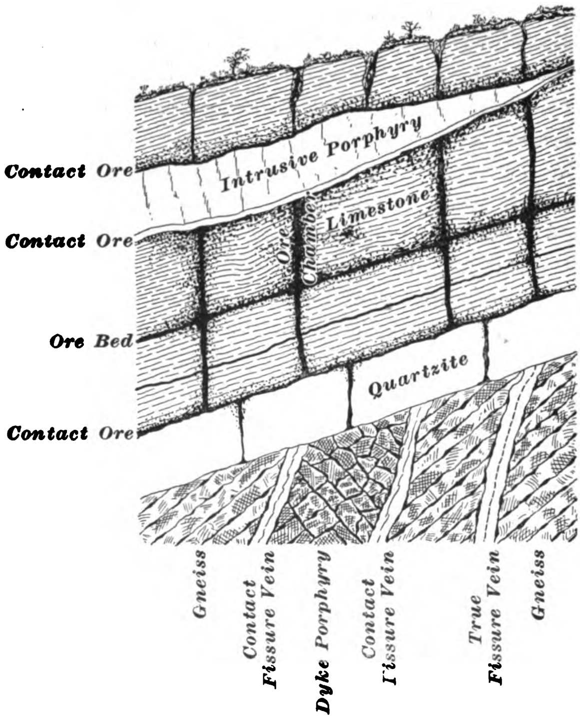
CONTACT ORE DEPOSITS BETWEEN PORPHYRY AND LIMESTONE.

INTRUSIVE IGNEOUS ROCKS

When these fault fissures descend to a very great depth, they may tap the molten-rock reservoir supposed to lie beneath great mountain ranges, and the molten lava or porphyry rushes upwards through the weak line of the fissure, fills it with its matter, which on cooling becomes a dike instead of a mineral vein. These eruptive rocks may or may not reach quite to the surface and overflow it in a lava sheet. If they do not, they find relief by intruding themselves laterally between the layers of stratified rocks, whose leaves or bedding planes may have been partially opened, like the leaves of a crumpled book, by previous action of folding. In such cases the porphyry dike or intrusive sheet may, if it be mineralized, answer all intents and purposes of a mineral vein, or the ore may be found on one or both sides of such a sheet, in the line of separation and weakness between it and the adjacent strata, or it may permeate and mineralize, by a "substitution" process, an adjacent porous or soluble rock, such as limestone. Thus both in the dike or intrusive sheet itself, as well as at its contact with other rocks, the prospector should look for signs of precious metal.

If the dike or sheet should be decomposed, clayey, and rusty, it may contain free gold disseminated through it, which, at a depth that may or may not be ever reached by mining, passes into the auriferous iron pyrites, from which the free gold originally came. In this case, the ore will be no longer "free" or "free milling," but of a character that must be subjected to the more expensive treatment of roasting or smelting, or, it may be, cyaniding or chlorination. Little stringers or veinlets of quartz, if observed in such an eruptive rock, should be carefully examined as the most likely source of the richest gold ore. Some of our most noted gold mines, in the West, are in these "rotten" mineralized dikes, or eruptive intrusive sheets. "Likely signs" in such would be rusty "gossan" stains of green carbonate of copper and gouge, or clay matter. It is worth observing that the dike may be only valuable as a mine as far down as the decomposition lasts and as long as the ore continues in a free state. With depth, the pyrites of the undecomposed lower portion of the dike may be found too poor in gold to pay for smelting or other processes.

As this desirable state of decomposition is the result mainly of the action of surface waters, a prospector may consider sometimes, where, on the outcrop of such a dike, the rock is most likely to be deepest affected by surface action; for example, more probably below the old stream bed than on the top of a mountain, but this is not always the case. Most dikes and intrusive sheets, when mineralized, are mineralized by pyrites rather than by galena; hence, they are generally more gold-bearing than silver-bearing. The contact deposits adjacent to a volcanic rock may have been aided in their deposition by steam issuing from the molten mass, or by heated waters or steam ascending with it, or generally by the heat of the dike, as heat,



"CONTACT BLANKET" ORE DEPOSITS AND "CONTACT FISSURE VEINS."

together with moisture, is a great solvent of rocks and promoter of chemical action.

In granitic rocks, if a "contact" deposit occurs adjacent to a porphyry dike, it is usually a quartz vein, or a vein composed of quartz and feldspar, commonly called "pegmatite." Such contact fissure veins may be on one or both sides of a dike. The telluride veins of Boulder, and the gold and silver veins of Idaho Springs, Central, and Georgetown, in Colorado, are often so situated.

CONTACT DEPOSITS

When a porphyry sheet intrudes itself into limestone, as at Leadville, the ore may be looked for on either side of this sheet; but more commonly below it. At first the ore seems to permeate the limestone immediately at the line of contact, but from this somewhat definite line it is apt to run down through joint cracks in the limestone, enlarging the cracks by solution, and substituting or replacing the dissolved rock with silver-lead ore, by a process called "metasomatic substitution."

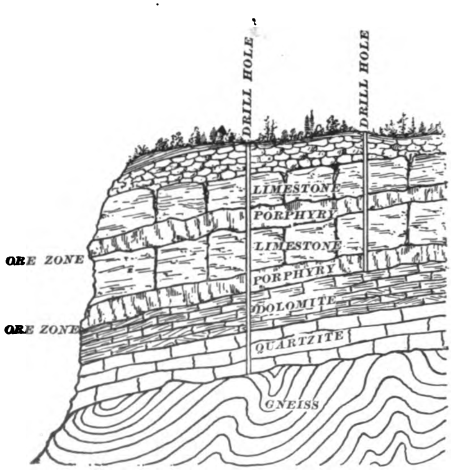
"Metasomatic" means, literally, "an interchange between one body and another." In this case it is an interchange between metal and limestone, by which the limestone is gradually replaced, molecule by molecule, with metallic matter. Thus we may suppose that, as the mineral solutions were working on the limestone, rotting and soaking and dissolving it, as each molecule of lime was dissolved it was replaced or substituted by a molecule of metallic matter, until a large body of the rock was replaced by ore. This appears to be the true way in which most of our ore bodies were formed in limestone and other soluble rock, rather than that they were washed in and deposited in "pre-existing large cavities," as some have supposed.

BLANKET DEPOSITS ON BEDDING PLANES

The solutions, having worked their way down through these vertical joints, may reach a second line of weakness, viz., the bedding plane or line of stratification between one bed or stratum of rock and another, and deposit along it as on a floor. This may be between one heavy bed of limestone and another. If it is between two *dissimilar* rocks, such as between limestone and quartzite, or even between limestone and magnesian limestone, called dolomite, it comes under the name of a "contact" deposit. Thus it is noticeable that besides great fissures, lines of weakness, or "bedding planes" are favorite places for ore deposits, to which the natural vertical joints often act as feeders, as well as themselves containing large "pockets" or "chambers" of ore. When the deposits are confined to these pockets and there appears to be no "blanket" deposit, the mine is said to be "pockety," and, after a pocket is exhausted, an immense amount of money and work and blind "gophering" often follows in hunting for another pocket. There is in this case little rule to guide the prospector. Locally, by experience in the mine, he may notice that a fine line of gypsum, calcspar, or iron stain is likely to lead to a pocket, and so follows it. In the mines of Aspen, where the mineral zone lies irregularly, but generally near about the line where the limestone becomes dolomized, a miner, when his ore "plays out," follows as closely as he can this line, which he is able to do by the different hardness of the limestone and dolomite, the latter causing his pick to ring. In every mine there is generally some local sign to assist the miner in following up his lost ore.

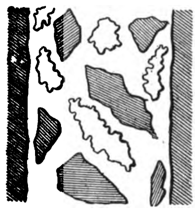
SURFACE SIGNS

The prospector, in hunting on the surface outcrop for signs of such contact or blanket or pocket deposits, must look out for signs of decomposition along the line of contact, such as lead carbonates, carbonate of copper, oxide of iron, together with crystalline matter, such as calcspar, gypsum, or baryte. He may also observe, in the vertical joints leading down from the surface into the body of the limestone, rusty clay fillings and iron stains. In these blanket-bedded deposits, prospects on a large scale may sometimes advantageously be made by drilling with diamond drills from the surface down through as many of the strata as are suspected of being ore bearing; the "cores" brought up will show if an ore body has been penetrated, together with its approximate thickness at a certain point, and if this process is continued over a



PROSPECTING WITH DIAMOND DRILLS.

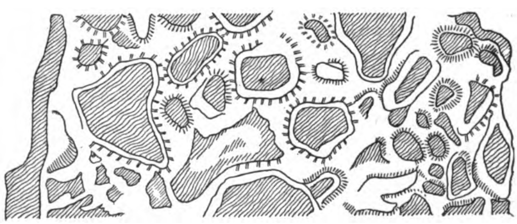
certain area, the approximate areal limit of the ore body may be ascertained. This work may follow upon a close examination of mineral signs along the outcrop. It is sometimes done, after an area has been exploited for some time by actual mining, with a view of discovering new bodies or continuations of the ore.



Brecciated Lode with Quartz Geodes.

TRUE FISSURE VEINS

While profound fault cracks may be filled by lava, those not descending to such great depths doubtless lay open till they were gradually filled by solutions carrying in earthy veinstone and metallic matter; in a word, they were the channels of mineral or hot springs. It must not be supposed that these fault cracks were ever "open chasms," commensurate in width with the wide dikes and veins now found in them, but rather in some cases very close-fitting cracks, mere lines of weakness, the walls appressed closely together by prodigious lateral pressure. In other cases, the fissure would be rather a shattered zone, passing down through the strata, than one definite line of fissure. Doubtless, when the molten lava ascended through

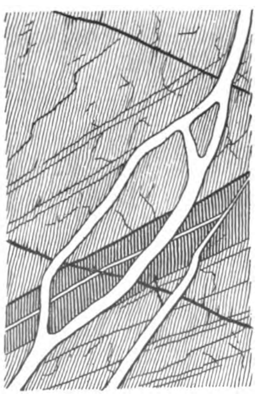


Brecciated Vein.

these fissures, it greatly widened them, to admit of its volume. In the case of true fissure veins, the fissure or shattered zone was enlarged by the corroding, substituting power of acid mineral solutions, till we have today a fissure vein 20 to 50 or more feet in width. In the shattered zone, this substituting process would go on easily and rapidly, until nearly all the shattered fragments were replaced by mineral matter except a few "indigestible" pieces, which, if small, would cause what is called a brecciated vein, and if large, "horses" in a vein. These fragments are not so much pieces that have fallen from above into an open fissure, gradually filling up with solutions of quartz and vein matter in which they became entangled, but rather undigested, unsubstituted fragments of the wall rock, immediately adjacent to the fragments, for at times some line in the fragment corresponds to a line in the adjacent wall rock, without evidence of any serious displacement. Again, the shadowy outlines of fragments can be observed partially, but not entirely, replaced by quartz or vein matter. Sometimes the "breccias" are surrounded by rings of quartz or metal, and called "cockade ores."

HORSES

In the San Juan region, in Colorado, where we have wonderful opportunities of observing extensive sections of great fissure veins descending the faces of cliffs on either side of a cañon, for two or three thousand feet, such broad veins, at intervals, split up into two or three arms enclosing large fragments, or "horses," of the lava country rock, and again unite to form the main vein. These veins occupy a once shattered fissure, the walls of which were originally neither straight nor regular, but shattered and cracked. The vein matter insinuated itself between the shattered portions, sometimes forming a breccia of the small fragments, at others "horses" of the large ones.


HORSE OR RIDER.

The appearance of these great San Juan veins, from a little distance, is that of broad yellow stains of oxide of iron, contrasted with the somber gray of the lava rocks. In some places in this region the quartz, by reason of its superior hardness, stands up above the softer lava like a low, rusty, or white wall. Again, at other localities, instead of being a bold outcrop, the vein is represented by a sharp, shallow depression, forming a narrow little ravine or trench, the path of a rivulet, and zone of abundant vegetation. In this case the vein was full of decomposable minerals, such as pyrite, whose oxidation decomposition products were washed out, leaving a depression in the rocks.

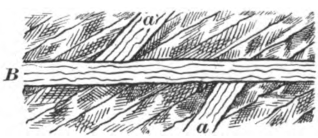
So, among some of the indications of a fissure vein to the prospector we may note:

1. Brown or green stains on rocks.
2. A bold quartz vein like a wall above the country.
3. A narrow ravine or gulch.
4. The path of a rivulet and exuberant growth of vegetation.

SIGNS OF FAULTING

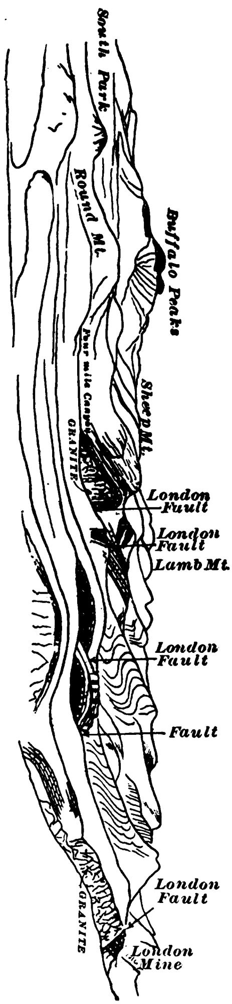
As these fissure veins are generally the filling of fault cracks, and the fissures are mainly due to faulting, a prospector should be able to recognize the surface and other signs of faulting.

Faulting, as we have said, is generally the result of extreme folding. So, in entering a mountain region by way, perhaps, of a cañon cutting right through it on the exposed face of the cliffs, he may observe some of these folds or arches, low and gentle at first, but gradually, as the range is penetrated farther, increasing in sharpness, steepness, and closeness; with this increase we may expect faults. The presence of the fault may be indicated by a little sag, or depression, in the outline of the hill, or by a line of rubbish and broken rock descending the face of the cliff, or by a zone of exuberant vegetation, or by the pathway of a little rivulet. He will observe a general fractured tendency of the rocks as they approach the fault line. By closer search, he may notice pieces of rock polished, or "slickensided," by the movement of the walls of the fault slipping and grinding upon one another. Slickensides is a sure proof of motion having taken place in the rocks, and is often observed on the walls of fissure veins. A much faulted region is often marked by a step-like outline, each step representing the fallen or risen side of a fault block. These fault lines should be carefully examined for mineral indications, especially if the fault line is occupied by a porphyry dike or a vein of quartz or



VEIN *a* FAULTED BY CROSS-VEIN *B*

calcspar. Sometimes these fault lines are totally barren, both of quartz, veinstone, or metalliferous matter. They may be filled up with clay, rubbish, and broken rock, or the two walls may be actually welded together by pressure accompanied by a certain amount of heat, producing local metamorphic action.



FOLDED AND FAULTED STRUCTURE OF MOSQUITO RANGE, COLORADO.

Faulting, too, in some regions, may have occurred comparatively recently, or at least after the period most marked by deposit of mineral solutions and ore deposits, in which case the fissures may be barren or at present occupied by hot or mineral springs making veins for the future. A stupendous, comparatively modern fault runs along the west base of the Wahsatch Mountains, in Utah; its line is marked by a series of hot springs.

Along the face of a cañon wall the prospector may notice some peculiar stratum near the top of the cliff, and its counterpart out of place near the bottom, showing that a fault has occurred, whose amount of slip he can easily estimate or measure; but when a fault of many thousands of feet occurs, a knowledge of the different geological periods involved in the slip is necessary to estimate the amount of fall. Thus, if a prospector by his geological knowledge should recognize a Cretaceous rock, brought up in close juxtaposition to a Silurian rock, he would know that a stupendous fault had occurred at that place, involving the entire thickness of the rocks composing the periods intervening between the Silurian and the Cretaceous.

That a faulted region is one in which great folding, due to lateral tangential pressure, has taken place, the folds eventually breaking down in faults, is well seen in the structure of the Mosquito Range, in South Park, Colorado, which embraces the Leadville mining district.

The comparatively horizontal strata of the Park, as they approach the Mosquito Range, begin to fold gently, the folds gradually increasing in steepness and closeness as they approach the axis of the range. As we pass up Four Mile Cañon, which shows a complete cross-section of the range, we find the axis to be formed by a magnificent and very steep arch, well shown on the face of Sheep Mountain, which, having arrived at its utmost tension, breaks down in what is called the London mine fault, traversing and splitting the range for twenty miles. The line of the fault is shown by a depression between Sheep and Lamb Mountains. In nearly every cañon along the flank of this range, the line of the fault is easily traced by similar arches and sags, and by a peculiar wavy look of the turfed strata as they bend down towards the fault. As we penetrate farther across the range, we pass a series of such faults, each one formerly represented by a steep fold that preceded the faulting. Hence it is that we descend from the top of this range down into Leadville and the Arkansas Valley by a series of gigantic steps or benches, each bench representing a fallen faulted block. Faults have their points of maximum depth and disturbance, from which they are apt to die out at either end in folds or rounded hills. Great faults are accompanied by minor parallel and cross-faults.

The ultimate cause of this folding and faulting is attributed by some geologists to the interior of the earth growing colder and contracting, causing the surface crust to shrink and fold in adapting itself to the shrinking interior. Prof. J. F. Kemp says: "The strains induced by cooling and contraction of the earth are the most important causes of fracture. The contraction develops a tangential strain, which is resisted by the arch-like disposition of the crust. Where there is insufficient support, gravity causes a sagging of the material into troughs or synclinal folds, which leave corresponding arches or anticlinal folds between them. Where the tangential strain is greater than the ability of the rocks to resist, they are upset and crumpled into folds from the thrust. Both kinds of folds are fruitful causes of fissuring cracks and general shattering, and every slip from yielding sends its oscillations abroad, which cause breaks along all lines of weakness."

JOINTS

Joints, common to all rocks, appear to be due not so much to faulting and motion, as to shrinkage of the rocks in passing from a soft matter, or muddy condition, to one of consolidation. A good many so-called fissure veins, even in the granite series, appear to occupy extensive joint cracks, rather than fault planes. These may be due to the general shrinkage of the whole mountain mass in consolidating from a semiplastic or igneo-aqueous state of softening to one more consolidated and rigid.

The joints in lava sheets forming curious columns, like those of the Palisades of the Hudson, are due to the same shrinkage from the molten state. Such joints may sometimes be mineralized for a short depth, forming what are called "gash" veins, rather than true fissure veins. The joints in sedimentary rocks are due to consolidation from a soft, muddy, incoherent condition; such joints may similarly be occupied by gash veins, or may lead to pockets or wide blanket deposits.

The line of weakness between one stratum or one set of strata and another, often a favorite line for blanket deposits, is due to one stratum being first laid down and partially consolidated, before the next was laid later on top of it.

IMPREGNATIONS

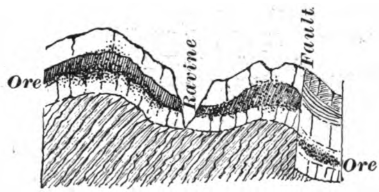
Rocks made up of loose material, such as porous sandstones and conglomerates, are sometimes permeated by ore solutions, as, for example, the "Silver-reef" sandstone of Utah. Sandstones are frequently impregnated with iron and copper stains. In fact, if we consider that ore bodies were deposited from aqueous solutions, we have only to consider the various opportunities the rocks afford by their texture, structure, etc. for this process. Veins, in a word, are filled waterways of many and various kinds.

CHAPTER VII

VARIOUS FORMS OF ORE DEPOSITS

ORE BEDS

"ORE beds are metalliferous deposits interstratified between sedimentary rocks of all geological ages. They lie parallel to the planes of stratification and follow all the contortions of the enclosing strata; hence, they are thrown into folds, troughs, arches, saddles, or basins. The upper portions of the arches may often have been removed by erosion, or the strata may be faulted." The ore deposits or beds at Aspen occupy a faulted synclinal fold or basin. The enclosing rock is limestone, in part dolomitic. At Leadville the deposits occupy part of a series of faulted anticlinal arches and synclinal troughs, of which the Mosquito Range is the main axis. The beds lie between dolomitic limestone and sheets of porphyry. The ore beds partake of all the folding, faulting, and other contortions which the enclosing rocks have suffered in the upheaval of the mountains. The thickness of such deposits varies much, and may gradually thin out and disappear, but may also continue long enough for mining purposes.



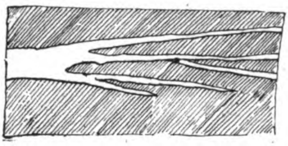
FAULTED ORE BEDS IN ANTICLINAL AND SYNCLINAL FOLDS.

Often there are no sharp limits between an ore bed and the enclosing rocks, or between the ore bed and the walls, if walls exist at all. The ore appears to impregnate the surrounding rock by a chemical interchange between the elements of the rock and the ore. Such a "metasomatic" interchange, substitution, or replacement appears to have taken place in the argentiferous lead deposits of Leadville and Aspen between the ore and the limestone.

According to Phillips, "a true ore bed never produces a 'combed' or 'ribbon' structure made up of symmetrical layers, such as are common in so-called 'true fissure veins,' and is usually without the crystalline texture observable in veinstones."

UNSTRATIFIED DEPOSITS, FISSURE VEINS, ETC.

Mineral veins are changeable in character, and their appearance is of a perplexing and complicated nature. There is a gradual passage from one form to another, so that it is difficult to classify them. There is often no such sharp distinction between one form of ore deposit and another as legal disputes would sometimes demand, and a witness should hardly be called upon to assert on oath that such a vein is a "true fissure," or another a "bedded" vein, or a third a "segregated" vein. "Nature abhors straight lines" and sharp distinctions, and delights in blending one form imperceptibly with another.



A Split Vein.

Phillips divides veins into two classes, "regular and irregular veins." Regular unstratified deposits include true veins, segregated veins, and gash veins. Irregular deposits include impregnations, fahlbands, and contact and chamber deposits.

Veins are collections of mineral matter, often closely related to, but differing more or less in character from, the enclosing country rock, usually in fissures formed in those rocks after the rocks had more or less consolidated.

All veins do not carry metals; some are merely barren quartz, feldspar, or calcspar, like the barren veins we so often see traversing granite or limestone rocks.

Veins may divide, "split up," or thin out, and are irregular in shape and structure, owing to the irregular width of the fissures and to other causes.

DEFINITION OF MINING TERMS

The rock in which a vein is found is called the "country rock," e. g., limestone, granite, porphyry.

The portions of country rock in direct contact with the vein are called, respectively, the "hanging wall," or roof, and the "foot wall," or floor. This is only in inclined or flat veins, as a vertical fissure vein can have neither roof nor floor, but only two walls, east and west, or north and south, according to the compass. The inclination of a vein to the horizon is its "dip."

The horizontal direction of a vein at right angles to its dip is its "strike." The latter may commonly be observed along the surface outcrop, the former either in the workings of the mine, or where the vein is exposed on the side of a cañon.

Both dip and strike of a vein often vary much, the former with depth, the latter with extension across the country. A vein or ore deposit will not unfrequently begin with a gentle dip, and increase rapidly in steepness with depth. The ore deposits on Aspen Mountain commonly begin with a dip of 25° and at a depth of less than 1,000 feet reach 60° or more.

As fissure veins commonly occupy fault fissures, their irregularities in dip and strike correspond to those we have already spoken about, under faults.

The angle of dip is usually taken from its variation from a horizontal, not a perpendicular, line. Thus, a dip of 75° means one that is very steep, while one of 10° is a gentle inclination.

A layer or sheet of clay called "gouge," or "selvage," often lines one or both walls of a vein between the country rock and the gangue or vein proper. It is derived from the elements of the adjacent country rock, decomposed by water, and sometimes by the friction of the walls of the fissure against one another, or against the vein matter, in the process of slipping and faulting, which is often shown by its being smoothed, "slickensided," polished, or grooved. Gouge often contains some rich decomposed mineral in it, such as sulphurets of silver. It sometimes occurs in the heart of a vein, especially if that vein has been reopened anew by movements of the strata. The "Chinese tallow" gouge of Leadville results from the decomposition of the feldspars in the adjacent white porphyry, and is a hydrous silicate of alumina.

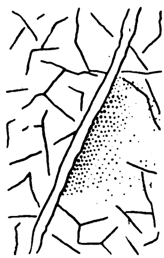
In the granite veins in Clear Creek County, the gouge is derived from the feldspars of the granite. Gouge is sometimes useful in defining the limit of the vein between walls, thus preventing unprofitable exploration into the "country." It is also a guide for following down a vein when mineral and gangue may be wanting or obscure.

Both walls are not always clearly defined by slickensided surfaces, by gouge or other mark, and so at times the vein is lost.

False walls, caused by movements in the adjacent strata, by joints, etc., also mislead.

It is not uncommon for a fissure vein to have but one clearly defined wall, the other, if it exists, being obscured or changed by mineral solutions. Sometimes two cracks or fissures occur parallel to each other, and the intervening country rock has been altered and mineralized into a vein. It is probable that in this way many wide veins were formed.

Mr. Emmons has found that fissures are formed by great movements of the earth's crust or by local contraction of the rocks, and that a fissure is not necessarily one with well-defined walls at considerable distances apart, filled after the formation of the fissure, but that the ordinary cracks or joints in granite quarries, extending regularly to great lengths or depths, illustrate the original fissures, which have been changed by percolating waters carrying mineral solutions into veins and deposits of ore. In all crystalline and sedimentary rocks, these cracks or joints run parallel to each other at various distances apart, often plentiful and close together. In cases where percolating waters were charged with the proper metals and veinstone matter and the necessary chemical and physical conditions existed, the rocks lying between those cracks or joints were altered into ore.


IMPREGNATION OF ROCK BY VEIN.

As one element was dissolved another took its place; so, according to this authority, it would seem that even a fissure vein may be only a sort of "metasomatic" replacement of rock by mineral. Hence, what is commonly accepted as a "wall" of a vein is not necessarily one, and cross-cutting, in order to determine the lateral boundaries of the ore, is safer than to rely on supposed walls. A so-called "slip" has often been followed by a miner as a supposed wall, until, by accident, he broke through and found good ore on the other side. If veins are formed according to Mr. Emmons' theory, the occasional loss of one or both walls is easily accounted for.

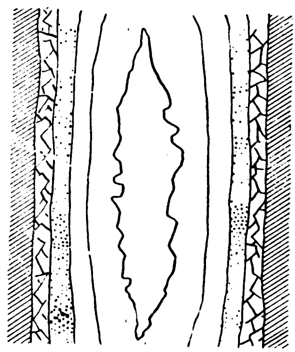
Cross-veins of a more recent age sometimes cut or fault an older vein. The point of intersection is generally rich in mineral. Cross-veins must not be confounded with "leaders," which are the filling of minor cracks extending off from the vein, and are sometimes sufficiently profitable to work. While they sometimes lead a prospector to the main vein, they may also lead a miner underground, astray from the true vein.

The splitting of a vein by a "horse," or large fragment of the country lying in the vein, may be mistaken for a true cross-vein, or the original fracture of the fissure may have been in the form of a star, or like the spokes of a wheel radiating from the hub.

In such cases there are no true cross-veins. But when, as in the San Juan district, we have two well-defined sets of veins, one striking northeast by southwest, and the other northwest by southeast, they cut each other diagonally, the cut vein being the older. These opposite sets of veins have been formed at different times. Many contain a characteristically different class or variety of minerals. Thus, in Cornwall, England, one set carries tin and the other lead.

SIGNS OF A TRUE FISSURE VEIN

True fissure veins show signs of motion or slipping on the sides of the fissure, such as slickensides, gouge, crushed walls, "horses," or "breccia," the latter being small portions of the country rock surrounded and cemented by vein matter. In the Comstock, the quartz is ground to powder. The vein itself, though occupying a healed fault fissure, may be itself faulted by the later movements in the mountain after the vein has been formed. Some of the fissure veins on Engineer Mountain, San Juan, are so dislocated.



COMBED, BANDED, OR RIBBON STRUCTURE WITH QUARTZ GEODE.

The vein-filled fissures, being a line of weakness, may be reopened by mountain movements, and other or different combinations of ore introduced into the heart of the vein. Such a reopening would be marked by a succession of "combs" or banded ribbon-like deposits of ore, and by gouge matter.

OUTCROP OF VEINS

The outcrop of a vein is that which appears at the surface, and usually attracts prospectors to the spot. Sometimes it may be, as in the San Juan district, a bold vein of hard white or rusty quartz, standing up in relief, by its superior hardness, above the surrounding country, like a low wall. Or again, in the same district, from being composed of softer or more soluble substances than the prevailing eruptive lava sheets, instead of a wall, it causes a depression or trough on the side of a hill, forming the pathway for a rivulet and marked by luxuriant vegetation. Commonly, the outcrop consists of a decomposed mass of rock, stained with oxide of iron, and streaked here and there with green or blue carbonate of copper, and is called "float" or "blossom" by the miners. This float is the chemically changed or oxidized portion of the true and unchanged vein lying deeper below the soil. On Aspen Mountain the float is generally a rough crystalline mass of calcspar and baryte stained with iron and copper.

In this "blossom" rock free gold is not unfrequently found, but unaltered sulphides, such as galena or iron pyrites, are rarely met with on the outcrop. In the San Juan district, on Mineral Point, we have, however, found galena at the grass roots, and broken off large chunks of it from a quartz vein outcropping on the surface.

In gold-bearing veins, such an oxidized condition is desirable, if it continues down to any depth, for, so far as it continues, the gold is free, and the ore is a free milling one, easily treated, and often exceedingly rich in gold, as in the celebrated Bowen mine of Del Norte; but as soon as the hard white quartz and the unoxidized pyrites of the true vein is reached, the ore is no longer free milling, but must be smelted. The gold may still be found free, perhaps, in the hard quartz, but if the pyrites should not prove rich in gold, the palmy days of the mine may be considered as past. Many such rich deposits on the surface, abounding with specimens of free gold, have proved great disappointments with depth.

WIDTH OF VEINS

Veins may vary in width or thickness from a half inch to a hundred feet. They also pinch or widen at intervals in their downward course. The widest "mother" veins are not always the most productive, though they are very persistent

Metalliferous Veins Exposed to View Near Howardsville, San Juan, Colorado, Showing Two Systems of Fissure Veins Crossing Each Other.

in length, and we may suppose in depth also. In the San Juan district, the "mammoth" veins of quartz, often a hundred feet wide, are not the favorites for development, the ore being found too much scattered in them, and the development less easy than in those 10, 20, or 30 feet wide, where the metal is more concentrated. These mammoth veins in the San Juan are easily traceable for miles over the surface of the country, and down the sides of the deep cañons. Their limiting depth has never been reached, and probably never will be by mining.

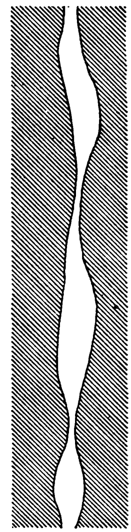
DEFINITION OF TRUE FISSURE VEINS

True fissure veins are popularly defined as filling fissures of indefinite length and depth, commonly occurring in parallel systems, traversing the surrounding rocks independently of their structure or stratification, and commonly, though not necessarily, at an angle different from that of the stratification—in other words, cutting across the planes of stratification. These veins originated in fissures, not necessarily wide-open ones, but, on the contrary, rather narrow cracks, descending, however, to great depth, such as those produced by faulting, or the general cleavage lines of the mountain. The latter may be frequently observed in every cañon, and also in the sedimentary rocks of the foothills, and even along the flat surfaces of the plains. They are very conspicuous in the plains around Trinidad, and are there not unfrequently occupied by a series of narrow parallel dikes of basalt, instead of by mineral veins. Cleavage lines or joints are familiar to every stone-quarry man.

FISSURE VEIN CONFORMING IN PART TO THE BEDDING PLANES OF STRATIFICATION, IN PART CROSSING THEM.

These cracks are caused by extensive movements of the earth's crust in the process of mountain uplift, and also, on a smaller scale, by contraction of the rocks in cooling from a heated or molten condition, or even in consolidating from a soft or muddy condition.

The two walls enclosing a vein do not generally coincide, as might be expected, if the vein occupies a line of fault. A true fissure vein may, in some part of its course, coincide with the dip of the surrounding strata. As the plane of stratification, or line of division between one stratum and another, is a natural line of weakness, a crack once started would be liable to follow it for some distance. And when uplift occurs, such places are liable to slip one upon the other, and a true parting fissure ensues conformable to the prevailing dip. Such a vein might appear at first to belong to the class of so-called "bedded" veins, but if with depth it should be discovered to be cutting across the strata, it would be pronounced a "true fissure" vein. The appearance of slickensides, or other signs of motion, on the walls of the apparently "bedded" portion would then prove it to belong to the "true fissure" class, and that actual fissuring had taken place prior to the vein filling.



Pocket and Pinches Resulting From Slipping of Uneven Walls of Fissure.

CAUSE OF POCKETS IN FISSURE VEINS

As a fault fissure in its downward course usually pursues a zigzag rather than a straight course with smooth surfaces on either side of the crack, the inequalities of one face of the crack are brought into opposition to the inequalities on the other face, as one or the other side of the fault slips up or down, and thus are produced pinches and wide cavities, which give rise to the "pinches" and "bonanza pockets" so common in fissure veins. A so-called true fissure vein may sometimes have advantages over some other forms of vein occurrence, from its persistency and comparative regularity to great depths. It must not, however, be expected that it will continue equally rich or equally poor throughout its course. There may be comparatively barren spots and rich spots, pinches, and widenings, local combinations of the richer or the poorer varieties of mineral; but the vein as a rule is not likely to entirely give out.

RICHNESS WITH DEPTH

The assertion frequently made, that a vein should "grow in richness and size with depth," does not rest on any scientific basis. This is a popular fallacy, originating from the theory that veins were formed by the precipitation of precious metals by heated rising waters or vapors, and, hence, that the greater concentration would take place at greater depths. The "lateral secretion" theory, now by some accepted, ascribes the depositions of ore to solvent waters reaching the vein from ground quite near to it, and coming naturally from above and the sides quite as often as it is ejected upwards by pressure from below.

In Idaho, says Mr. A. Williams, "the rule is rather that veins grow less rich and strong with depth, though strong veins may continue metalliferous to a much greater depth than mining can ever reach.

"The thickness of the earth's crust which we are able to explore is very limited. Increase of heat, as in the deep Comstock mine, and other natural difficulties, limit us to a few thousand feet—3,000 at most. These deep mines have not, as a rule, proved richer with depth, but to the contrary. Some veins have been worked through alternate zones of richness and barrenness. The Comstock, which has been opened for four miles in length and to a depth of 3,000 feet, shows the ore bodies to be scattered irregularly, and the barrenest ground is at the bottom. On the other hand, some of the most celebrated mines derived their wealth from rich ores encountered near the surface, and have proved most disappointing with depth."

Atmospheric action for a long period has often reduced the ore to its richest compound, and when the hard material is reached, leanness sets in. This, as we have observed, is commonly the case with gold veins. The richness of the Leadville mines is derived from their decomposed compounds. Again, as the surface crust can be so little explored by mining, it is to be remembered that the erosion by glaciers and waters has already removed thousands of feet of the vein, so that we are able to examine only a small fraction of it, while an unknown quantity lies in the depths below. If these veins, then, continue to the supposed great depths below, we are very far from their starting point, and erosion having removed their upper portions, we cannot find their surface finishing point; in other words, it is not a fresh "ready-made" vein we find, but portions of an old vein already extensively mined by the processes of nature.

So far as our experience goes in Colorado, after a moderate depth is reached below surface action, or below the water level, a fissure vein may grow richer or poorer, wider or narrower with depth, without any law except local experience in a district.

VEINS IN GROUPS

Fissure veins occur in clusters and nearly parallel groups, forming a mining district, and, again, in that district, certain peculiar veins may be grouped together, forming a "belt." Thus, Boulder district occupies a certain isolated area, outside of which few mineral deposits occur for a long distance. We have, also, in that district, several distinct belts carrying different characteristic ores, such as the telluride belt, marked by rare telluride deposits, the pyritiferous gold-bearing belt, and the argentiferous galena belt. The Central City region is characterized by auriferous pyrites belts, Georgetown district, not far distant, by argentiferous belts, and Idaho Springs, lying between the two, by both gold and silver belts.

CHAPTER VIII

RELATION OF VEINS TO ERUPTIVE FORCES

THE ultimate cause of the richness in veins of a district or locality is that local dynamic and eruptive forces were more energetic there than elsewhere, causing great disturbance of the rocks, accompanied by fissures and eruptions of porphyry.

Thus, at Leadville the Mosquito Range is violently folded and fractured, eruptive rocks have issued abundantly, and, associated with such phenomena, we find great lead and silver deposits.

Farther south, the great San Juan district is split up in an extraordinary manner with great fissure veins. The region is an eruptive one, consisting of prodigious flows of eruptive rocks, traversed, not unfrequently, by newer eruptive dikes.

In the Gunnison district the strata have been overturned, disturbed, folded, and faulted in an extraordinary manner by the intrusion of great masses of eruptive rock forming the peaks of the Elk Mountains. The strata everywhere are riddled by dikes or intrusive sheets, and the evidence of heat is apparent in the general metamorphism of the entire region. Mineral veins abound. The same phenomena are repeated more or less in the neighboring region around Aspen, and at Pitkin and Tincup.

At Boulder, Central, and Georgetown there is a concentration of eruptive dikes locally in each district, and a few dikes or eruptive rocks outside of those districts. On the other hand, we have no ore deposits in the undisturbed rocks of the plains or the flat basins of our parks, and notably our mining districts are for the most part well into the core of the mountains, where, in the nature of things, folding, crumpling, faulting, eruptions, and metamorphic heat were more energetic than along the flanks and foothills of the ranges that have usually proved unproductive.

The older eruptive rocks, such as the quartz porphyries and diorites of the Leadville, South Park, and Gunnison districts, are more favorable to the production of ore deposits, as a rule, than the more modernly erupted lavas, such as basalt or dolerite, which we commonly find occurring in dikes and surface overflows, traversing or capping our Cretaceous and Tertiary coal fields along the foothills, as at the Table Mountains at Golden and Trinidad.

Some of the lighter-colored and somewhat recent lavas like the tufaceous rhyolite, which caps so many of the Tertiary mesas on the Divide between Denver and Colorado Springs, have also hitherto proved barren. Yet the volcanic rhyolites, andesites, and phonolites of Silver Cliff, Cripple Creek, and Creede are productive of both gold and silver. A large portion of the eruptive rocks of the San Juan region, productive of gold- and silver-bearing fissure veins, are in andesitic breccias of comparatively modern date. The older eruptive rocks, as we have stated, are nearly all of an intrusive character, never having reached the surface, while the newer ones bear evidence of having flowed over the country like modern lava streams, as is shown by spongy scoria on their surface, and may be called "effusive."

In Colorado the ore body is not usually found in the heart of an eruptive sheet or dike of porphyry, so much as at the line of its contact with some other rock, such as limestone, granite, or gneiss.

CONTACT DEPOSITS

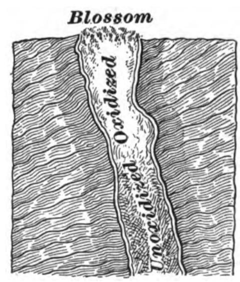
The "contact" ore deposits of Leadville occur at the contact of quartz, porphyry, and dolomitic blue limestone.

Some of the veins at Boulder, Central, and Georgetown are at the contact of porphyry and granite or gneiss.

Exceptions occur, however, where mineral is found either in the heart of a dike, or the whole dike may be so impregnated as to constitute, in a sense, a vein. These exceptions are generally confined to pyritiferous gold deposits, and telluride gold deposits, as at Cripple Creek.

GOLD-BEARING DIKES

Suppose a dike or mass of eruptive rock to be thoroughly impregnated with gold-bearing pyrites. Near the surface, and often for a considerable depth, the rock is decomposed and the pyrites oxidized into rusty iron ore, liberating the gold which is entangled in the "gossan" in wires, flakes, or even small nuggets. As long as this decomposed or oxidized state continues, the ore is free milling, but with depth the dike is found in its primitive hardness, studded with iron pyrites, which may or may not prove rich enough for the more expensive treatment of smelting. Such gold-bearing dikes are found at Breckenridge, South Park, also in Idaho, Cripple Creek, Colorado, and in old Mexico, and many other gold-bearing regions.



GOLD VEIN OR GOLD-BEARING DIKE, SHOWING OXIDIZED AND UNOXIDIZED PORTIONS.

The Printer Boy gold mine, at Leadville, is a vertical deposit in a jointing or fracture plane in a dike of quartz porphyry, rusty and much decomposed near the surface, where it yielded free gold; with depth this passes into copper and iron pyrites. The vein is from 1 inch to 4 feet in width; stringers carrying ore extend into the porphyry, which is highly charged with pyrites, which doubtless supplied the vein with mineral through the agency of surface waters. In Arizona, near Prescott, at the Lion mine, we find a green dike of eruptive diorite penetrating granite. This dike is traversed by numerous small veins of white quartz, which, near the decomposed and rusty surface, are rich in free gold. At slight depth the quartz veins become charged with unoxidized iron pyrites, sufficiently rich in gold to merit treatment by smelting. The surface ore is treated by a single "arastra," and is, of course, free milling. The gold seems to be mostly confined to the quartz veins.

FISSURE VEINS IN IGNEOUS AND GRANITIC ROCKS

The San Juan district is an exceptional case, where immense numbers of fissure veins penetrate igneous eruptive sheets. The fissure veins consist of hard gray jaspery quartz, traversing lava sheets whose united thickness is from 2,000 to 3,000 feet. The veins produce lead, bismuthinite, gray copper, and other silver-bearing ores.

In Colorado, true fissure veins are most characteristic of the Archæan granitic series. In fact, all the veins in that series are fissure veins. Locally they occur as in the San Juan, cutting through eruptive rocks. Outside of these formations few true fissure veins occur.

An exception may be made of the Gunnison and Elk Mountain region, where the fissures traverse all the formations from Archæan granite to the top of the Cretaceous coal beds. Nearly all other mineral occurrences, such as those in the limestone regions, come under the class of bedded veins, or blanket veins, pipe veins, or "pockets," and show none of the characteristics of slipping motion or fissure action. Under this latter class the Leadville and Aspen deposits may be grouped.

Ore deposits commonly occur at the junction or contact of two dissimilar rocks, as between quartzite and limestone, or limestone and dolomite.

Lodes occur also between the stratification planes of the same class of rock, sandwiched in between two layers of limestone, and sometimes impregnating the layers on either side for some distance from the dividing line between the two strata, which is commonly the line of principal concentration of ore, and often descend from this concentration line, through the medium of cross-joints, to form large pockets in the mass of the limestone. The Aspen and Leadville deposits are of this character. Also, when ore bodies occupy a true fissure, i. e., one cutting across the stratification planes, they may locally, for a short distance, impregnate the adjacent walls or country rock more or less. Our fissure veins in granite and gneiss often impregnate the walls to a small extent.

Mineral deposits favor, as a rule, the older rocks, such as the Archæan and Paleozoic series, probably because heat and metamorphic action are commoner in these older rocks, which have felt all the throes of the earth from past to present times, than in the more recent ones, and such circumstances as we have stated are peculiarly favorable to vein formation and mineral deposition.

The bulk of our precious minerals in Colorado comes from the older Archæan and Paleozoic series of rocks, the exception being the Gunnison region around Crested Butte, Irwin, and Ruby, where ore comes from fissure veins in the Mesozoic Cretaceous rocks. The exception is accounted for by the local metamorphism, heat, and eruptive phenomena of that region.

The veins in the San Juan have also been ascribed by some to the Tertiary period, owing to their occurrence in certain supposed Tertiary lavas covering that district.

Besides heat, metamorphism, dynamical disturbances, and eruptive agencies, other minor circumstances may favor ore deposition. Certain rocks, such as limestones, may offer, by their tendency to solubility and chemical reactions, more favorable conditions than others for mineral solutions to deposit by "metasomatic" interchange between mineral and limestone, until the limestone is gradually replaced by ore, much in the same way as the elements of a water-logged trunk of a tree are replaced by silica in the process of fossilization.

CHANGE OF MINERALS WITH DEPTH

Lodes often change in the character of their minerals with depth, not only after they have left the zone of secondary decomposition and surface action, but also far below it. Thus, in the San Juan, some of the mines abound in zinc blende near the surface, which with depth almost disappears, giving place to gray copper and other superior ores. In Cornwall, England, the shallow workings yield copper, and with depth, tin; and locally many such changes may characterize a particular district, but cannot be formulated as a rule for other localities.

INFLUENCE OF COUNTRY ROCK

In most mining regions, to which Colorado is no exception, a relation has been observed between varieties of "country rock" and ore deposits. Veins, in passing from one country rock to another, are liable to change in the size or variety of the ore, widening in connection with some rocks, and pinching or growing narrower in connection with others.

Certain rocks are notorious ore-bearers, while others are notoriously barren over large regions, or in special localities.

The presence of certain rocks adjacent to other different rocks has an enriching tendency on the ore bodies.

As regards rocks that are good ore carriers or receptacles of particular classes of ore in Colorado, we may say:

That quartzites and silicious rocks generally carry more pyrites, and are gold-bearing.

That veins in granitic rocks carry a greater variety of minerals than others, and may be both gold- and silver-bearing.

That certain limestones carry much argentiferous galena.

That sandstones and other unaltered rocks carry little ore of any kind.

The influence of country rock on veins may be from several different causes, for instance:

Certain rocks are, by their structure, better adapted than others for forming regular fissures. Thus, massive limestone is better fissured than slate or shale, leaving wider open spaces for the ore to collect in.

Other rocks may be more porous, and admit mineral solutions through their pores. Of such a kind are some of our porphyries, andesites, and phonolites.

Others, like limestone, are easily acted upon by solutions dissolving out the rock and replacing it with mineral by substitution.

Some are better conductors of heat, and therefore would assist chemical action and mineral solution.

And lastly, if modern theories of "lateral secretion" be true, viz.: That most ore comes from the adjacent country rock and is precipitated, substituted, or collected in the vein fissure, and further, that the metals themselves are derived from certain metallic elements in the ordinary constituent minerals of the country rock, such as mica, hornblende, or augite, it is clear that a rock composed largely of such minerals would be liable to influence the vein as an ore generator. Granite, porphyries, and andesites are largely composed of these minerals.

The frequent presence of eruptive porphyry rocks near veins and ore deposits in Colorado shows that they have an important influence on those deposits, which may be of various kinds.

First, that in their component minerals and mass they actually contain the elements of the precious metals subsequently deposited in another form in the fissure vein, or in the soluble limestone in contact with it.

Second, by the heat which they retain for a long time after they have congealed and hardened, they would assist in the reactions of any chemical or mineral solutions that might be on hand. Lava, at the time of its eruption, is always highly charged with steam and other gases. By reason, also, of the chemical composition of porphyry, waters passing through it would be alkaline and assist in dissolving silica and other gangue or veinstone matter, and when the porphyry has thoroughly cooled it is exceedingly porous, and, being much jointed and cross-fractured, becomes like a great sponge for the absorption of all surface waters. This may be noticed at Aspen, where all the mines that are at present penetrating through the "porphyry cap" are much troubled with water, far more so than in the underlying limestone. Surface waters, then, becoming alkaline by passing through this rock, and also more or less charged with carbonic acid, chlorine, and other solvents, would be ready to dissolve both gangue and vein ingredients out of the porphyry and redeposit them in the vein fissure, or, by metasomatic substitution, in the limestone usually beneath it.

Water circulating in fissures, changes or dissolves the ingredients of the surrounding rock. The rocks enclosing lodes are always so altered, and this decomposition and alteration is not always merely local or confined to the close proximity of the ore body, but we often find a whole mining district, such as Leadville, Aspen, and San Juan, pervaded by this feature. So much is this the case that it is often difficult to get a fresh, unaltered specimen of porphyry or some other country rock within the district.

The brilliant red, yellow, and maroon tints that color so much of the mining district of San Juan, result from the oxidation of pyrites and other iron-bearing minerals pervading the eruptive rocks, and it is noticeable that this color, resulting from alteration and decomposition, is most prominent in those parts where lodes have been discovered, as, for example, the gorgeous tints of the Red Mountain area around the celebrated "National Belle," "Yankee Girl," and Ironton mines, between Silverton and Ouray. The rocks in Geneva Gulch, Hall's Valley, Buckskin Cañon, and in other mining centers, display the same beautiful tints of oxidation in the vicinity of the mines.

"In lodes, a mutual exchange takes place through the reaction of the ingredients of the rock and the materials of the vein. Thus, when water containing carbonates comes in contact with rocks or minerals containing alkalies, a chemical reaction takes place. When these last are combined with silicic acid, these silicates are decomposed by the carbonic acid and the bicarbonates. This explains both the crystallizing out of the carbonates and the frequent decomposition of rocks containing lodes, especially those which, like our veins in granite, are feldspathic."

The same principle applies to other ores and minerals in lodes. Thus, the precious metals in the mines of Leadville, in their original condition, have been proved by depth to have been in a sulphide state, such as iron pyrites (sulphide of iron), or galena (sulphide of lead), etc. Surface waters charged with carbonic and other acids, passing through the overlying porous alkaline porphyry, and entering the underlying limestones, have, as we have previously observed, changed the sulphides into sulphates, oxides, and carbonates.

The presence of a dike near to or cutting a vein has been found often to enrich the latter at the point of contact.

In the "Colorado Central" mine, at Georgetown, a narrow dike of brown obsidian traverses a large dike of ore-bearing porphyry. The valuable ore is found close to the obsidian dike. This might be the result of greater heat at that point. The "black dike" in the Comstock mine is a somewhat similar case.

PREJUDICE IN FAVOR OF AND AGAINST CERTAIN ROCKS

There is often a prejudice among miners in favor of certain rocks and formations, and against others. Miners who have, perhaps, worked in the great Comstock mine, of Nevada, or the Leadville mines, of Colorado, or the fissure veins in granite of the Old World, are apt to look out for and favor certain rocks and formations they find like those they have been accustomed to. Thus, as Mr. Williams says: "The peculiar 'porphyry' of the Comstock was hunted up in other districts, but did not prove metalliferous. Solid granite was looked upon by others as unfavorable, generally, because locally some granite above the gold belt of California had proved barren. Yet some of our best veins are in granite.

"Limestone was at one time a very unpopular rock, and supposed only locally to produce lead, till the discoveries of Leadville, and Eureka, Nevada, overturned the scale in its favor."

In the Leadville "excitement" not only was the particular Carboniferous limestone of Leadville hunted for and prospected, but every other limestone in the South Park region, no matter what its geological age or position, was extensively prospected without results, miners not recognizing the fact that it was not limestone generally that produces rich ores, but a *particular* limestone of a particular geological period (the Lower Carboniferous) not over 200 feet thick, that happened locally to be rich near Leadville; and the reason of its being locally rich at that point was owing to the concentration of eruptive energy and the intrusion of an unusual amount of porphyries, which, in point of fact, are far more responsible for the ore than the limestone, which happens to be merely the receptacle.

It was also quite common after the Leadville excitement to find shafts in all sorts of improbable and hopeless localities, whose owners would tell you: "At Leadville it didn't matter where a man 'went down.' It was all luck whether you 'struck it' or not, and so they might as well 'go down' where they were as elsewhere." It was often said "that Leadville had exploded all so-called scientific theories about ore being in one formation or locality more than another. It was all a case of luck."

The excuse for this is to be found in the fact that in the immediate vicinity of Leadville it did scarcely matter where you "went down," seeing that that area was practically underlaid by bedded sheets of mineral, but that such would be the case elsewhere and everywhere, or anywhere, experience unfortunately has shown to be untrue. It is not a particular rock or formation, but a combination of favorable circumstances, that alone can make a rich mining district.

As experience advances, geologists and miners have proved that ore deposits have a much wider range than was once supposed. Formerly only the Archæan granite series was supposed capable of bearing ore deposits, because in the Old World, tin, copper, and lead came principally from fissure veins in those rocks. Then deposits were found in the Paleozoic series and supposed to ascend no higher. But in the present day, and even in Colorado, they are traceable even to the Tertiary.

It is not the rock, nor the age, but a combination of circumstances, principally heat and metamorphism, that may make any rock of any period an ore-bearing one. And in prospecting in new regions it is these combinations, rather than any particular rock, that should be looked for.

STRIKE AND DIP OF VEINS

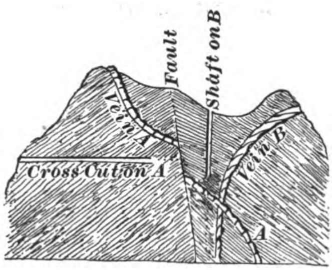
The dip of veins approaches more nearly the vertical than the horizontal, usually from 75° to verticality. Nearly all our ore deposits, in Colorado, even those of the bedded class, dip more or less steeply from 25° to 75°.

For a few feet from the surface, on the steep slope of a mountain, it is common to find an ore deposit dipping quite gently, or even folded over and dipping in a contrary direction to that which it assumes with depth. This appears to arise from the weight of the strata above it tending to bend it over downward, in the direction of the slope of the hill.

There is generally a prevailing dip and strike among a number of parallel fissure veins of a district. In the San Juan, the bulk of the fissure veins have a prevailing northeasterly strike and dip to the southeast. The angle of dip is generally between 60° and verticality.

CROSS-CUTTING UNCERTAIN

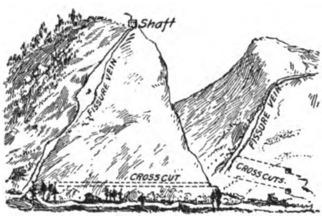
The dip, as we have said, not unfrequently changes considerably with depth, usually becoming more and more vertical. From the degree of uncertainty as to the continuity of the dip, it is not always safe, on the discovery of an outcrop, to endeavor to cut it at a much lower point, so as to get the coveted depth, and better opportunities for stoping, drainage, and other developments of the mine. Owing to a change of dip or fault, perhaps the miner may have to make a much longer cross-cut tunnel than he had calculated upon before striking the vein. Sometimes, too, he may miss the vein altogether, cutting it perhaps at some point where it is exceedingly thin or poor, so poor, in fact, that he passes through it without noticing it or believing it to be the same vein whose outcrop looked so promising on the surface. Cross-tunnels through "dead rock" should hardly be undertaken until the vein has been proved to be a strong one for a considerable depth. As we have already shown, great depths may not, after all, be so desirable in even a fissure vein, as there is no certainty whatever about veins becoming richer or poorer with depth. Extensive cross-cut tunnels have seldom proved paying concerns. The greatest in the United States, the Sutro tunnel, six miles in length, which tapped the Comstock fissure at a depth of 2,000 feet, did not prove a financial success, and had it tapped the fissure still lower, at 3,000 feet, it would have found the vein in the impoverished condition it is today. It is not uncommon for a miner to strike a rich outcrop on the top of some mountain, and on the strength of its richness induce a company to run a long cross-cut tunnel in "dead rock" half through the mountain to cut this vein, and the company's resources are nearly exhausted in so doing, while the vein itself gives no returns, owing to its being left idle. Finally, perhaps, the vein



SHOWING HOW CROSS-CUT TUNNELS AND SHAFTS MAY MISS VEINS BY CHANGE OF DIP OR FAULTING.

is missed, or if struck, proves far poorer than was anticipated. Of course there are exceptions where cross-cut tunnels in "dead rock" may be advisable.

If a fissure vein, as in the San Juan, should outcrop near the top of a mountain and be exposed on its dip all the way to the bottom, there may be some reason for opening a tunnel in it near the base, thereby facilitating drainage, development, and exportation. In that case the miner is *on* the vein, with no fear of losing it; but even here, there is no guarantee that it will prove rich all the way to its outcrop a thousand feet above. "Follow your ore, and be careful how you leave it for any experimental theories," is a common and wise saying among experienced miners. We remember a tunnel in the Gunnison region which was run several hundred feet, at a cost of many thousands of dollars, all through "dead rock," in the hopes of cross-cutting a certain ore body that had proved rich near the surface. At last it was given up, and subsequently a short cross-cut was made from it, and the original vein was found only a few feet from the tunnel, which had been running parallel with it all the time. The cause of the mistake was an unforseen fault in the vein that had shifted its dip much farther on one side than had been calculated upon.



FISSURE VEIN EXPOSED FROM OUTCROP TO DIP.

CHAPTER IX

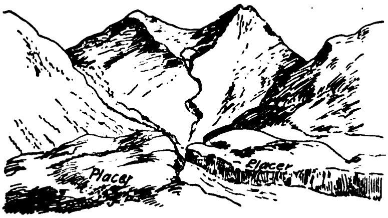
GOLD PLACERS

PROSPECTING FOR PLACER GOLD AND GOLD VEINS

HAVING given in preceding chapters a sketch of veins and ore deposits in the rocks, it follows in order to speak of gold placers, because these are derived from the former by the agencies of water, either in the form of glaciers of old, or of ancient or modern streams.

The glaciers in olden times heavily mined the rocks and the veins, by cutting broad gashes through them, thus originating the cañons. In this way millions of tons of rock were mined, together with the gold-bearing veins in them, and also the precious metals minutely diffused and scattered throughout their masses.

After the glaciers, the rivers took up the work, deepened the cañons, broke up the boulders and sorted them, setting free the gold and other metals they contained, and again sifted and sorted them, and deposited them along their banks and in their beds. Of the various metals thus handled by nature's jigging process, many were dissolved and destroyed by various acids in the waters, and by acids of vegetation and iron salts percolating through the placer dumps after they had been laid down. So with the exception of a few very hard minerals, such as magnetite, diamonds, garnets, rubies, etc., little remained in the placer but the imperishable gold, and even that appears to have been refined of its alloy of silver which it contained in the original vein, for placer gold is generally much purer and more valuable than that in the original vein.



OPEN PLACER GROUNDS IN CAÑON.

In some cases, too, the fine gold disseminated through the placer appears to have been acted upon by certain salts, such as the persalts of iron, and concentrated and amalgamated into large nuggets. Some contend, however, that these nuggets are only water-worn pebbles of gold, brought direct from the vein, the result, perhaps, of concentration there of the contents of large masses of gold-bearing pyrites; it is to be noted, however, that while gold-bearing nuggets of various sizes are to be found, not uncommonly, in gold placers, they are very rarely found in gold veins.

With the gold in placers is commonly found what is called "black sand," which is composed of grains or pebbles of magnetic-iron ore, relics of the gold-bearing pyrites chemically changed. Being near in gravity to gold, and originally associated with it, the two are generally found together in a placer, and a prospector in surveying a bank of placer material, made up of sand, pebbles, and boulders, generally looks for a streak of "black sand" as a likely place for gold. Also by reason of the gravity of gold he is inclined to look for it more down on bed rock than in the upper looser strata.

Ancient river beds, as well as those of modern rivers, may be found gold-bearing, rivers that have long ceased to flow, by reason perhaps of change in the configuration of the country. In California and Australia many of these ancient gold-bearing river beds have, at a period not long distant, been deluged and covered by lava, and the gold is extracted by tunneling beneath the lava sheet or by shafting down through it to the gravel below. These are called deep leads, while the ordinary uncovered gravels are called "shallow placers."

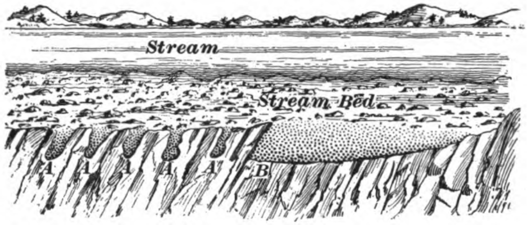
SECTION IN GOLD PLACER.

Almost anywhere along ancient or modern watercourses, not far from mountains, a prospector, by panning, can get colors of gold even on the pebbly "wash" covering the surfaces of large portions of our plains, or even on the tops of table lands that once were plains, over which broad rivers and glaciers and large bodies of water distributed their débris, but as a rule it will only pay to work where the "wash" or "drift" or "alluvial" matter is plentiful and thick, and more than this, only where water is accessible to the work.

PROSPECTING

A prospector hunting for a gold placer follows up the water channels in which he finds specimens of all the rocks in the neighborhood. In Australia, the prospector looks among these to find samples of granitic, porphyritic, and quartzose rocks or clay slate as likely signs, and also pieces of quartz, honeycombed and rusty, which we have described before as "float," or "blossom." Plenty of broken up quartz he considers a good sign, but very pure, hard, dull-white quartz is generally considered as "hungry" or "barren"; the size of the fragments denotes his nearness or otherwise to the reef, i. e., the vein.

A prospector examines closely the fine sandy matter of the stream bed, especially where eddies and backwater have been formed. A likely deposit should be scraped up, even down into every crevice and depression in the bed-rock or solid-rock bottom over which the river, modern or ancient, has worn its channel. This material should be panned. Gold, too, is often found on points and slopes of the bed rock as well as in the deepest portion. Nuggets found on high reefs above the level



SHALLOW PLACER.
Gold Sand in Potholes *A, A* and Below a Hard "Bar" *B.*

of the stream, imply that their weight enabled them to remain in their position, during the deeper erosion of the neighboring streams, and that the original vein from which they came is not far off. As a rule, large nuggets and coarse gold are found much nearer to the source whence they came, than fine or "flour" gold, which is often carried to unlimited distances away out on the plains.

The character of quartz veins and of their enclosing rocks in the immediate vicinity, decides the character, too, of gravels derived from them; hence, sometimes a peculiar pebble may be traced up to the peculiar rock whence it came, and the gold vein be found near it in place.

It has been observed that "leads" *following* the course or lines of a gold-bearing reef, maintain a more continuous yield than those *crossing* a number of gold reefs at intervals.

Gold occurs in pockets and "shoots" at intervals, with barren portions between, which accounts for what we have stated above. In a country where the gold-quartz veins are small, though rich at wide intervals, the gravels will also be small.

In very deep ground, where the "wash" is very heavy, a series of borings or even shafts are made to test the quality of the bank. The following points have been observed as worthy of note in prospecting for gold placers.

1. Streams crossing the lamina or stratification planes of gold reefs at right angles are likely to be richest.

2. Gold is rarely found plentiful where there are indications that the current was strong, but rather in the lee, under projecting points of rock, where beaches are usually formed and the water was slack.

3. Gold in streams is deposited in crevices of the "bed rock," which should be laid as dry as possible and picked up to such depths as the sand descends between the laminations.

4. Terraces are shelf-like excavations and deposits upon hill slopes above valleys, and are the remains of old glacier or river beds. The prospector should discover the inlet and outlet of the terrace, and examine the gravel. The "wash" sometimes contains gold in layers one above the other.

5. While working up stream, attention should be paid to the banks on each side where sections are exposed, so that no outcropping vein may be overlooked.

6. Alluvial gold should, if possible, be traced to its source whence the "float" came. When the gold is large and plentiful, and the boulders large and angular, the reef is likely not far distant.

7. Sometimes there is a distinct peculiar feature in all the veins of a district, such as a peculiar band of a definite color.

8. Coarse alluvial gold is not always incompatible with fine reef gold as a source, because the reef gold may be so fine in general as to lend itself to very wide distribution when once it is liberated, while the rarer coarse grains would not be transported far.

9. Alluvial placers are richest where the current of the stream is interrupted by diminution in fall, by sudden change of direction, or by entrance of a tributary, also by reefs, bars, eddies, etc. Absolute richness depends upon local circumstances and the size and weight of floated masses.

10. Creases, holes, and fissures of bed rock over which the stream passed are favorite places.

11. The lowest layers of each separate period of deposition are the richest. Sometimes several different periods of deposition have succeeded each other.

12. The courses of present streams and of ancient channels are placers.

"*Loaming*" is a form of prospecting. It is preliminary to such prospecting as cutting experimental trenches, or sinking

SHALLOW PLACER—GOLD SAND BEHIND BAR *B* ON ONE SIDE OF CREEK.

trial shafts or boring. It consists in washing surface prospects from the bases and slopes of the ranges, until specks of gold, or specimens are found to be obtainable with tolerable frequency, within certain limits. The prospector then proceeds to trace the gold up hill to its source, narrowing the limits of his work as by patient search he approaches the vein whence the gold has been derived. When he can obtain surface prospects of gold up to a certain point, or line, but no farther, he then proceeds, by means of trenching, to search for the gold vein. The prospector has often to work along a steep, scrubby mountain side, selecting his prospects, numbering them, and placing samples in his "loam bag." If he discovers prospects of gold, he finds his way back to the spots the samples were taken from, so as to continue his up-hill search, and trace the gold to its source or vein. Sometimes there is no indication of a vein, soil and bushes and débris covering its outcrop, but by loaming, the prospector ascertains its position, so as to expose it by a trench not many feet in length.

We remember an ingenious way in which a valuable and long-sought-for vein was at last discovered. Prospectors had long found very rich "float" at the base of a hill whose surface was so deeply covered with loose débris that no trace of the vein could be found. A prospector found a small lake on top of this hill, and conceived the idea of cutting a trench from this body of water to the edge of the hill, and by damming up the trench, and then suddenly letting out the water to full force, it cut a deep trench through the loose débris down to bed rock, and the vein was discovered. This process is called "booming."

The cleavage of quartz is said to be freer, sharper, and better defined, in gold-bearing quartz, than in that which is barren. Pyrite is a good indication. A soft, fatty clay or gouge often flanks the vein in its gold-bearing portions.

The mountain spurs should first receive attention for veins. If the quartz is hard, it stands up; if soft, as it more commonly is, it will leave a streak-like depression. On finding such, the prospector should first wash out some of the decaying rock. If only a trace of gold is found in the quartz, there is probably a gold vein in the neighborhood, and trenches should be dug and exploration systematically followed up. Gold is generally near one wall of a vein—seldom all through the stone. Quartz gold occurs in "shoots" with barren spaces.

Before setting a valuation on a discovery, the facilities for working the mine, such as we have alluded to, should be considered. Placer mines, as well as other mines, are often supposed to be "worked out." These are sometimes well worth investigating and examining by cross-cuts or other means. Sometimes it happens that more gold is obtained from "leader" veins, that have been overlooked, than from the main worked vein.

Quite commonly, especially in the lower part of a placer, the pebbles and sand are firmly cemented together into a coarse conglomerate by infiltration of iron oxide and clay. This may consolidate into a false bottom and not be true "bed rock." Generally two or three such false bottoms, with intervening strata of greater richness, alternate with barren ones. So, many old diggings, thus supposed to have been exhausted, may be worked again, the true bottom not having been reached. These conglomerate bottoms may lie just upon bed rock, with a white clay rich in gold beneath them. Gold occurs also in the conglomerate, and must be stamped out.

Modern rivers frequently cross in their course old river courses, and redistribute their golden sands.

Placers are richer in their richer parts, than the veins from which their gold was derived.

When shallow placers are due to the wearing down of quartz veins, no placer will be found above these veins, or above the point where the vein crosses the placer. In the Sierra Nevada there is but little alluvium—the gold comes from veins near by.

Gold placers may sometimes occur below silver mines. Thus, the Comstock vein was discovered by following up placer gold to its source. This vein has produced a gold-bearing silver ore, the silver rapidly disappearing and leaving the gold behind.

EXAMPLE OF A PLACER

In Ballarat, Australia, the "wash dirt" runs in a series of "leads" of varying width, starting from the same point, and trending in different directions towards the "deep leads." The "reef wash" is about 100 feet deep, the "pay dirt" 5 feet. The barren drift wash overlying the pay dirt is of black clay. The reef itself is of green slate, the bed rock is sandstone. Gold lies sometimes on thin layers of sand or "pipe clay" on the surface of the "bed rock," more often in crevices of the bed rock itself, which is more or less rotten. This bed rock is broken up for some 12 to 20 inches, and the gold is found in "pot holes" in it, 15 to 18 inches in diameter and 6 to 10 inches deep, cut out of the solid rock. The alluvial gold is found chiefly in bed rock of slate, dipping 90 degrees. Some of these slates are soft and rotten, others are indurated. On the soft rock only is the gold found. Nuggets are found in the soft clay lying on bed rock. Slate forms natural "riffles" for catching the gold.

Deep pools under waterfalls in gold-bearing streams rarely carry much gold. So, in rivers, gold is found in "bars" or points, rather than in deep pools or bends.

CHAPTER X

"DEEP LEADS"

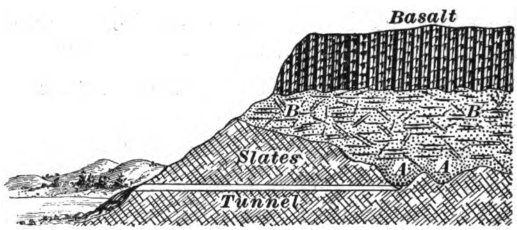
A "DEEP LEAD" lies deep below the surface, often covered by beds of lava, especially in California. These lava beds may be many in number, and hundreds of feet in thickness. The deep lead is an ancient river bed.

In the Sierra Nevada the gold is derived from metamorphic crystalline rocks of the range, partly from quartz veins in the slates, and partly from gold distributed in minute quantities all through the metamorphic rocks. The quartz veins lie between the planes of stratification of the slates, also in irregular bunches and lenticular masses of limited extent. In many localities the rocks are penetrated in every direction by little irregular quartz veinlets, which often carry gold, and in spots are extremely rich, even where the quartz vein is only an inch thick. In some California districts, wherever a basalt capping exists, the drift beneath it is auriferous.

In California the modes of occurrence of auriferous gravel deposits are various.

"Sometimes they exist in well-defined ancient river beds, under a capping of basalt which has filled the channels of the rivers in past ages. Again, they appear in isolated mounds or hillocks, evidently the remains of such channels, which, being unprotected by a covering of lava, have been broken up by the action of the elements; also, in basins or flats that have received the wash of these disintegrating rivers; also, in low, rolling hills, near the base of the Sierras, and beyond the reach of the lava flows." One of the most remarkable and important gold leads is that beneath Table Mountain, in Tuolumne County. "The waters percolating through these lava flows and reaching the gravels beneath, are charged with alkali from the lava. These alkaline waters are charged with silica in solution from the same source. Hence, the fossil driftwood of these ancient rivers has all been silicified by these silicious waters. The gravels are also cemented by the same material. These percolating waters also contained iron, for iron pyrites is found in contact with the silicified woods. In this iron cement, gold is found in rounded grains and in minute crystals, and threads deposited by a solution of sulphate of iron at the moment of the reduction of the latter to a sulphide."

The dead rivers of California are on the west slopes of the Sierra Nevada, from 500 to 7,000 feet above sea level. The largest and richest lead is the "Big Blue Lead," traced 65 miles and even 110 miles. It is parallel with the main divide of the Sierra Nevada. The live modern rivers run at right angles to it, cutting cañons 1,500 to 3,000 feet deep. The "Blue Lead" runs across these ridges from 200 to 1,000 feet below their summit. The lead was discovered by following up surface washings. Miners found that the modern streams were richly gold-bearing up to a certain point, increasing as this point was neared, but ceasing when it was passed. These parts were in the line of the different streams, and by following up indications, the lead was eventually struck on several sections and tunneled on. The deposit is 300 feet deep, composed of gravel, boulders, clay, and sand, on strata distinguished by



DEEP PLACER, TABLE MOUNTAIN, CAL.

A A, Ancient River Channel, with Gold-Bearing Gravel; *B B*, Sandstones and Shales with Fossil Bones and Silicified Wood.

degrees of fineness, by the character of the rocks, and the amount of gold; also, by colors, the prevailing color being a blue gray. Gold is coarser near the bottom, and contains a greater alloy of silver. The silver in the gold in the upper strata has been eaten out by sulphurous acid resulting from decomposition of iron pyrites. The whole deposit is like that in existing rivers, showing banks, bars, eddies, falls, rapids, and riffles. There is much gold in the eddies, and but little in the rapids. The space between the boulders is filled with sand and contains gold ; the bed rock is slate.

Where dead rivers meet, the "wash" is generally rich. Where a lead becomes very narrow, dips fast, and is enclosed between steep walls, the gold will be very sparingly distributed in holes and behind ridges, and will be coarse in size.

Very large and abundant boulders in gold-bearing stream beds are often a serious obstacle in getting out the gold, from the difficulty of handling them. More than one placer has been abandoned from this cause alone.

HYDRAULICS

Placer banks are worked on a large scale by "giant nozzles" or "hydraulics." Before commencing such work the total depth of the placer deposit should be examined and ascertained, and the richness of the strata throughout tested. Shafts should be sunk here and there to bed rock for this purpose, and topographical surveys made to ascertain what fall and head of water can be obtained, and what outlet also for the tailings, as the latter would soon choke up the work ; the ground sometimes may be too flat to dispose of the tailings by stream power. The choking of outlets is a most fertile source of abandoning placers.

Beach Mining.—"The beach sands of the Pacific and elsewhere contain minute scales of gold, and sometimes platinum, together with a great deal of magnetic-iron ore. Winds, tides, and surf act as natural concentrators or separators in parting the light and useless material from the heavier. Wind drives heavy swells on the beach at high tide, together with sandy matter. At ebb of tide, the surf lashes the beach and carries back light portions of the mass with the undertow, leaving some iron sand, gold, and platinum, whose weight enables them to hold their place. At low water, miners go down on the beach, scrape up the iron sand, which is generally left in thin layers, stacking it back from reach of the surf, and subsequently washing out the gold." In some beaches much of this sand contains titaniferous iron ore, and if attempts are made to use certain processes to save the finer gold, the character of the iron may be a formidable obstacle.

EXAMPLE OF COLORADO PLACER GOLD MINES

California gulch, the site of the present Leadville, furnished a great amount of gold in the early days, till the discovery of the lead-silver deposits in place. This discovery, also, was due to placer mining. While examining the gravel in the gulch, Mr. Stevens, an intelligent prospector, was struck by the appearance of what the miners called "heavy" rock, some of which he assayed. His specimens yielded 27 per cent. lead and 15 ounces silver to the ton. He put prospectors to work to find the croppings of the ore deposits, and in June, 1874, the first "carbonates in place" were found on Dome Hill. This was practically the beginning of Leadville. It is said that upwards of 2,000,000 dollars worth of gold was taken out of this gulch in one summer, before the mines in place were discovered or opened up.

It is noticeable that California gulch alone furnished almost all this placer gold, while Iowa and Evans gulches, adjoining it on either side and carved out of the same series of rocks, yielded little or nothing. Why should the smaller gulch contain exceptionally rich gravels and its neighbors be barren?

The richest portions of California gulch were found at bends in the course of the gulch. In one place, near Oro, in the narrow bed of the gulch, a gold-bearing cement was found containing hydrated oxide of iron, below the gravel, yielding 1 ounce of gold to the ton. The gulch gold was worth $19 an ounce, while that from the mines in place was worth only $15. The Printer Boy porphyry, containing actual gold veins in place, may have been the source of some of the gold in the gravels, together with the oxide of iron resulting from the decomposition of pyrites in the pyritiferous porphyry as a cementing material. Also the "Weber grit" sandstones at the head of the gulch have been found to carry small gold veins, and from their abrasion also gold-bearing gravels would have been carried down the gulch. Also of late the rich gold deposits of Breece Hill, at the Ibex and Little Johnnie mines, have been found.

"It is doubtful," says Mr. Emmons, "whether in general all or even the greater part of the gold contained in placer gravels is derived from the abrasion of actual gold veins. Traces of gold may be found in a very large proportion of the massive rocks which form the earth's crust. Gold veins are concentrations of this mineral in sufficient quantity to attract attention and yield a profit. But doubtless there are vast amounts of smaller concentrations which may escape notice. As the rock disintegrates, and is worn away by atmospheric agencies, the gold from these smaller deposits, as well as from the larger, is set free from its enclosing rock and subjected to the concentrating action of mountain streams.

"Placer deposits are the results of nature's vast sluicing processes. To bring them into the condition in which they may be made available by man, requires not only the gold-bearing rock, which her agencies may grind up into sand and gravel, but the sifting power of rapid streams, which may carry down the lighter and coarser material, and a suitable channel in which the heavier particles may lodge, as in the riffles of a sluice box. All mountain gravels, all sands of rivers coming from the mountains, contain a certain amount of gold, but it is only under peculiarly favorable conditions that the gold is so concentrated as to render the gravel remunerative.

"Among the most favorable of these conditions is a comparatively narrow channel having a hard and compact bed rock, and ridges or bends in its course, which, by causing a partial arrest in the rapidity of the current, shall allow the heavier particles of gold to settle to the bottom, and hold them there when once they have settled.

"From this point of view there is a very evident reason why California gulch should have furnished rich placers, and why the gold that may exist in Iowa and Evans gulches should not yet have been extracted, even though the detrital material that has been carried down the gulch should originally have been equally rich in gold.

"California gulch is a valley of erosion, formed entirely by the action of running water, and since the glacial period. It has therefore a bottom or bed of hard rock. Its transverse section is V-shaped, and therefore favorable for the concentration of heavy particles at its bottom. When comparatively full of water, its numerous bends formed eddies in the down-flowing currents, and allowed a longer time at these points for the settling of the surface particles, and, as it cuts across many different formations in its course, its bed must have transverse ridges, which have caught some of the gold and prevented it from being carried farther down the stream.

"Evans and Iowa gulches, on the other hand, are glacier-carved valleys. Their courses are straight, their bottoms broad and comparatively smooth. The glacial moraine material, with which they are largely filled, has not been subjected to the sifting or jigging process to which gravel is subjected in the bed of a stream. The lower part of their present beds is cut, not out of rock, but out of the loose gravelly formation of the 'Lake beds.' This later bed, along which the material brought down by post-glacial erosion has been carried, has not a sufficiently hard and permanent bed rock to allow of the concentration of gold on its surface."

ALMA AND FAIRPLAY PLACERS, SOUTH PARK

Along the banks of the Platte River are enormous masses of glacial morainal matter, consisting of boulders and sand brought down partly and principally from Mount Lincoln, and receiving contributions from side glaciers of the Mosquito Range. This material forms undulating banks on either side of the river. This placer "wash," from 50 to 100 feet thick, is worked for gold principally at Alma and Fairplay.

At Alma the heavy bank of "wash" is mined by the giant nozzle. The banks are also cut back into blocks of ground, by water from a flume, which is let out at intervals along the bank above; at each place it cuts a narrow ravine in the loose débris and at the same time makes the banks easier to be attacked by the water of the giant nozzles, which rapidly undermine them. The water and sand from these streams run down into the sluices, whose bottoms are paved with disks of wood, forming "riffles" to catch the gold, while the lighter sand is carried onward by the stream. In their "clean-up" in the stream bed, they not only wash down to bed rock, but after hunting with their knives in every crack and crevice of the latter, they dig it up for a foot or two, and further examine it. The rock is a jointed sandstone.

Quicksilver is thrown into the sluices, to collect the finer gold, which is afterwards retorted. While gold is found all through this bank of "wash" from "grass roots" down to bed rock, the greatest quantity of gold and largest nuggets are found at "bed rock" or in interstices.

The source of some of this gold may be a series of large, but not very productive, quartz veins in granite, near Mount Lincoln, whence the main glacier originated. It is also probable that a good deal of the gold came, as said before, from the breaking up of the various rocks in which it was disseminated, more especially the porphyries and crystalline rocks.

In the winter, owing to freezing of the water supply, the work has to be discontinued till the following spring.

CHAPTER XI

MINING REGIONS SHOWING EXAMPLES OF ORE DEPOSITS

FISSURE VEINS IN GRANITIC ROCKS

HAVING described, in previous chapters, the nature of veins, ore deposits, etc. and how to prospect them, it will be of interest as well as profit to the prospector, to learn something of the mines and mining regions themselves. For this purpose we propose giving a sketch of some of the leading mining regions of Colorado and the West, as instructive illustrations and examples of what we have written in previous chapters. As we said in our advice as to the education of a prospector, the best education for him is to go to, and spend as much time as he can in, the mines and mining regions themselves.

We will take first the regions characterized by *fissure* veins. These veins are in the granitic and igneous districts of Colorado. In the granitic ranges, the mining districts of Boulder County, Gilpin and Clear Creek, are the most noted, the principal mining towns being Boulder, Jimtown, Georgetown, and Central and Idaho Springs.

BOULDER MINES

The geological features of Boulder consist of a series of ridges or hogbacks rising up from the prairie and flanking the granite mountains. These represent Mesozoic strata consisting of sandstones, limestones, and shales, containing beds of coal and other economic products, but no precious metal. Volcanic action has occurred in their vicinity, as shown by a large dike of basalt at Valmont. These hogbacks, so universally present flanking the granite mountains, are, in Colorado, destitute of precious ores. Inside of and west of these is the Archæan granitic front range, consisting of heavily bedded granite-gneiss, profusely traversed by veins of "pegmatite" or very coarse sparry granite, consisting of white feldspar and quartz, with very little mica, and from a few inches to 40 or 50 feet in width. With these also occur some dikes of eruptive rock, some of it a dark black rock, like basalt, called "diabase"; others are lighter colored quartz porphyries and diorites. In the telluride belt, while pegmatite veins are abundant, eruptive rocks are scarce, but west of the telluride belt, which is more or less confined to a special area underlying the Magnolia, Sugar Loaf, Gold Hill, and Central districts, enormous masses of eruptive rock are found, but no tellurides. In the non-telluride districts, such as Caribou, Ward, and Jimtown, rich silver ores are found associated with galena, gray copper, etc., and gold ores associated with copper and iron pyrites. Thus there are two or three distinct belts in the region, a telluride gold belt, and a silver belt, and a gold pyrites belt. It is noticed that the entire region has been locally disturbed by volcanic forces, and volcanic rocks abound; outside of this disturbed region there are no mines for a long distance.

The Boulder mines are celebrated for the occurrence of telluride minerals, some of the richest and rarest ores occurring in nature. These ores are confined to a belt occupying the eastern part of the district, and nearer to the hogback region of the plains than any other important ore deposits in Colorado.

West of this belt, in the Caribou district, the ores are argentiferous galena, with brittle silver. In the Ward district, pyrites abound, and where it is decomposed the gold is free. The pyrites, though gold-bearing, are difficult of reduction.

The pegmatite veins containing the ore stand at a high angle and are often very wide, but the rich ores, especially the tellurides, are concentrated in thin streaks and not very continuous bodies. The gangue or vein material is simply an alteration of the adjacent granite, or gneissic country rock, into a more sparry, larger crystalline form, consisting of quartz feldspar and some mica. This is impregnated with rich mineral whose source is probably not far to find, the metal elements being microscopically or chemically diffused through the mineral elements composing the adjacent country rock, which is sometimes porphyry, and at others gneiss. This impregnation has taken place either along the contact of an eruptive rock, with the country-rock granite, or else in a preexisting vein of pegmatite, or along some fault or jointing plane in the country rock itself which has been favorable to the concentration and precipitation of metallic minerals from their solutions. The direction of the veins is generally between northeast and northwest, or east and west; their dips are steep or vertical.

The quartz of the pegmatite gangue, when impregnated with telluride ore, has a pale, bluish-gray, and rather greasy appearance, streaked here and there with a dull blackish, greasy stain, upon which sometimes the true telluride minerals, such as sylvanite, can be seen, generally in long thin crystals of a bright tin-like appearance. It is sometimes called graphic tellurium, because the crystals crossing one another assume the form of Hebrew characters. Sylvanite is a telluride of silver and gold. There are many varieties of tellurides, some rich in silver and others in gold, and some with both combined. When a piece of gangue containing tellurium is roasted, the gold comes out in good-sized globules on the surface.

Two great mother-veins, called the Maxwell and Hoosier veins, traverse the telluride district for several miles, easily traceable by their rusty color. One carries pyrites and tellurides, the other silver ore and gray copper.. Gold Hill district, in the telluride belt, is traversed by the Hoosier gangue. Several veins cross the Hoosier gangue and are richer in its vicinity; in some, the ore is a telluride at the surface, but with depth passes down into gold-bearing pyrites.

The Ward district outside the telluride belt carries copper and iron pyrites bearing gold. Caribou is silver-bearing; its ores are galena, copper pyrites and zinc blende occurring in gneiss, near a dike of eruptive diabase. The No-Name vein crosses and faults the Caribou vein. Its ores carry both silver and gold; the ores are silver glance, brittle silver, gray copper, galena, copper pyrites, with native and ruby silver. The copper pyrites carries more gold than silver.

The granitic rocks near Boulder are thrown into a series of parallel folds, one series cut diagonally by another. The telluride veins run along the slopes of these folds. The veins are in cracks and fissures coinciding with this folding, some of the main fissures being filled at once by porphyry dikes, the others more gradually by vein material. The veins occur along, on, and near these dikes, along lines at the junction of the more massive granite with the bedded gneiss, along and between stratification planes of schist, and along the joint planes of granite. The veins are due to percolating alkaline waters dissolving metalliferous material and veinstone from the surrounding rocks. It is noteworthy that alkaline springs still exist in the neighborhood, as they do also at the mining district of Idaho Springs. The veins occur where the foldings are abrupt, and the direction of the veins is parallel to the strike of the stratification. As a rule, the veins are not of great extent. A single vein can rarely be traced on the surface or beneath it for more than 600 feet. Before that distance is reached, the vein spurs off again into another.

Where veins cross at a small angle, or where a spur branches off from the main vein, accumulation and enrichment of ore takes place. There are two courses of veins, one east and west, the other northeast and southwest; the former system appears to be the older, as the latter faults it.

The ore occurs in chimneys or pockets, with a good deal of barren ground between.

Small veins run parallel with each other for some distance, the interval filled with granite or pegmatite. Sometimes a vein pinches out entirely (contrary to the general habit of true large fissure veins, occupying great fault fissures). The ore streak is from 1 to 20 inches wide, containing more of this blue, greasy, fine-grained "horn quartz" than the country rock. Some of the veins interlace like arteries in a human body. Minute particles of pyrites (marcasite) often produce the dark stains we have noted on the telluride quartz. By moistening the stone, the telluride minerals and pyrite appear distinctly.

A TYPICAL BOULDER COUNTY MINE

A good typical and very instructive example of a contact fissure, gold-bearing vein is that of the Golden Age, at Jimtown, north of Boulder.

"At Jimtown a quartz-diorite dike occurs, of light color, containing much hornblende and titanic iron, running nearly through the street of the village. The cliffs at Jimtown, over 500 feet high, are of quartz porphyry, of white color, consisting mainly of large crystals of quartz and feldspar, set in a fine-grained crystalline ground mass or paste."

GOLDEN AGE AND SENTINEL VEINS

From the town the road winds up a steep mountain composed of coarse gray granite, with occasional belts of gneiss. Here are located the Golden Age and Sentinel mines.

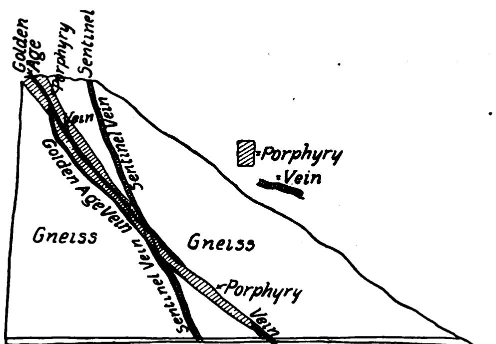
The Golden Age covers the outcrop of a quartz-porphyry dike cutting through the granite. This dike varies in width, from a few feet to about fifty. The outcrop of the main ore chute of the Golden Age extends along the "contact" on the lower side of the porphyry dike. At a depth of 100 feet, the main shaft discloses a split in the vein. The hanging wall of the vein continues into the dike, but with porphyry hanging and footwalls, until a depth of 330 feet, where it enters the upper contact between the porphyry and granite. The dike has been much acted upon and decomposed by vein-forming agencies in the upper workings, but in the lower it is less decomposed, and shows considerable pyrites. The Golden Age veins are well defined, presenting a banded or ribbon structure. They are enclosed in distinct walls, with gouge or selvages, which at times show slickensides. The seams and feeders that have enriched both veins come in from the porphyry dike.

The ore from the Golden Age contains rich and magnificent specimens of free gold. It is a free milling ore. When rich, the gangue is a hard, flinty, vitreous white quartz. The gold is seldom accompanied by pyrites. It is generally imbedded in the white quartz as bright, yellow gold, in size from coarse grains to nuggets several ounces in weight; after it reaches the lower contact, between the porphyry and granite, and enters the granite, there is an increase in the baser metals, such as zinc blende, galena, and pyrites, but the ore still retains its value in free gold.

Returning to the surface, the Sentinel location covers the apex of a vein, which there appears enclosed in a belt of schistose or gneissic rock.

This vein dips south at an angle of 70° and passes through the Golden Age vein on its course.

The Sentinel vein ore is entirely distinct from that of the Golden Age. It is the characteristic bluish horn quartz of the tellurium veins of Boulder County, with characteristic chalcedony quartz crystals and finely disseminated pyrites. The value is in metallic gold and such tellurium ores as petzite and sylvanite. While most of the gold was deposited as native



SECTION OF GOLDEN AGE VEIN, JIMTOWN, BOULDER COUNTY, COLORADO.

gold, a portion has evidently been rendered free by partial decomposition of the tellurides. This ore is very rich. The richest ore usually occurs in two narrow seams or streaks, from 1 foot to 10 feet apart, the intervening space being more or less mineralized country rock. It is richest when in the schistose rock, and poorest when it passes through the porphyry dike. The crossing of the Sentinel vein through that of the Golden Age is very clearly marked; it very slightly faults the Golden Age vein.

The gold mines of Boulder County belong to two distinct periods of vein formation ; to one belong the non-telluride ores, and to the other those producing tellurium. The tellurium veins appear to be the later of the two.

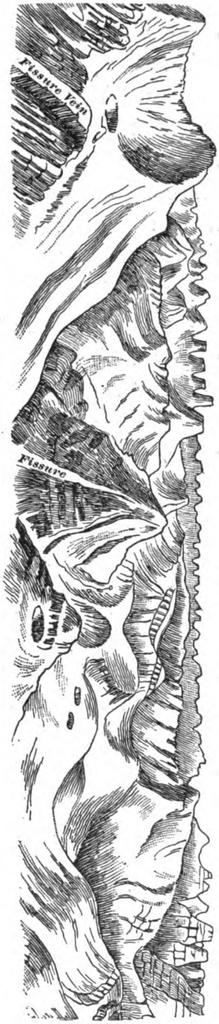
The ores of the Sentinel tellurium vein are lower grade where the vein passes through the porphyry dike. This is due to the Golden Age vein being formed first, and draining the dike of its disseminated mineral values. The Sentinel received its mineral from the schistose or gneissic rocks, and is consequently richer where enclosed in those rocks than when in the dike.

Prospectors look for richer or larger bodies of ore when veins unite or cross each other. In the Golden Age the two veins unite about 100 feet below the surface. There are similar veins of the same age, and large and rich ore bodies are found at their junction. On the other hand, the Sentinel vein of later age, passing through the earlier Golden Age vein, produced no enrichment of the ore bodies. To form such ore bodies, the veins should be of contemporaneous origin.

The ore deposits of Gilpin and Clear Creek Counties are very similar to those of Boulder, only they do not produce tellurium ores. The country rock is the same granite-gneiss, penetrated here and there by porphyry dikes. The pegmatitic veins are either in the gneiss or between the dikes and the granite. In some cases the porphyry dike constitutes a vein in itself, such as the Minnie, which is a felsite porphyry, and the Cyclops, a quartz porphyry. In Gilpin County, around Central City, the ores are a mixture of copper pyrite and iron pyrite, with a very little galena and zinc blende. All are gold-bearing.

The richer ore occurs in streaks not over a foot wide, in a compact, fine-grained mass of pyrite. Copper pyrite is richer than iron pyrite. The rest of the vein, often many feet wide, carries pyrite irregularly disseminated through decomposed country rock. The bulk of these ores are difficult to treat, and are milled, the loss being 40 per cent. higher in the unoxidized ores than in the oxidized. The veins follow the cleavage planes of the gneiss, cutting the stratification planes at right angles, with a vertical dip. The porphyry dikes are older than the veins, as the cleavage planes intersect both the porphyry and gneiss alike. For an interval of 20 miles between these mining districts and the plains there are no ore deposits of any importance known.

In Clear Creek County the ores are mainly silver-bearing; the silver is derived mainly from galena and gray copper. Dikes of obsidian occur in one of the mines, parallel with the vein, which is itself a porphyry dike. The richest mineral is close to the obsidian dike.



San Juan Volcanic Plateau Mountains.
Composed of a Succession of Lava Sheets Resting on Granite.

FISSURE VEINS IN TRUE IGNEOUS ROCKS

While most of our fissure veins, and ore deposits generally, are more or less associated with the *presence* of igneous rocks, there are some which are essentially *in* igneous eruptive rocks alone.

The most remarkable of these are the fissure veins of the San Juan region in southwestern Colorado.

This region consists of an enormous plateau of lavas of great thickness, resting upon and originally overflowing a low mountain range or plateau of granitic and upturned sedimentary rocks, the latter representing most of the geologic periods from Cambrian to Tertiary. The thickness of these great lava flows, which were erupted about the Eocene period of the Tertiary, is upwards of 1,500 feet; glacial and river action by profound cañons has cut up this lava mass into a rugged mountain range, the summits of some of the castellated mountains reaching a height of 14,000 feet above the sea. The lava sheets are also traversed to a depth of 1,500 feet, more or less, by an extraordinary number of great quartz fissure veins. These veins appear to fill shrinkage cracks resulting from the contraction on cooling of the lava sheets; strictly speaking, they are rather "gash veins" on a large scale than "true fissure veins," for they are mostly *limited to the thickness of the lava overflows* and cease when they reach the underlying granite.

There appear to have been two principal eruptions; the first, during the early part of the Tertiary, covered the higher region of the San Juan mountains to a depth of 1,500 feet, with an overflow of brecciated andesitic lava, which, on cooling, developed fissures of contraction traversing the lava mass in all directions; these were subsequently and slowly filled with a hard bluish quartz containing more or less ore.

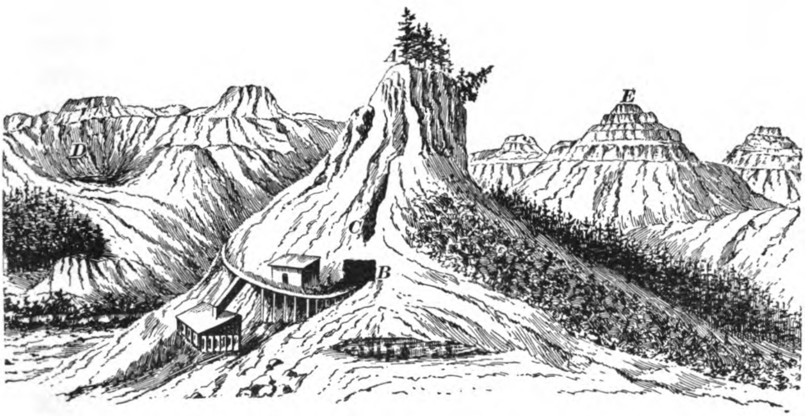
Following the first grand overflow were others of less magnitude, consisting of non-brecciated andesites and rhyolites. This second dynamic movement produced, locally, fissures extending below the horizon of breccia into the stratified rocks. These, however, are seldom productive below the eruptive zone. There are also metal deposits in connection with still older eruptions of andesite and diorite, such as Mineral Farm, Calliope, etc.

RED MOUNTAIN

In the Red Mountain district the ore deposits form a peculiar group. They occupy a series of more or less connected irregular chambers, trending downwards, probably channels of ancient hot mineral springs. The mineralizing water completely silicified the surrounding eruptive rock for some distance away from the ore chambers. So the ore bodies are distributed through a huge irregular column of quartz extending to an undetermined depth.

Large masses of brilliantly colored material are conspicuous in this region. They have been acted upon by mineral waters circulating through their crannies and fissures. Ore bodies are occasionally found in these, and such mines are locally known as cave mines.

The ores of the San Juan are mostly argentiferous gray copper, copper pyrites, and galena associated with zinc blende and iron pyrites in usually hard horn-quartz matrix. Some of the ore locally contains a high percentage of bismuth; others produce pyrargyrite and polybasite, rich silver minerals; others carry considerable gold, such as the recently discovered gold belt at Ouray. This belt occurs in Dakota Cretaceous sandstone, which has been altered into a quartzite by the intrusion of dikes and sheets of eruptive diorite. One of these sheets spreads out in the quartzite. The ore occurs at the top of the quartzite, at its junction with a bed of shale. The gold, which is free and enclosed in brown oxide of iron, doubtless originated from the porphyry, and entered the joints and bedding planes of the quartzite, where they were opened by faulting. Above the shale the ore does not penetrate, the



NATIONAL BELLE MINE, RED MOUNTAIN, SAN JUAN, COLO.

A, Column of Quartz and Porphyry; *B*, Tunnel; *C*, Cave in Ore Chamber; *D*, Bright Red and Yellow Rocks; *E*, Lava-Terraced Mountains.

shale acting as an impervious resistance to uprising solutions. Ore bodies also occur in the Jurassic limestones below the quartzite, especially where they are penetrated by eruptive rocks.

In the eastern portion of the San Juan region, some important deposits of gold occur in the vicinity of Del Norte, in the Little Annie or Bowen mine, which appear to be a decomposed dike of eruptive rock, containing free gold in brown iron, in the upper portion, and with depth, iron pyrites, which is also gold-bearing.

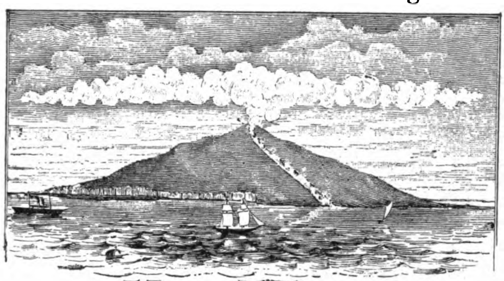
CREEDE

At the newly discovered camp of Creede, not very far from Del Norte, the fissure veins are very similar in character to those elsewhere in San Juan; they are quartz fissure veins, traversing andesitic breccia and other volcanic rocks. The gangue matter in these veins is exceedingly rich in silver-bearing ore, so much so that the amethystine quartz, composing the gangue or veinstone, is quite in a minority to the ore, and the vein may be said to be nearly a mass of ore from wall to wall. The thick lavas of Creede rest doubtless with depth upon Carboniferous limestone or else on bare granite; the former is found outcropping at some distance from Creede, from beneath the lava overflow, and being penetrated by intrusive eruptive rocks, shows signs here and there of productive ore deposits, similar probably to those at Leadville. Creede is an encouraging example, to a prospector, that all productive veins in Colorado have not been discovered yet, even in districts that have been pretty well tramped over. Creede had doubtless often been more or less walked over by prospectors for years before the great discovery was made, and in a year's time we may hear of several more similar discoveries in the great San Juan.

ROSITA AND SILVER CLIFF

The next important and peculiar igneous district carrying fissure veins, is that of Rosita and Silver Cliff, in the Wet Mountain Valley, near the edge of the prairie country, in southeastern Colorado. Here a local eruption of considerable power and magnitude and of comparatively recent date has occurred. These eruptions, consisting of andesitic, rhyolitic and trachytic material have built up cones and rounded hills largely of fragmental material, such as consolidated tuffs, ashes, and breccia, all of which, as at Cripple Creek, rest on granitic basement rock. From the fragmentary character of the rocks, it is evident that most of the eruptions were explosive, alternating, however, with quieter flows; in some cases the dikes can be seen, whence some of the lava came, at others the "necks" or throats of the volcanoes themselves filled up with volcanic boulders—of such is the celebrated Bassick mine. The mine is in the throat of an old crater of andesite, filled with boulders of granite and andesite bedded in gravel and sand. The ore of the Bassick appears as concentric zones or shells around these boulders, as a replacement of the gravelly matrix. The entire mass has been permeated by heated waters, which have decomposed the rocky fragments, depositing opaline quartz and kaolin in abundance.

The concentric shells around the boulders carry alternately several minerals, such as galena, antimony, zinc blende, copper and iron pyrites, all more or less gold-bearing. The ore deposition in this region seems to have taken place at the close of the eruptive period, when the eruptions were dying out into hot springs, fumaroles, etc., and producing great decomposition of the lava rocks. The district was not thought much of, until



STROMBOLI VOLCANO.

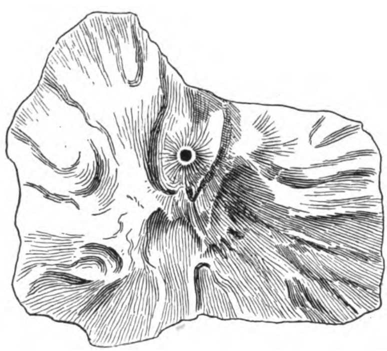
Mr. Bassick made his discovery in the unpromising-looking throat of the old volcano, containing a formation quite anomalous, and which the regular prospector, accustomed to true, orthodox fissure veins, would have passed by as very unlikely. So it may happen, to future prospectors, that some very unlikely formations may turn out great riches; hence, it is well to keep a sharp lookout for everything examinable.

A STUDY OF MODERN LIVING VOLCANOES TO UNDERSTAND THE CRIPPLE CREEK VOLCANO

By far the most typical, instructive, and important gold camp in Colorado and the West is that of Cripple Creek. To understand the geology of the Cripple Creek region and gold-bearing volcanic regions and rocks, and their relations to the ore deposits, a knowledge of the phenomena attending modern volcanic eruptions are necessary. Let us take that of the living volcano of Stromboli, described by Professor Judd, as throwing some light on the phenomena that may have occurred many thousands of years ago in the now extinct volcano of the Cripple Creek district.

From a point on the sides of the mountain of Stromboli, masses of vapor issue and unite to form a cloud over the mountain. This cloud is made up of globular masses, each of which is the product of a distinct outburst of the volcanic forces. At night a glow of red light appears on the cloud, which increases gradually in intensity, and then as gradually fades away.

After an interval this is repeated and continues till the light of dawn causes it to be no longer visible. When we land on the island we find it built up of the "ejecta" from the volcano, like a gigantic iron furnace with its heaps of cinders and masses of slag. The irregular shape and surface of the land is due to erosion removing the loose materials at some points, and leaving the hard slaggy masses standing up prominently, as dikes and hard portions of lava flows, as Pisgah, Rhyolite Mt., and others at Cripple Creek do, above the eroded and more fragmentary tuffs and breccias. This great heap of cinders and slags rises 6,000 feet above the sea bottom, with a base 4 miles in diameter; 2,000 feet above sea level is a circular depression, the crater of the active volcano.



MAP OF ISLAND OF STROMBOLI.

Looking down into the crater, an outburst takes place. Before the outburst, many light curling wreaths of vapor ascend from fissures on the sides and bottom of the crater. Possibly this is the origin of some of the dike-filled fissures of Cripple Creek. Suddenly a sound is heard like a locomotive blowing off its steam. A great volume of watery vapor is thrown up into the atmosphere, and with it a number of dark fragments are hurled 500 feet above the crater, some falling on the mountain, others back into the crater, with a loud rattling noise. Those rolling down the mountain are still hot and semimolten. This is a clue to the origin of the fragmentary materials composing the tuffs and breccias at Cripple Creek. The black slaggy bottom of the crater is, as we have said, traversed by many fissures emitting jets of vapor. Some of these are quite large, and vary in size and number and position at different periods. From some, only steam is emitted, in loud snorting puffs. In others, molten material is seen welling up and flowing outside the crater. Such fissures, when all eruption has ceased, would be found, as at Cripple Creek, sealed up with solid lava, with a lava flow on their tops. From this liquid mass, steam escapes in considerable quantities. Within the walls of the fissures, a viscid semiliquid lava heaves up and down, and churns around, till at last a gigantic bubble or blister is formed, which bursts violently, and a great rush of steam takes place, carrying fragments of the scum-like surface of the liquid high into the air. At night the fissures glow with a ruddy light. The liquid matter is white hot and the scum on it a dull red. Every time a bubble bursts a fresh glowing surface is exposed. It is the reflection of this surface upon the clouds of steam above the mountain that causes the fitful glow of light we mentioned.

STROMBOLI CRATER.

DIKES CUTTING BEDS OF SCORIA AND TUFF IN THE WALL OF A CRATER.

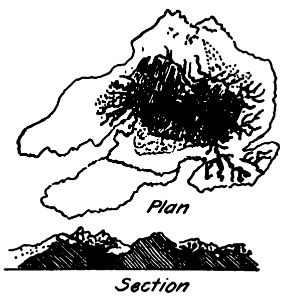
The phenomena show there are cracks communicating with the earth's interior highly heated matter beneath the surface, together with great quantities of imprisoned water, which, escaping as steam, give rise to all the active phenomena.

What is popularly supposed to be flame in an eruption, is the reflection on the cloud of steam and dust, from glowing masses in the mouth of the crater. Sulphur is not, as commonly supposed, erupted from a volcano, but is formed by the union of sulphurous acid and sulphureted hydrogen issuing from volcanic vents.

A volcano is a steam vent, like a geyser, which may be called a water volcano.

ORIGIN OF FISSURES

Some light is thrown on the possible origin of some of the Cripple Creek dikes and fissures by the eruption of Vesuvius in 1872. The bottom of the crater was entirely broken up, and the sides of the mountain rent by fissures in all directions. So numerous were these fissures that liquid matter appeared to be oozing from every part of its surface and the mountain to be "sweating fire." One fissure was enormous, extending from the summit to far beyond the base of the cone. This, filled with a dike of lava, is visible today. From both crater and fissures enormous volumes of steam rushed out with a prodigious roar. This roaring was from explosion of bubbles one after another, and the vapor cloud above Vesuvius, as at Stromboli, was made up of globular masses of steam, ejected at successive explosions. Each explosion carried upwards quantities of fragments, which fell back on the mountain. All along the course of the stream of lava, volumes of steam were thrown off.



PLAN AND CROSS-SECTION OF THE ROOTS OF A CRATER.

Black = Dikes Filling Fissures.

ORIGIN OF TUFFS

The discharge of such large quantities of steam causes the atmosphere to be saturated with watery vapor, which, condensing, falls in excessive rain storms, producing mud streams, formed by rain water sweeping along the loose volcanic dust and débris. In some such way, doubtless, the Cripple Creek tuffs and breccias were formed.

GASES AND MATERIALS EJECTED FROM VOLCANOES

The most abundant of the substances ejected from volcanoes is steam, and with it many volatile materials, such as hydrochloric acid and carbonic acid, also hydrogen, nitrogen, and ammonia, and at Cripple Creek, fluorine gas.

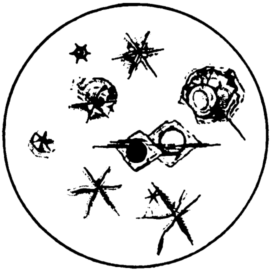
These different gases at Cripple Creek had much to do with the formation of ore deposits. Volatile metals, such as arsenic, antimony, and cinnabar, are erupted; these substances, issuing from volcanic vents at high temperature, react upon one another, forming new compounds, such as sulphur. Hydrochloric acid unites with the iron in the rocks to form yellow ferric chloride, common in Cripple Creek, and looking like a greenish-yellow sulphur. Acid gases change lime, alkaline, and iron elements into sulphates, chlorides, carbonates, and borates, which, when removed by rain, leave a white substance similar to chalk, composed of pure silica. Beds of such material occur not far from Cripple Creek, and powdered silica is found in some of the mines.

The lips of fissures from which steam and gases issue, are coated with yellow and red incrustations of sulphide and oxide of iron, such as are common in many prospect holes at Cripple Creek.

Solid materials are ejected in vast quantities; fragments of the rock masses, through which the fissure is rent, are carried upwards by the steam blast, together with other matter far beneath the surface, in a semifluid condition. Hence it is that at Cripple Creek we occasionally find fragments of red granite imbedded in the volcanic breccia torn from the throat of the volcano, in its passage through the underlying granite of the region.

MINERAL AND CHEMICAL ELEMENTS OF LAVAS

Eight chemical elements make up the mass of lavas: oxygen, silicon, aluminum, magnesium, calcium, iron, sodium, and potassium. Oxygen makes up the larger proportion, so that lavas are mostly oxides. Next is silicon and aluminum, giving the quartz and feldspar and silicate element.



MICROSCOPIC STRUCTURE OF GLASSY LAVA SHOWING MICROLITES AND CRYSTALLITES.

Lavas are of two kinds, acidic and basic. Acid lavas contain eighty per cent. silica; basic, forty-five per cent. The former are rich in potash and soda, the latter, in lime and iron; the former are commonly light in color and weight, the latter, dark and heavy. Rhyolite is an example of an acidic lava; basalt, of a basic one. The andesites and phonolites of Cripple Creek are intermediate. The minerals composing these lavas are principally quartz and feldspar, together with the dark minerals, mica, augite, hornblende, olivine, and magnetite.

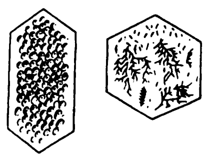
CRYSTALS AND MICROSCOPY OF LAVA

Many lavas are of a glassy nature; others contain many crystals, some of large size.

Microscopic sections of lavas show them to be made up of a ground mass of a glassy character, with distinct crystals set in it like plums in a pudding.

In others, the crystals are so thick that the glassy base can scarcely be seen.

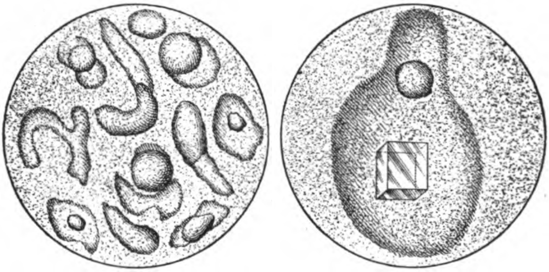
Through the midst of the glass, cloudy matter is observed; a higher power shows this "nebula" to be composed of minute particles called crystallites, the embryonic forms of crystals. Sometimes we can see an attempt of these particles to aggregate into a geometrical form, sketching out the outline of the large crystal they intended to form, but were prevented from finishing, by the cooling of the glassy magma. These crystallites assume forms like ferns, hairs, spiders, etc. (See illustrations on this page.)



MICROSCOPIC STRUCTURE OF SOME CRYSTALS SHOWING MICROLITES AND CRYSTALLITES.

In subterranean regions the conditions were particularly favorable for the development of crystals. The lavas cooled with extreme slowness, under enormous pressure, allowing plenty of time for the crystals to form.

Those lavas containing most soda and potash (acid lavas) assume a glassy condition, and these have often cooled near the surface rapidly, the more crystalline varieties slowly, at great depth. Obsidian and rhyolites are glassy types; granite and some porphyries with large crystals are of the latter class, while



MINUTE CAVITIES CONTAINING LIQUIDS IN THE CRYSTALS OF ROCK.

andesite and phonolite may be intermediate. The latter, however, at Cripple Creek, may have cooled quickly near the surface, and the crystals are for the most part small.

Besides the natural imprisoned water, crystals in lavas are found microscopically to contain globules, sometimes filled with gas, salt, and water, which may add to the materials for the production of steam.

ERUPTIONS OF DUST

Steam escapes from lava so violently that the froth, or scum, called scoria, is broken up and scattered in all directions. This scoria, like pumice, is full of little holes like a sponge, due to escape of the steam in it. Such spongy scoria is found scattered over the hills of Cripple Creek. During violent eruptions a continuous upward discharge of these fragments is maintained; the cindery masses hurtling one another in the air, fall back into the vent, or are scattered over the mountain. Being often shot up again and again from the vent, they are reduced to the finest impalpable dust. They fill the atmosphere to such an extent as to bring on an "Egyptian darkness." This dust, mingling with descending rain, forms destructive mud flows, and sets or consolidates into the tuffs, so abundant at Cripple Creek. When large angular fragments are caught up and consolidated with these, the rock so formed is a breccia, as already illustrated.

Volcanic craters, after having been formed, are liable to be disturbed by later eruptions. Thus, the crater of Vesuvius was reduced 400 feet by a later eruption, the old crater blown up, and a much vaster crater opened.

Cripple Creek also witnessed its second disturbance, after the andesitic eruption had ceased, by one of phonolite lava.

FLUIDITY AND OTHER PROPERTIES OF LAVAS

Some lavas, such as basalt, are reduced to such a state of fluidity that their streams run like water to great distances. Others are of a more viscid, mortar-like consistence, especially the acid lavas, such as those of Cripple Creek. These are apt to flow but a short distance from their source, and to build up big domes and thick masses ; of such a nature seems the structure of Nipple Mountain, south of Cripple Creek.

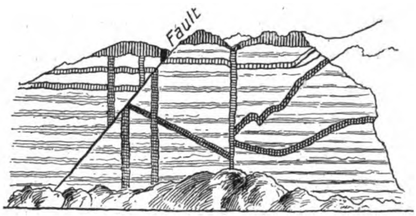
The peculiar columnar structure often observed in basaltic lava sheets, and, in a rough way, developed in the phonolite of the cliff above Victor mine, is due to cooling and contraction, somewhat in the same way as mud cracks are formed in a drying-up pond. A block of lava isolated by these cracks assumes a polygonal form, like the basaltic columns of the Giant's Causeway.

During the cooling down of lava and the escape of steam and gases, deposits of sulphur, specular iron, and (at Cripple Creek) fluorspar are deposited. Specular or micaceous iron is not uncommon at Cripple Creek. Rock masses are completely disguised by these incrustations.

STRATIFICATION OF TUFFS

Tuffs and breccias are often found stratified. The fragmentary materials in falling through the air are sorted, the finer particles being carried farther from the vent than the larger ones. Craters built up of tuffs and breccias fallen in the condition of a muddy paste, show very fine stratification.

Large cones are built up of uniformly spread layers of more or less finely divided material, disposed in parallel succession. At Cripple Creek the bedding is indistinct, and often difficult to trace, the dip of stratification being still more compressed by the cross-fracturing of the rocks; hence, it is hard to tell whether the lines represent cross-fracture cleavage, or bedding planes. In most volcanoes the stratified tuffs are cut and crossed, as at Cripple Creek, by numerous dikes running in various directions, cracks filled by lava from below.



CLIFF SECTION, COMPOSED OF ALTERNATE BEDS OF LAVA AND SCORIA, CUT BY LAVA DIKES, AND FAULTED.

Movements, too, have taken place subsequent to the accumulation and consolidation of the whole material, as shown in the illustration, whereby the masses are faulted and fresh fissures opened in them. Faults are found in some of the mines at Cripple Creek, faulting not only the lavas, but the veins also. Cliff sections of volcanoes show alternate beds of solid lava, scoria, and tuff, representing different eruptions and flows.

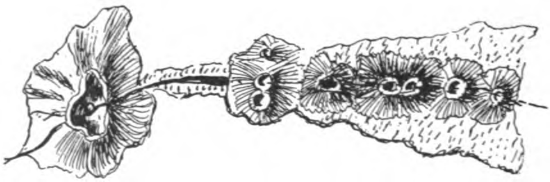
There seems an order and succession in the eruption of the different varieties of lava. During the earlier periods, rhyolites, andesites, and phonolites are erupted, and later basalts. This appears to be the case in the volcanic region west of Cripple Creek, around Mt. MacIntyre, Thirty-Nine Mile Mt., and Black Mt. The prevalence of basalt capping the other lavas in that region, together with the greater freshness of the rocks, imply that its eruptions were somewhat later than those of Cripple Creek, where basalt is not found, and where the rocks are much decomposed.

Volcanic eruptions shift their centers from time to time, making new cones along a line of fissure (for volcanoes are built upon lines of fissure). (See page 140.) Extinct craters are frequently filled by beautiful deep lakes. Cones rise within cones, and within great crater rings. At each successive great eruption, the old cone is blown away, and a new one formed.

Hot springs contain large quantities of silica or quartz in solution. The solution of silica is effected at the moment of its separation from combination with the alkali, during the decomposition of volcanic rocks, and is favored by the presence of alkaline carbonates in the water, high temperature, and the pressure under which it exists in subterranean regions. When the water reaches the surface, and is relieved from pressure and begins to cool, silica is deposited. So are the basins of geysers formed, and so the opal and hydrated quartz we find in many of the Cripple Creek veins, and in resilicated rocks.

Hot and cold springs rising in volcanic regions are charged with carbonic acid, and passing through calcareous rocks, dissolve large quantities of carbonate of lime, and redeposit it in a crystalline form known as "travertine." Near the base of Mt. MacIntyre, west of Cripple Creek, a prospect is opened on a fissure filled with this substance.

Nearly all eruptions take place along lines of fissures Probably all volcanoes are located upon fissures of some kind, and even the general distribution of volcanoes over



SHOWING CRATERS FOUND ALONG A LINE OF FISSURE IN THE ERUPTION OF ETNA.

the earth's surface has been attributed to lines of fissures, as if the earth had been cracked like a glass globe. We have plenty of opportunities of seeing ancient fissures filled with lava in the numerous dikes at Cripple Creek, and in the greater volcanic region west of it; but so far no distinct volcanic craters have been found. Nevertheless, it is probable that craters existed along these fissures, long since removed by erosion, or buried deep under flows and surface matter. We not unfrequently find at Cripple Creek that fissures did not all succeed in breaking through to the surface, for at some depths in the mines the apexes of buried dikes are found and fissures filled by vein matter, whose outcrops do not appear at the surface. A single vein is followed from the surface, and with depth two or more veins are often encountered, together with various small fissures.

Earthquakes doubtless accompanied the eruptions, and developed many smaller fissures, and further shattered the rocks. Added to this, at Cripple Creek, there was the second eruption of phonolite, after the andesite had ceased. This second eruption doubtless added new fissures in the efforts of imprisoned vapors to force for themselves channels to the surface.

GASES AND SOLFATARIC ACTION

The several stages in the decline of each volcanic outburst are marked by the appearance at the vent of certain acid gases. As the temperature at the vent declines, the nature of the volatile substances emitted undergoes a regular series of changes.

In fumaroles, sulphurous acid and hydrochloric acid abound, with sulphureted hydrogen and carbonic acid in much smaller proportions. Around these fumaroles, deposits of sulphide of arsenic, chloride of iron and of ammonia, boracic acid, and sulphur take place. Arsenical pyrites are a common associate for the ores near the surface at Cripple Creek, and many rocks are permeated with iron pyrites.

Where a volcanic vent sinks into extinction, hydrochloric and sulphurous acids are first evolved, and later sulphureted hydrogen and carbonic acid springs. Such springs are common in the volcanic districts of Colorado today, but we have long passed the stage of the stronger acids, which could only be expected in the pit of an active modern volcano like Kilauea. We may, however, expect to find traces left of these gases, in the rocks of Cripple Creek, such as a bleaching and decoloration of the rocks, leaching and precipitation of iron, forming those varied patterns of oxidation so common at every prospect hole; also deposits of various sulphates and chlorides, rocks deprived of iron and alkalies and reduced to powdery silicious masses.

One action of subterranean springs, is the transportation of material in a state of solution and redepositing of it elsewhere, especially in lines of relief of pressure, such as fissures, shattered rocks, and decomposed rocks and zones in the rocks.

At Steamboat Springs, Nevada, metallic gold, cinnabar, and other minerals have been found coating the sides of fissures from which living hot springs issue at the surface. In great volcanic foci the transfer of various sulphides, oxides, and salts, which fill veins, has been effected either by solution or sublimation, or the action of powerful currents. This applies to the veins and ore deposits in question.

As the igneous activity of a district declines, the temperature of the issuing gases and waters diminishes, till at last the volcanic forces appear to have wholly abandoned the region and been transferred to another. This may have been the case with Cripple Creek and the volcanic region west of it, of apparently later date. The history of a volcanic disturbance is as follows:

1. The area is troubled by subterranean shocks and earthquakes.

2. The origination of fissures is indicated by the appearance on the surface of hot springs and of various gases.

3. With increased subterranean activity the temperature of the springs and gases increases.

4. A visible rent is formed at the surface.

5. From this, fissure gas and imprisoned vapor escapes so violently as to disperse the lava in clouds of scoria, or dust, or to cause it to well out in flows.

6. Volcanic action concentrates at one or several points, and the ejected material accumulates from volcanic cones.

Sometimes the volcanic activity dies out entirely, leaving cones thrown up along the line of fissure. At others, some such center becomes for a long time the habitual vent for the volcanic forces of the district, and a large cone is built up.

When the height and thickness of the cone have grown great, the succeeding eruption rends the sides of the cone, producing fissures, quickly filled by lava, forming radiating dikes, and surmounted by parasitic cones. The dikes of Cripple Creek may in cases represent such occurrences.

When volcanic energies can no longer raise material to the summit of the crater, nor rend the sides, they find relief by making new fissures and small cones in the country outside the main volcanic crater. The numerous phonolitic dikes in the granitic region, outside of the main center at Cripple Creek, may have so originated. At last, volcanic energy diminishes, eruptions of lava cease, fissures are sealed up with solid lava, volcanic cones crumble away.

But still the existence of heated matter at no great depth is indicated by outbursts of gases and vapor, formation of geysers, mud volcanoes, and hot springs. As the underlying rocks cool down, the issuing jets of gas and vapor lose their high temperature, diminish in quantity, geysers and mud volcanoes become extinct, hot springs disappear, and all is quiet.

It was in the latter or hot-spring stage, that the ores at Cripple Creek were leached from the volcanic rocks, probably from great depths as well possibly as from the sides, and concentrated and deposited in the fissures, shattered zones, and decomposed rocks. The last stage is as we find things today.

GENERAL SUMMARY OF PROBABLE VOLCANIC EVENTS THAT OCCURRED AT CRIPPLE CREEK

At Cripple Creek there was a volcanic eruption in Tertiary times, due, probably, to some mountain elevation going on in the region of Pike's Peak or generally in the mountains.

We may assume that preceding the eruption, the area was troubled by earthquakes. Various kinds of acid and hot springs appeared above the surface, indicating the fissuring of the ground that followed.

At the bottom of these fractures, which may have been numerous, molten rock appeared, giving off imprisoned vapor from bursting blisters of lava. These shoots of steam formed into a cloud overshadowing the area, and carried upwards quantities of scoria and fragments which fell back around the orifice, forming a crater cone, or craters. These fragments being repeatedly shot up, and falling back into the crater, were comminuted into fine dust, and fell, together with larger angular fragments, over the surface.

The atmosphere charged with condensing steam gave rise to heavy rainfalls. The water descending the ravines caught up the volcanic dust and fragments, forming mud flows, the material rapidly setting into the rocks we call tuffs and breccias.

As the first eruption at Cripple Creek was of andesite, these are called andesitic tuffs and breccias, and constitute the principal mineralized rock of the mining area.

These tuffs are sometimes stratified by the materials being sorted at the surface by the water.

After this first eruption ceased, there may have been a rest for a time, the lavas may have cooled and consolidated, and the region been covered by various acid and hot springs issuing from fissures caused by the late eruption.

Then the district was a second time disturbed, this time by an eruption of phonolite, ascending through numerous rents and fissures, not only in the overlying andesite, but also in the granitic region outside of the first volcanic "focus," probably finding the old seat of action too much choked by eruptive matter. This second eruption added many new fissures to the already shattered rocks, and gave many opportunities for the deposition of metallic and vein material deposited through the medium of gaseous and hot-spring and solfataric action which followed upon the cessation of the phonolite eruption.

After the eruptions at Cripple Creek ceased, the volcanic forces seem to have transferred their field of action to the area west of Cripple Creek, in the Four-mile district. The rest is the history of today.

CRIPPLE CREEK AS A PROSPECTING FIELD

A visitor standing on top of one of the hills like Mt. Pisgah, overlooking Cripple Creek, and glancing at the various mines and multitudinous prospect holes speckling the hills, is struck with the compactness of the mining district within the limited area of 18 square miles. In this small area all the principal mines are located, and one can ride around the entire camp in an hour or two. Outside of this area, there are as yet no mines of importance, though prospect holes may be found for a circuit of many miles.

ANDESITIC AND GRANITIC AREAS

He will observe that the principal mines are located on the round smooth hills, on their tops, slopes, and on the gulches, where the vegetation is mostly grass and quaking aspen. These, too, are within a sort of natural rampart of more rugged hills, wooded with pine. In these outlying hills, only a few scattered prospects are visible. The reason for this is to be found in the geology of the region, and the differences between the areas occupied by andesitic breccia and granite. The rounded grassy aspen-covered hills representing the andesitic breccia, carry most of the ore bodies, and the principal mines are restricted to them. The more rugged hills, covered with fir trees, represent the granitic area, and in them for the most part are few mines of importance, though many likely prospects are opened upon dikes of phonolite.

There are intermediate areas, such as that of Battle Mt., characterized by the presence of both andesitic breccia, phonolite dikes, and granite, in which are some of the richest mines of the district, such as the Independence, Portland, Annie Lee, and others.

It will appear how important and useful a geological survey is of such a region—a fact not always recognized by practical miners. If the ore bodies are mainly associated with the particular rock called andesitic breccia and phonolite, it is well for them to be able to recognize these rocks, and ascertain the limits of their area.

SIGNS THAT LEAD TO PROSPECTING

The next thing that strikes the observer is the prodigious number of prospecting holes and prospecting trenches, the latter being particularly common. He may ask what was there in the general appearance and character of this district that led the "eagle-eyed" prospector to suspect the existence of ore bodies in it, or that it was "a kind'er likely-looking place"? Again, how is it that it was so long overlooked by the "eagle-eyed," especially when so easily accessible?

On general principles, in past years, miners in Colorado, after the Leadville and Aspen excitement, were more on the lookout for silver than gold; they looked, therefore, for rocks like those of Leadville, with contacts between porphyry and limestone, and every limestone ledge in the country was ransacked. Silver was rarely found in volcanic lava rocks, except perhaps in the great San Juan region, and miners thought as little about prospecting unpromising-looking hills of lava, as they would the basaltic caps of the table mountains on the plains. Again, gold leads do not show their ore on the surface, like some silver-lead veins. There is nothing perhaps but a little seam of rust that might occur almost anywhere, and in any kind of rock. Hence, lava districts of somewhat recent origin were overlooked, rather than looked over. The discovery of the gold-bearing properties of the Cripple Creek lavas, together with the increased thirst for gold, turned the tables, and now throughout Colorado every lava formation is being prospected with as much zeal and indiscriminateness as were the limestones in the Leadville days. The prospector now needs to know volcanic lavas at sight, to distinguish varieties, and to know all he possibly can about their origin, varieties, and mode of occurrence. Hence the importance we gave to the subject in the preceding remarks on volcanoes. A prospector *now* would, at a glance, consider the area about Cripple Creek as worth looking over; and the geologist would consider it a very likely place, not merely from the presence of the lavas, but mainly from the great decomposition of the rocks, and the evidence of the presence of past solfataric action.

DIFFICULTIES IN PROSPECTING

But the "eagle-eyed" one did not entirely overlook this district in the past, for some years ago he was sufficiently prepossessed with the appearance of things to drive a couple of short tunnels in Arequa gulch, and narrowly escaped becoming a millionaire. What troubled the prospector was, that though he found the hills covered with an extraordinary amount of "float," he could not trace this float to any ledge or rocks "in place." For the most part, the hills were grassed over, or covered with vegetation; and through the turf were very few outcroppings of a likely kind, so far as he could see. There were no prominent quartz veins, or zones deeply impregnated with iron, hence he gave up the region, mentally wondering where on earth all this rich float could have come from, perhaps solacing his mind by one of his igneous, brimstony theories that it had been scattered over the country from a distant volcano, or washed there by flood or glaciers from some unknown distant region. The former theory, after all, was not far from the truth, but the absence of all rounding and smoothing of the fragments of float precludes the latter hypothesis. Evidences of former glaciation are remarkably absent from the vicinity.

THE REGION IMPREGNATED WITH ORE

To those who have studied Cripple Creek of today, the source of this "float" is no mystery. Little, if any, of it has been broken off from orthodox quartz fissure veins, or even extracted from well-defined ore zones. The fact is that the whole andesitic area is more or less impregnated with the precious metals, and the float on the surface is little more than the surface débris of the general underlying rock. There is scarcely a stone that you may kick with your foot over the entire area, but that will show some trace of gold. On one hill an experienced mining superintendent told me that, for an experiment, he went around with a wagon and picked up the "float" almost at haphazard, and it averaged twenty-two dollars in gold. That such a "floaty" region should receive attention some day is not to be wondered at, and we believe men of Colorado Springs were among the first to give it serious attention by opening holes and prospecting trenches almost at random, resulting in important discoveries. As a rule, even after this, the best mines were discovered by mere chance and guess work, or by plodding but blind prospecting, something like the Leadville prospector, who in early days had all Leadville before him to prospect, but did not know where to begin, till, sitting down under a tree, eating his lunch, he saw a squirrel scratching in the ground; he accepted the happy omen and "went down," so the story goes, and of course "struck it rich"; and in this manner, we understand, the Pharmacist and many other now noted mines were discovered at Cripple Creek.

MODE OF PROSPECTING

This absence of surface outcrops, or visible leads, when the "rush" came, led to indiscriminate and abundant prospecting, which has been kept up till the present time; hence the extraordinary freckling of the hills with prospect holes and trenches.

Sometimes they would select any piece of land they thought, for some reason or other, or without any reason at all, likely, and go to work to punch holes and dig trenches all over it, to find something. In this way they frequently came across enough signs to warrant putting down a prospect hole, and holding the claim, and then went on "to pastures new."

CHARACTER OF FLOAT AND OTHER SURFACE SIGNS

As we have said, the whole region is covered with float. This float is usually a somewhat porous piece of lava, or andesitic breccia, or tuff, stained with yellow, brown, or red oxide of iron, sometimes in patterns or concentric rings. It is often found to be honeycombed when broken with a hammer. There is no visible ore, but an assay will most likely show traces of more or less gold. Again, a species of red porphyritic granite has been desilicated and robbed of many of its crystal constituents, and left as a porous skeleton of a rock by the action of gases and springs. The pores in this are often occupied by oxide of iron, or even by crystals of fluorspar. This is a likely kind of float. Honeycombed rusty rock, with quartz crystals, is a likely float, both of these representing the action of mineral hot springs. At rare intervals we may see a little of this oxidized rusty rock in place protruding from under the grass, and if so, there is sure to be a prospect hole alongside of it.

PROSPECTORS OPENING A PROSPECT IN A NEW REGION WEST OF CRIPPLE CREEK.

Bold outcrops of lava rock are comparatively scarce, and when they do appear, as in the cliff above Victor mine, Mt. Pisgah, Bahr, and Rhyolite peaks, the rock is apt to be so hard as to preclude the probability of much ore deposits in it.

Pieces of rock or float stained a violet-purple color by fluorine are considered a good sign of an ore body not far off, this fluorspar being found characteristic of some of the richest veins in the camp; and fluorine gas was doubtless connected with the deposits of ore matter, especially of the tellurium, the present matrix of the gold in the deeper parts of the mines.

Pyrites is not usually found on the surface till the rock is broken open, and tellurium in little silver scales and spots, not till considerable depth is attained. But free gold may be found in surface float, and from the grass roots down, and in the early development of a mine, in the oxidized upper portions, associated with iron oxide and black manganese or "psilomelane."

Micaceous or specular iron is seen in some prospect holes; and localities marked by evidences of past hot-spring action, such as the appearance of botryoidal chalcedony or opal, should be prospected. A common and curious marking in some of the bleached volcanic lavas is that of an imitation of trees, ferns, and mosses, scientifically known as "dendrite" or "tree-rock," but popularly called "photographic rock." This remarkable eccentricity of nature is due to crystallization of solutions of manganese, and may be compared to fern-like appearances on a frosty window pane in winter, which are certainly not of organic origin, or in any way connected with the processes of photography. These dendritic markings may or may not be considered as signs of ore. Similar markings are very common in the porphyries of Leadville overlying the silver deposits.

SURFACE PROSPECTING OF A MINE

In some of the surface discoveries of mines, when a considerable area, covered by a blow-out of iron oxide associated with purple fluorspar, has been found to run well in free gold, the ground is prospected and developed to the depth of a few feet and over a certain area with plows and scrapers, the material so obtained being sent wholesale to the stamp mill and often giving rich returns. The object of this work is not merely to get all the values out of this rich float, but in hopes of uncovering the vein or veins of which it is the oxidized cap or blossom. This was the way in which the Deerhorn mine was opened up, and its veins discovered on Summit Hill. The ground on the top of the hill is observed to have been "gophered" in all directions, like the catacombs, to a depth of about 20 feet, and over an area of a square acre or so. This was done partly to gather up and collect the rich float that was found scattered over the hill, and partly to discover the leads in place.

This rich float was stained with purple fluorine, and upwards of 25,000 dollars' worth of gold was obtained from this, the material being dug up by plows and scrapers, before the subsequently discovered veins were found or worked.

In the case of the Anaconda mine, on Gold Hill, the outcrop of a dike of andesite was discovered on the hillside, covered with an oxidized crust carrying gold. The owners developed this by an open quarry, about 100 feet in length and 40 to 50 feet deep, from which they extracted the bonanza that made this mine at its outset so celebrated, and later proceeded to uncover the dike on the surface, to a depth of about 20 feet along the entire length of their claims, but nothing comparable with the bonanzas of the first quarry has been found since in extension or depth.

RICHNESS WITH DEPTH, ETC.

Many of the mines shipped their best ore from the grass roots and upper oxidized portions of the veins, which contained free gold and were free milling. With depth some of these mines have not done nearly as well, especially when they reached the unoxidized zone, away from surface influences, and the ore was found wrapped up in tellurium or iron pyrites.

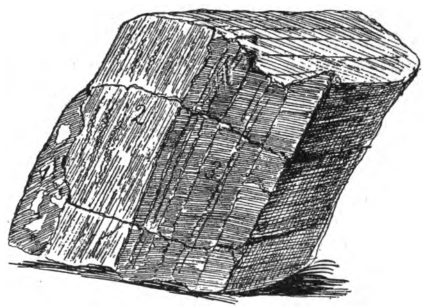
The palmiest days of many a gold camp are its earliest days.

SUGGESTIONS TO PROSPECTORS

In the more productive area the prospector will do well to keep to the andesitic breccia, and follow the signs we have mentioned. Outside of this area his course may be a little different, as then he is in the granitic district, and looks out for the appearance of dikes of phonolite, rarely more than a few feet, though sometimes many yards, in width, and easily distinguished from the red granite by their light gray or white color. These dikes do not often appear outcropping in the granite cliffs, but are more commonly to be found buried beneath the débris and grass of the slopes. On these he may find no indications, and may be compelled to trust to haphazard trenching; or a few stray pieces may lead him to the spot.

The more rusty, oxidized, and decomposed the phonolite, the more likely it is to carry gold; at times he may find ore and free gold in the dike itself, but more often at its contact, on one or both sides, with the granite. There he is likely to find a crevice filled with clay or iron oxide, carrying seams and cavities lined with quartz crystals or stains of purple fluorspar.

Sometimes he may find the coarse granite, as in the case of the Independence mine on Battle Mt., just at the contact with the dike of lava, to be very rotten, much honeycombed, and robbed of many constituent minerals, and these, by replacement with metals, may yield him the richest ore. Again, the dike between walls may be reduced to a blue or yellow jaspery clay, with a vertical lamination or cleavage. These lines of cleavage are filled with quartz and iron oxide (see Section of Moose Mine vein), in such lines he is apt to find the richest ore.



A SECTION OF MOOSE MINE VEIN, RAVEN HILL.

1, Country Rock Breccia. *2*, Yellow Jasper, with Cavities of Quartz Crystals. *3*, Blue-Gray Jasper, with Seams of Quartz and Iron Containing Gold.

After opening a prospect, the ore signs, consisting of stains of oxide of iron and manganese, instead of pursuing an even or regular course, are apt to scatter among the infinite number of crevices shattering the rocks, no one little lead being of sufficient richness to follow with profit, and the whole body between walls scarcely paying to work.

The ore signs often follow a very uneven course, now lying upon a fairly defined wall, then running for a distance into one wall or other, or again following the main course of the creviced lava breccia between walls, now in pockets and crevices, again scattered, or again impregnating the porous and decomposed rock. There are very few true, well-defined veins in the camp; the ore rather impregnates certain ill-defined shattered zones of rocks between certain ill-defined boundaries called walls. At others the ore occupies narrow cleavage planes in the rock, of which there may be two or three in a mine, some of them productive, others very little so. Ore bodies in the harder or more compact rocks, such as Buena Vista and Victor mines, are apt to have something more like defined veins and defined walls. In some cases surface signs have been poor, and with depth have done well; the exact opposite has often been the case. Some mines have been good from bottom to top, but we have to be careful here, as in most gold camps, of the old fallacy of "richness with depth." There is little more criterion for this than in other camps, and many a once famous mine is looking vainly with depth for its lost bonanza, though in other respects doing fairly well.

As regards the granite itself, we have heard of few ordinary quartz fissure veins, unaccompanied by lava intrusions, proving productive.

The fine-grained, red, eruptive granite on Barnard Creek, north of Cripple Creek, has shown a promising ore body in a lava dike in the granite, which, singularly enough, produces a fine-grained galena, rich in gold. Galena is quite a rare ore in Cripple Creek. Green carbonate-of-copper stains appear at times in the schists and gneisses, but none so far productive.

The railroad from Canyon City to Cripple Creek did some good prospecting work in the granite area, its cuttings exposing quite a number of phonolite and other dikes, together with some granitic veins.

Outside of Cripple Creek, in the great volcanic area to the north, between Cripple Creek and South Park, is a fair prospecting field. The rocks are mainly granites, rhyolites, trachytes, andesites, and basalt, the products, as at Cripple Creek, of a series of volcanic eruptions, of which the latest appears to have been basalt, which commonly caps the other and lighter-colored lavas.

The rocks in this region are for the most part less decomposed than those at Cripple Creek, which is not so favorable a sign. Here the prospector should look out for all signs of decomposition, such as we observed at Freshwater district, a not unlikely spot. The very hard, massive rocks are not likely to be productive, such as the hard black basalts. The lighter-colored and more decomposable lavas offer a better chance.

Centers of eruption, such as relics of old craters and dikes from which these different lavas issued, should be sought for and prospected. Balfour, a small mining camp at the north of this area, is established among granite and eruptive rocks, which have been found to be mineralized by pyrites. The granites here have several fissure veins and dikes in them, showing considerable disturbance to have taken place in that neighborhood. The low hills in which the prospect holes are located are capped with basalt, apparently resting on volcanic tuffs and other lavas. So far, nothing very productive has been found, though here, as elsewhere, much is hoped for with depth. Singularly enough, in one of these veins in lava, we noticed a tarry substance or inspissated bitumen in the cavities of the rock, an unusual occurrence in fissure veins or in volcanic rock.

CHAPTER XII

ORE DEPOSITS IN SEDIMENTARY ROCKS

BLANKET ORE DEPOSITS, CONTACT DEPOSITS

This great second class of ore deposits, occurring principally in Paleozoic limestones at contact more or less with intrusive sheets of porphyry, is mainly represented in Colorado by the Leadville and South Park mining district, the Kokomo and Red Cliff districts, and the Aspen and Gunnison districts, though locally here and there, wherever Paleozoic strata accompanied by igneous rock may be exposed, silver mines may be found. We will begin with Leadville and South Park as primarily instructive and typical.

SOUTH PARK ORE DEPOSITS

The basin plain of South Park is underlaid by sedimentary rocks from the Cambrian below, to the Upper Cretaceous on top. These strata slope up to the crest of the Mosquito Range on the west, where they become violently folded, faulted, and eroded.

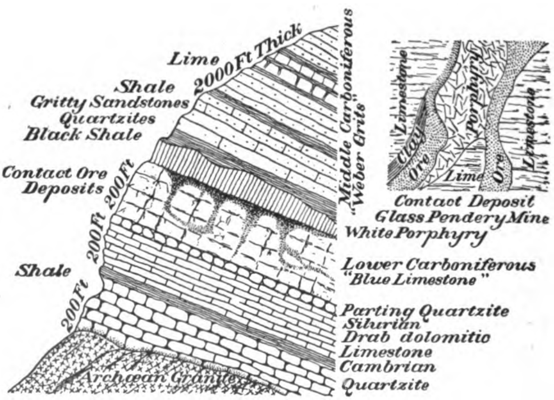
The mineral developments are on the slopes of this range, on both sides of it.

The order of succession of strata forming the structure and cliffs of the range, and resting on the granite, is as follows, beginning with the lowest:

	Feet Thick.
Cambrian quartzite	200
Silurian drab limestone (dolomite)	200
Lower Carboniferous blue limestone	200
Middle Carboniferous sandstones and quartzite (Weber grits)	2,000
Upper Carboniferous limestones, reddish sandstones	1,000
Total	3,600 to 4,000

These formations have been traversed by eruptive quartz porphyry and porphyrite dikes and intrusive sheets. The dikes occur principally in the Archæan, but the intrusive sheets are many and are spread out between the quartzites and limestones of the Cambrian, Silurian, and Carboniferous.

The connection between the eruptive masses and deposition of ore is very marked. The ore bodies are a concentration of the metallic

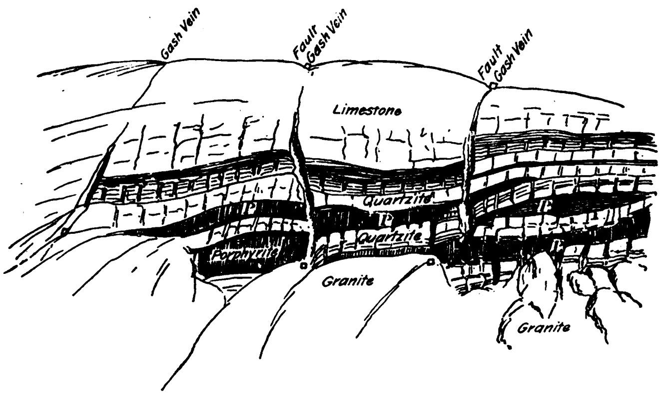


SECTION OF LEADVILLE CLIFF.

minerals originally disseminated through the mass of these eruptive porphyries and deposited along their plane of contact with the sedimentary beds, and by metasomatic substitution extending more or less into the mass of the latter.

On mountains Lincoln and Bross, in the principal mines, the ores are mainly argentiferous, yielding galena and its products of decomposition, viz., carbonate of lead (cerussite) and sulphate of lead (anglesite) with chloride of silver. Baryte (heavy spar) is a common gangue or vein rock especially in the richest parts of the mine. Iron pyrites, decomposed and passing into a hydrated oxide of iron, together with a black oxide of manganese, give to the ore its rusty and black color.

The deposits occur in irregular bodies or pockets, often of great size, in the blue limestone, near its upper surface, but not always easy to find or follow. This limestone was originally covered by a sheet of quartz porphyry which has been locally removed from the ore deposits, but exists in the peak. This porphyry, generally recognized by its large feldspar crystals, is



SILVER-LEAD GASH VEINS IN FAULTS.

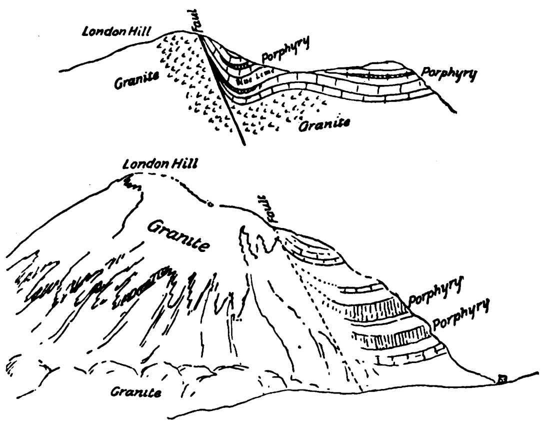
Gash Veins in Paleozoic and Porphyry Rocks, Buckskin Cañon, South Park. These Veins do not Extend Down to the Underlying Granite.

called Mt. Lincoln porphyry, and is quite common and characteristic of Western Colorado. In the Dolly Varden mine the ore occurs in the limestone at contact *with a vertical dike of white quartz porphyry.*

In the Fanny Barrett mine, on Loveland Hill, rich deposits of galena and anglesite occur in a vertical fissure (probably a gash vein) crossing the hill from side to side, and traversing the Paleozoic strata at right angles to their dip, but probably not entering into the underlying granite. This mine was discovered by noticing little pieces of iron following a general line across the hill.

In Buckskin gulch the Phillips mine is an immense mass of gold-bearing iron pyrites, deposited in beds of Cambrian quartzite *near a dike of quartz porphyry.* This mine was discovered by its rusty outcrop being exposed along the edge of the stream. At first this crust of iron oxide was loose enough to be panned for gold with good success by the old-timers, and the residue was afterwards milled. But when the hard pyrite set in, the ore was found to be too low grade to pay for roasting and smelting, and for many years lay idle. The Criterion in the cliff above this consists of *large caves* in Cambrian quartzite, still partly occupied by oxidized gold-bearing iron ore, and galena-bearing silver *close to a porphyrite dike.*

The London mine, in Mosquito gulch, is peculiar and instructive, as being involved in the great London fault. There are two strong veins or deposits of pyrites, carrying both gold and silver; the gangue of one is quartz, the other, calcite. They



THE LONDON MINE FAULT.

occur in the limestone in connection with an *intrusive bed of white porphyry.* These deposits stand in a vertical position, the beds containing them having been turned up abruptly against the great London fault, by whose movement the Archæan granite rocks forming the eastern half of London Mt., are brought up into juxtaposition with the Silurian and Carboniferous beds at its western point.

Going south along the Mosquito Range the intrusive *porphyries diminish in extent and with them also the mineral deposits.*

The Sacramento mine is a good example of a "pocket" mine. Rich bodies of galena and rich decomposed ores have been found at uncertain intervals in a series of pockets or cavities. Some of these pockets or cavities are empty, and lined with modern stalactites; others contain loose sand, with pebbles of rich ore; others are quite full of rich ore deposits. These deposits are difficult to follow with any degree of certainty, and much of the profits made in the rich pockets have been used up in blindly "gophering" after other pockets. From some of these chambers open fissures or joint planes ascend to the surface. The limestone was originally capped by a porphyry which has since been eroded off. This porphyry doubtless supplied the ore.

LEADVILLE DISTRICT

The western boundary of this district is the Sawatch Range of Archæan granite. The slope of the Mosquito Range in the east, and the hills on the north, forming the watershed between the Grand and Arkansas Rivers, have a basis of Archæan granite and gneiss more or less covered by patches and remnants of the Paleozoic formations, i. e., Cambrian, Silurian, and Carboniferous, which have escaped erosion.

Their lower position relative to corresponding beds on the eastern or South Park side of the Mosquito Range is due in part to faulting, and in part to folding of the beds.

Within these Paleozoic formations, these beds of quartzite and limestone, *there is an enormous development of eruptive rocks,* principally quartz porphyries, partially occurring as dikes, but generally as immense intrusive sheets, following the bedding plane of the sedimentary rocks.

Glaciers have been at work, also, in this neighborhood. A huge "mer de glace" occupied the great valley of the Arkansas, to whose bulk numerous side glaciers contributed, and these glaciers have carved and sculptured the mountains. In the flood period following the first glacial epoch, a lake was formed occupying the head of the Arkansas Valley. The stratified gravel and sand beds that were deposited at the bottom of this lake now form terraces bordering the valley of the Arkansas River. These beds, known as "wash" or placer grounds, yield gold and are open to further development. Leadville is the center of the mining district. The ores are argentiferous galena and zinc blende, and are smelting ores. Their value is increased by their having been oxidized, the lead occurring as carbonate, the silver as chloride in a clayey, or else silicious, mass of hydrated oxides of iron and manganese.

The ore is principally confined to the horizon of the "blue" or Lower Carboniferous limestone, covered by an intrusive sheet of "white Leadville quartz porphyry." The ore bodies occur not only at the immediate contact of these rocks, but extend down in irregular pockets and chambers into the mass of the limestone, sometimes to a depth of 100 feet. Sometimes the ore completely replaces the limestone between two sheets of porphyry, as in the "Col. Sellers mine," Chrysolite, Little Pittsburg, and on Fryer Hill. A few ore bodies occur, carrying more gold than silver, found at other horizons, usually as "gash" veins running across the stratification or along bedding planes. Such are the Colorado Prince in quartzite, the Tiger and Ontario in the Weber grits of the Middle Carboniferous.

The "Printer Boy," one of the oldest mines, has produced a good deal of gold, found as free gold associated with carbonate of lead and galena, passing down, as is usual in gold mines, into unaltered auriferous iron and copper pyrites, which occur in a body of quartz porphyry along a vertical cross-joint or fault plane in the porphyry. The gangue is a white clay resulting from decomposition of the quartz porphyry, and though the clay ore is rich, it shows no minerals to the eye.

The Paleozoic formations, together with the intrusive porphyry sheets sandwiched in between them, have been compressed into gentle folds, and where the fold was at its greatest tension, a series of parallel faults have occurred having a general north and south direction; their uplifted side is generally to the east.

The prevailing eruptive rock is the "white Leadville porphyry," occurring generally above the blue limestone, but also in places below it and at other horizons.

There are also other intrusive sheets of different varieties of quartz porphyry. The ground is generally buried beneath a hundred feet of glacial moraine material, locally called "wash."

The general geology of the South Park and Leadville region has been so elaborately traced by the labors of the United States Geological Survey that we cannot do better than give an abstract of their report in this connection :

MOSQUITO RANGE

A study of this range is necessary to the understanding of the Leadville ore deposits, which occur on its western side. It comprises a length of 19 miles along the crest of the range, and in width including its foothills bordering the Arkansas Valley on the west, and South Park on the east, a slope, in one case of 7½ miles, and in the other of about 9 miles. All of it is about 10,000 feet above the sea level.

The range has a sharp single crest, trending north and south. To the west this crest presents abrupt cliffs descending precipitously into great glacial amphitheaters at the head of the streams flowing from the range. Mts. Bross, Cameron, and Lincoln constitute an independent uplift. The abrupt slope west of the crest is due to a great fault extending along its foot, by which the western continuation of the sedimentary beds, which slope up the eastern spurs and cap the crest, are found at a very much lower elevation on the western spurs. The jagged step-like outline of the western spurs is due to a series of minor parallel faults and folds.

The secondary uplift of Sheep Mountain on the eastern slope is due to a second great fold and fault.

The elevation of Mount Lincoln is the result of the combination of forces which have uplifted the Mosquito Range, and those which built up the transverse ridge separating the Middle from the South Park.

The range has been sculptured by glaciers into cañons, and the Arkansas Valley is covered with horizontal terraces representing the distribution of material by waters, on the melting of the glaciers.

In the seas of the Paleozoic and Mesozoic eras that surrounded the Sawatch Islands, some 10,000 to 12,000 feet of sandstone, conglomerates, dolomitic limestones and shales were deposited. Towards the close of the Cretaceous, eruptions occurred by which enormous masses of eruptive rock were intruded through the Archæan floor into the overlying sedimentary beds, crossing some of the beds, and then spreading out in immense intrusive sheets along the planes of division between the different strata.

The intrusive force must have been very great, since comparatively thin sheets of molten rock were forced continuously for distances of many miles between the sedimentary beds.

That the eruptions were intermittent and continued for a long time is shown by the great variety of eruptive rocks found. That this eruptive activity preceded the great movement at the close of the Cretaceous, which uplifted the Mosquito Range, as well as the other Rocky Mountain region, is proved by the folding and faulting of the porphyry eruptions themselves.

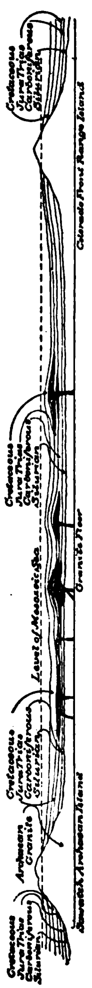
In the period intervening between the close of the Cretaceous and the deposition of the Tertiary strata, during which the waters of the ocean gradually receded from the Rocky Mountain region, the pent-up forces of contraction in the earth's crust, which had been long accumulating, found expression in dynamic movements of the rocky strata, pushing together from the east and the west the more recent stratified rocks against the relatively rigid masses of the Archæan land, and thus folding and crumpling the beds in the vicinity of the shore lines.

The crystalline and already contorted beds of the Archæan doubtless received fresh crumples in this movement.

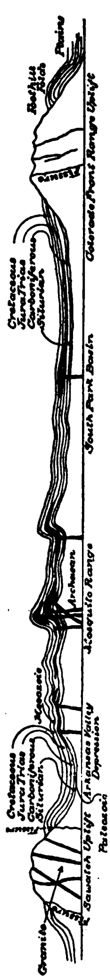
A minor force also acted north and south, thus producing gentle lateral folds along the foothills and at right angles to the trend of the range. These movements were not paroxysmal or sudden and violent, but protracted for an enormous lapse of time, and appear to have been continued in diminished force up to the present day.

MINERAL DEPOSITION

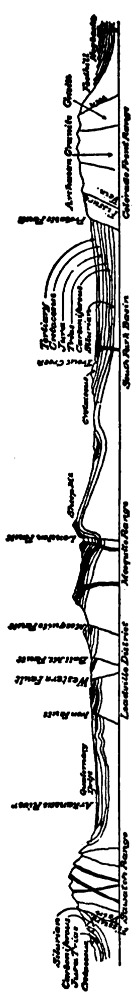
It was during the period intervening between the intrusion of the eruptive rocks and the dynamic movements that uplifted the Mosquito Range, that the original depositions of metallic minerals occurred in the Leadville region in the form of metallic sulphides, though now they are found largely oxidized and in other combinations. They were derived from the eruptive



No. 1. Ideal Section, Showing Paleozoic and Mesozoic Strata, with Intrusions of Eruptive Rock, Lying Beneath the Mesozoic Sea, Between Sawatch and Front Range Islands, Prior to the Great Mountain Elevation at Close of Cretaceous.



No. 2. Ideal Section, Showing Result of the Great Post-Cretaceous Uplift and the Folding Up of the Mosquito Range.



No. 3. Average Section of Leadville District, Mosquito Range and South Park as it is Today, Showing Result of Faulting and Subsequent Erosion.

SECTIONS TO ILLUSTRATE THE GRADUAL GEOLOGICAL DEVELOPMENT OF THE LEADVILLE AND SOUTH PARK REGION, COL.

rocks themselves, and are therefore of later formation than they. Their having been folded and faulted with them shows that they must have been formed before the great Cretaceous uplift, and, therefore, they are older than the Mosquito Range itself. The deposits were formed by the action of percolating waters taking up certain ore materials in their passage through neighboring rocks, and depositing them in more concentrated form in their present position. This may have taken place while the sedimentary beds were still covered by the waters of the ocean, and the waters therefore may have been derived from it, or the area of the Mosquito Range may have already emerged from the ocean and the waters have been estuarine. The uplift of the Mosquito Range consisted of a series of folds fractured by faults. The crest is formed by the Mosquito fault; another parallel fracture is the London fault. The greatest movement is towards the center, or Leadville, region, dying out at either end, north and south; the greatest displacement is 10,000 feet. Whatever cliffs may have originally been formed by this faulting have been planed down by glacial erosion.

ORIGIN OF LEADVILLE ORE DEPOSITS

The ores are deposited for the most part in the blue limestone of the Lower Carboniferous. As the ores were deposited by water solutions, the soluble limestone beds would be more easily acted upon by solutions than the sandstones and shales composing the other rocks of the neighborhood, which are less susceptible to percolating water. The Paleozoic formations in America are the principal repositories for lead and silver ores, not by reason of their geological age, so much as by their containing such a quantity of soluble limestone and being physically, as well as chemically, favorable for the reception of mineral solutions.

The physical structural conditions of Leadville are particularly favorable to the concentration of percolating waters in the blue limestone. Great intrusive sheets of porphyry follow the limestone persistently, principally on its upper surface. This porphyry is very porous, and full of cracks and joints, affording ready channels for water from above, and also channels for ascending water from below, along the walls of the fissures, through which it is erupted. Such waters passing through a medium of different composition would be ready for a chemical interchange with the limestone.

COMPOSITION OF ORES

The ores were deposited originally as sulphides. This is shown by the fact that the oxidized ores near the surface pass down, with depth, into sulphides. In Ten-Mile district these oxidized ores are seen to result from the alteration of a mixture of galena, pyrite, and zinc blende. There is very little gold in the average Leadville ores ; what little there is comes from the Florence mine (native gold), and from others where it is associated with pyrites. It is usually associated with porphyry rocks, and a porphyry commonly called pyritiferous porphyry, shows gold to exist diffused through the pyrites disseminated through its mass.

Silver occurs as chloride, a secondary condition, its original condition probably being sulphide.

Lead occurs as carbonate and sulphate and, deep in the mines, as sulphide. Specimens are common of galena nodules surrounded by a thin coat of sulphate, and that again by a coat of carbonate, showing the order of transition from sulphide to sulphate and thence to carbonate.

In the iron mine, native sulphur occurs as an alteration product of galena.

Iron and *manganese* constitute rather a gangue material than an ore. They are hydrated oxides and protoxides. The iron was originally deposited as sulphide, or pyrites, but has been wholly transformed by oxidation.

Zinc is not common, but occurs as calamine (zinc silicate) in needle-like hairs and white crystals in cavities in the mines. Its original form was zinc blende (zinc sulphide), as shown in the Ten-Mile district.

The earthy minerals, alumina, lime, silica, and magnesia, are in fair proportions, as might be expected from ores which are a replacement of limestone in close connection with porphyry. The alkaline element among the ores might also be traced to the influence of the latter rock.

The agents of alteration were surface waters, which contain everywhere carbonic acid, oxygen, organic matter, chloride of sodium (common salt), and phosphoric acid. The rocks through which these waters passed, such as porphyries and limestones, were found to contain phosphoric acid and chlorine, while organic matter exists in the blue limestones; and in the overlying shales and sandstones are many carbonaceous beds, and even beds of coal. Water passing through these rocks would take up all these elements and be ready for chemical reactions.

Galena (lead sulphide) is much richer in silver than its alteration product, carbonate of lead, or cerussite. On Carbonate Hill the carbonate averages 40 ounces silver; the galena is 145 ounces to the ton. But galena is harder of treatment.

Silver is found at times disseminated through vein matter and country rock, without the presence of lead, proving that during alteration, silver was removed farther from its original condition and more widely disseminated than lead.

Outcrop deposits have proved in many cases richer than those at depth. The deposits near the surface have been the refined, concentrated remains of larger bodies, gradually removed by erosion, as the alteration by surface waters went on. The baser and more soluble metals have thus been removed in solutions, leaving behind the more valuable and perhaps less soluble metals in new and richer secondary combinations.

"*Kaolin*" or "Chinese talc," which occurs both along the line of contact and between the porphyry and limestone, and also in the heart of the ore deposit, is a decomposition product from porphyry. It consists principally of hydrated silicate of alumina derived from the feldspars of the porphyries, perhaps at the time when acted upon by sulphurous waters, which brought in the original ore deposits.

Calcite occurs incrusting recent crevices and lining recent cavities.

Baryte is common, generally associated with chloride of silver and manganese, and is locally recognized as a sign of rich ore.

MODE OF FORMATION OF LEADVILLE ORE DEPOSITS

The ores were deposited from water solutions by a metasomatic interchange, i. e., substance exchanged for substance with the limestone; and lastly, or originally, as sulphides.

Mineral matter is carried from one place to another within the earth's crust by heat and water, or these combined. Metasomatic interchange of metal for limestone and the removal of dolomite could only have been produced by water. The ores were not deposited in preexisting cavities, but are a replacement of the country rock, i. e., dolomitic limestone.

The ores grade off gradually into the material of the limestone, with a definite limit, as would not have been the case if the limestone had been previously caverned. The only limiting outline to the ore bodies is that formed by the contact porphyry.

Fragments of unaltered limestone are found entirely enclosed within the ore bodies, and ore bodies often occupy the entire space for long distances between two horizontal sheets of porphyry, which space further on is occupied by the limestone. This is seen in the Colonel Sellers mine. Examination of ores and veinstone shows lime and magnesia, not in the crystalline condition they would have shown had they been brought into a preexisting cavity and deposited, but in the same granular condition in which they exist in the country rock.

The deposits in rocks other than limestone consist of metallic materials and of altered portions of the country rock, in which the structure of the latter can sometimes still be traced, and are not the regular layers of matter foreign to the country rock, which result from the filling of a preexisting fissure or cavity by materials brought in from a distance and deposited along the walls.

In the Ten-Mile district the arrangement of the particles of the original rock is frequently seen to be preserved in the metallic minerals, which maintain a certain parallelism with the original bedding planes in the lines defined by minute changes in these minerals.

The common characteristic of caves that have been dissolved out of limestone is that their walls are coated with a layer of clay that has been left undissolved by the percolating waters, and these walls have a peculiar surface of little cup-shaped irregularities from which also stalactites frequently hang. There is also an accumulation at the bottom of the cave of fragments of limestone, fallen from the sides of the roof.

None of these characteristics are found associated with the ore replacements.

Also, when mineral matter is deposited in preexisting cavities it takes the form of regular layers parallel with the walls of the cavity, as is beautifully shown in geodes lined with a succession of zeolites or with the layers of chalcedony, opal, and quartz.

No such successive arrangement in layers is found in the Leadville ore bodies.

Again, could such large, open cavities have existed for long distances without support between the layers of porphyry? Why did not these porphyry sheets close together? And further, how could such extensive cavities have been formed and kept open under a pressure of 10,000 feet of rock, which the geology of the region shows to have existed above the deposits at the time they were being formed? Such cavities as we do find in the region are all of very recent origin, cutting through both limestone and ore bodies, and have been hollowed out by surface waters more recent even than those which produced the secondary alterations in the ore bodies.

The ore deposits of Ten-Mile district, about Kokomo, not far north from Leadville, are very similar in character to those of Leadville. They occur, however, in a somewhat higher division of the Carboniferous, and the ores as a rule are not so decomposed and oxidized, and the transition from the original sulphide character of the deposits to the oxidized condition is more easily shown.

RED CLIFF GOLD DEPOSITS

At Red Cliff, still further north of Leadville, in the valley of the Eagle, the same geologic series are found, penetrated, as at Leadville and Kokomo, by eruptive sheets. In the limestones at contact with the porphyries, much the same classes of ore deposits occur, but the peculiar and instructive feature of the camp is the rich deposits of gold in chambers and cavities in the hard and usually unproductive Cambrian quartzites resting on the granite.

The gold in these chambers often occurs as nuggets. The quartzites dip about 10° N. E., and between their bedding planes lies the ore. The so-called contact or bedding plane between one stratum of quartzite and another is clearly defined. At this line there is a filling, so to speak, of "brecciated," broken up quartzite fragments cemented by iron rust and at times by iron pyrites. The thickness of this breccia varies between 4 and 6 feet. Ore chimneys on this breccia occur at intervals.

Their presence is indicated on the outcrop by seams of rusty clay, which lie on top of the ore body and follow it along the roof of the deposit for 100 to 200 feet, then thin out gradually and disappear entirely; at the point of disappearance unaltered iron pyrites set in.

These ore chimneys are about 4 feet in width; their thickness is limited to the space between the floor and the roof. The quartzite roof is always smooth, but the lower quartzite floor is rough and corrugated, and shows chemical action on it, attendant on deposition of ore. The floor at times is impregnated with ore, which does not, however, extend any great distance into it. Though the ore chimneys are from 4 to 6 feet wide, the pay ore is only a few inches, swelling from floor to roof. The pay ore in the oxidized rusty portion yields 7 ounces gold and 50 ounces silver.

In mining, the floor is followed as a guide. Individual ore chimneys are connected laterally by ore chutes, like a network. These ore chimneys divide and separate, the branches reuniting or again splitting up. The whole ramification comes together again at intervals in one main chimney. The rock filling the space where the divergence has taken place is the same as the breccia filling, only more compact, and impregnated with pyrite. These fillings are left standing as pillars after the ore is mined.

To sum up, the characteristics of these deposits are:

1. The outcrop of the ore chimney, indicated by what is locally called a "joint-clay."

2. A zone of oxidation for 200 feet, which gradually merges, as the natural water level is approached, through a zone of mixed oxides and sulphides to the zone of unaffected sulphides.

3. The "joint-clay" gradually disappears as the sulphides are approached. The ore on analysis shows sesquioxide and

sesquisulphate of iron, silica, and alumina, and sulphate of barium.

In the Ground Hog mine the ore chimneys are 600 feet apart, but are probably connected. They abound in nuggets; the latter are sometimes twisted like bent horns; in other chutes they are lumpy, composed of crystalline gold particles cemented together by sesquisulphate of iron and horn silver.

Nuggets are found in troughs in the quartzite floor, imbedded in clay associated with rich silver or horn-silver ore. With the nuggets are lumps of sesquisulphate of iron, carrying much gold. This proves, according to Mr. Guiterman, that the secondary deposition of gold in crystals was, through the medium of persulphate of iron, derived from slow oxidation of iron pyrites, and is an admirable confirmation of the theory as stated by Prof. Le Conte in his geology.

ASPEN ORE DEPOSITS

The Aspen mining region is geologically related to that of Leadville; each is on the shore line of the old Archæan island of the Sawatch, one on the east, the other on the west, opposite one another, but about 50 miles apart.

The ore deposits occur in the same general horizon, viz., the Lower Carboniferous.

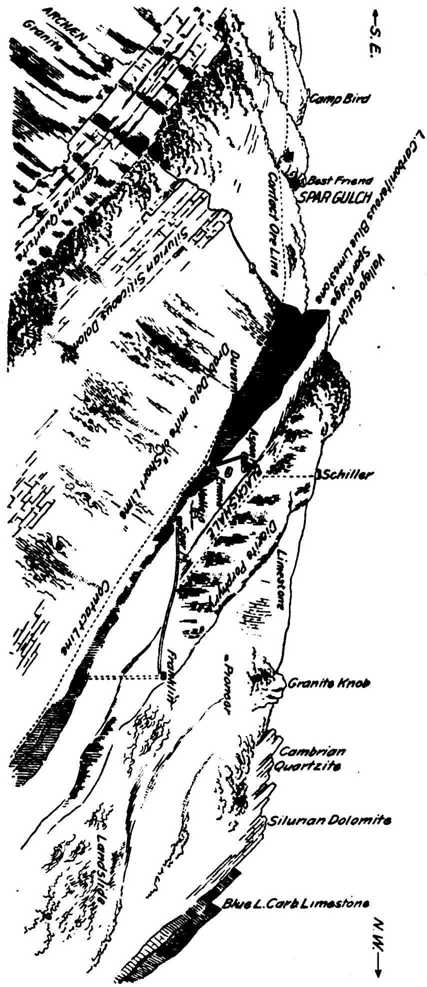
Both regions show intense disturbance, both by volcanic intrusions of igneous rock, folding, and faulting. The process of ore deposition in both regions has been an actual replacement of the country rock by vein material.

At Aspen the ore is not found in *actual* contact with the overlying eruptive igneous rock, but at some depth down in the limestone, at a zone where the "blue limestone" becomes dolomitized, or, as Aspen miners say, "passes from blue lime into short lime."

The mines of Aspen are situated in Paleozoic strata reclining upon the slope of a narrow-ridged mountain, forming a granite spur "*en echelon*" with the Sawatch Range.

The strip of country in the vicinity of Aspen constitutes the dividing line between the two distinct uplifts of the Sawatch Range on the east, and the Elk mountains on the west, and has been successively affected by each upheaval.

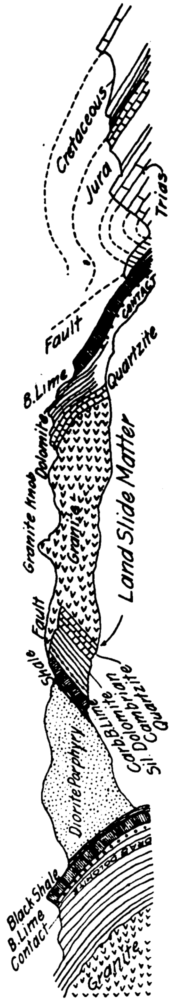
The Sawatch upheaval was a gradual elevation of this mountain mass resulting from a gradual subsidence of the adjoining sea bottoms, which caused the sedimentary beds deposited in those sea bottoms to slope up at varying angles all along the ancient shore line towards the central mass of the Archæan island.



ASPEN MOUNTAIN.

The Elk Mountain range, which extends to the west and south of this region, was upheaved later than the Sawatch, with greater violence and eruptive energy, and the upheaval was accompanied by enormous intrusions of eruptive rock, which were forced into the sedimentary strata already shattered by the forces of upheaval, in great "laccolites," or solid masses, and spread out through them in every direction in the form of dikes and intrusive sheets. The surface exposures of these igneous bodies cover areas of twenty-five to thirty square miles, and their extension below the surface is doubtless very much greater.

The intrusion of such enormous masses of foreign matter must not only have greatly disturbed the beds within the region of upheaval, but also have so expanded the volume of the earth's crust in this area as to cause a severe lateral pressure in the adjoining region. That adjoining region was Aspen and its neighborhood.



SECTION OF ASPEN MOUNTAIN.

It would be just in the strip of sedimentary beds along the Aspen Mountain ridge, which is backed by a projecting point of the unyielding Sawatch Archæan, that this compression would be most severely felt, the Sawatch granite mass acting as a point of resistance against the intense lateral compression caused by the younger Elk Mountain uplift.

The sedimentary beds resting against the Archæan correspond generally, with slight differences, to those in the South Park and Leadville region in a similar position.

The latter were deposited in a partially enclosed bay, now constituting the South Park basin, the former on the west side of the Archæan island, in a wider and deeper sea, and on this western slope the beds are generally much thicker than those of corresponding geological horizons on the east.

STRATIGRAPHY OF ASPEN

1. The horizons represented are the Upper Cambrian quartzites, 200 feet, resting on the Archæan granite.

2. Silurian silicious limestones and quartzites, 340 feet.

3. Darker limestones, rusty brown and dolomitic at base, blue, compact and pure on top, 240 feet. (These are Lower Carboniferous.)

4. Carboniferous clays and shales and thin-bedded limestones, 425 feet. These belong to the Weber grits (Middle Carboniferous).

5. A series of variegated green and red sandstones, clays and

shales, some limestones and red sandstones of the Upper Carboniferous.

6. Heavy bedded red sandstones (Triassic).

Above these again are several thousand feet of Cretaceous strata, up to the base of the Laramie coal beds. (The Cretaceous, however, and the Jurassic do not rest immediately upon the granite.)

Diorite.—On Aspen Mountain is a bed of "white porphyry" (diorite) in the black shales, 60 to 100 feet above the top of the blue limestone. It is 260 feet thick on the slope back of town, but thickens considerably to the south, and is traceable to Ashcroft. It appears to extend also across the valley of Roaring Fork to Smuggler Mountain. Small intrusive sheets also occur in the lower quartzites near the point of Aspen Mountain and on the east face of Richmond Hill.

As affected by the Sawatch upheaval, these beds wrap around the Archæan mass, resting against or dipping away from it at varying angles.

The quartzites and limestones cross the valley of Roaring Fork from Smuggler Mountain to Aspen Mountain, striking northeast and southwest, dipping northwest. The angle of dip is about 45°, varying from a minimum of 30° to a maximum of 60° in "flats" and "steeps."

THE ORE BODIES

The Lower Carboniferous "blue limestone" is compact, homogeneous and composed of pure carbonate of lime. The "brown" or "short" dolomitic limestone is of a dark-gray color, finely crystalline, finely granulated, and traversed in every direction by a network of minute veinlets containing iron salts, which, when oxidized, color the surface a rusty brown. The oxidation along these minute veins makes the rock break easily into dice-shaped fragments, giving the rock a "crackly" structure, hence its local name of short lime.

Ore Distribution.—The outlines of the ore bodies cannot be detected by the eye, owing to the gradual transition from ore to country rock.

The ore is not confined to the brown dolomite below the so-called contact, but several ore bodies extend 20 or 30 feet above this contact into the blue limestone, and in some cases follow the lines of cross-fracture entirely across the blue limestone.

The ore is not confined, either, to a definite plane or contact between two dissimilar beds of limestone and dolomite, from which its solutions have eaten into the underlying dolomite, for in the first place there is not one single contact, but many; and if this so-called contact constitutes an essential condition of ore deposition, there is no reason why it should be confined to the one and not found in the others where the rocks have the same composition. Again, ore-bearing solutions would not be likely to eat upwards for any great distance from the contact plane if they entered the beds along this plane.

This so-called contact plane is well defined on Spar Ridge, and continues down with the dip in the underground working, but ore bodies occur above and below it.

The rock thus mineralized is dolomite in most cases, but it is none the less above the true bedding plane called the contact.

In other parts there has been fracturing across the beds, as shown by a vertical breccia of limestone fragments with a cement of iron oxide and manganese.

Over the ore bodies are lines of open cavities following the lines of cross-fracture, through which the ore solutions passed which deposited the ore bodies. These caves are now being hollowed out by water descending from the surface, dissolving the limestone in the roof and flowing off along the floor, depositing a mud of silica, alumina, lime, magnesia, and iron oxide.

Hence this contact is not necessarily the only ore channel of the district, and other channels may be sought for.

Portions of the ore bodies have been formed by solutions percolating through cross-fractures and spreading out between the parallel bedding planes.

This would happen if these solutions derived their metals from the overlying porphyry, for it is separated from the limestone by argillaceous shales which would be impervious unless fractured across the bedding. The analysis of the lime mud at the bottom of the cave shows by its preponderance of alkalies, which do not exist in the composition of either brown or blue limestone, that the waters dissolving it came from the porphyry. The waters brought both alkalies and silica from the porphyry, and probably the iron and baryte.

DOLOMITIZATION

This is a secondary process upon the blue limestone by magnesian waters, which is proved by irregular tongues of dolomite extending up into and across the blue limestone. The lenticular bodies in the Durant cliff point to the same fact. The crackly structure of the brown lime results from the replacement of a molecule of lime by a molecule of magnesia, involving also a contraction in volume of the rock itself, which would cause it to separate in angular fragments, the intersections filled by material more soluble than the rock itself.

The magnesian waters may have been connected with those which brought in the vein materials.

In the ore bodies the partially mineralized rock on the borders of the ore is changed to dolomite, hence dolomitization either preceded or accompanied ore deposition.

Mr. Emmons suggests as *probabilities* only, that the porphyry intrusion preceded the faulting; that the ore deposit followed the intrusion of porphyry and also the principal faulting movements; that small movements have taken place in recent times, both in the strata and contained ore bodies since the oxidation of the latter; that at the time of the great faulting, the beds may not have attained entirely their present position.

In the vicinity of Aspen Mountain ore bodies, the strata appear to have been synclinally folded and faulted between the main Archæan area on the east and a mass of granite at the western extremity of the mountain, thus producing a second series of oppositely inclined beds, also containing a few ore bodies. Intrusions of altered eruptive diorite occupy a prominent position in the intervening trough and may have seriously faulted or dislocated the strata in the depths. The bulk of the Aspen ores are largely oxidation products of argentiferous minerals with true silver minerals, associated with calcspar and baryte; it is a "dry ore," requiring to be mixed with silicious lead ores before it can be treated. Such rich ores as polybasite and brittle silver occur also.

A great deal of the ore consists of fine-grained steel galena, very rich in silver.

ASPEN AS A PROSPECTING GROUND

Aspen, again, is an example of a region that had often been skimmed over by the prospector and abandoned before the final thorough prospecting revealed its great riches. Years ago some prospectors found signs of "float" and "blossom" cropping out under the blue limestone of Spar Ridge. They even went so far as to sink an incline of a hundred feet or more, but though they found ore, its character was so low grade that the mine was for a long time shut down and practically abandoned. Then an enterprising individual conceived the idea of boring down on the sloping back of the limestone in the adjoining Vallejo gulch, to tap the ore body, already discovered along the outcropping, on the under side of the limestone. At about 50 feet deep the limestone was pierced, and an enormously large and rich ore body was discovered. Immediately the original locators began again with all speed to push on their incline, and then originated the celebrated "apex and side-line" lawsuit. The original locators had the apex on the outcrop. They therefore claimed the whole mountain, and tried to drive out the side-line men. Finally a compromise was effected, but that boring down on the back of the limestone and its discoveries led immediately to an army of prospectors examining the mountain, and it was astonishing how many ore deposits were discovered in a region that was supposed to have been prospected and given up as no good. Of course Aspen is an example of "*richness with depth*"—a dangerous precedent and encouragement to that often ruinous policy of running long cross-cut tunnels to cut an ore body at depth, which has only proved indifferently good near the surface, on the fallacy we have before alluded to, of the improbable possibility of "richness increasing with depth."

AN EXAMPLE OF PROSPECTING

Now supposing our prospector was the first man to enter that region years ago. What signs were there to lead him to think it was a good prospecting ground? Supposing him to be fairly versed in geology, he would have noticed, as he came down over the Sawatch range, that the Paleozoic strata he had observed as ore-bearing at Leadville, outcropped also on this western side, together with the "blue limestone"; secondly, he would have noticed the presence of large masses of *eruptive* rock constituting the Elk range; thirdly, he would observe the region was much disturbed, that the strata were intensely folded, and intensely faulted. All these signs he would have considered likely. Then, after following up the various creeks, he would select such spots where he saw the massive blue limestone outcropping. He would readily find this bed from its relation to the granite and Cambrian quartzite below. He would look for places where porphyry was intruded into the limestone, or where great masses of it lay above or in vicinity of the limestone. This would probably have led him, on nearing Aspen Mountain, to give that mountain more than a passing look. He would notice that the strata on Aspen Mountain were very much disturbed and faulted, that a spur of granite, quite out of place, came right up through the middle of the mountain, that strata were pitching in various directions off from this, and moreover that in the lap of this fault-fold was a very thick bed of porphyry. He would observe the line of change from the blue limestone to the dolomite, and at that line he would have prospected and found and followed up the "blossom" at the line, consisting of calcite and baryte running in a rusty line, like the outcrop of a coal seam, all up the side of Spar Gulch, and so he would have discovered the great Aspen ore deposits, and by following up the indications along the outcrop and locating claim after claim, as along an outcropping coal seam, he could have secured practically the whole "apex" of the hill, and become master of the mountain and all it contained; but had he known then the litigation of "side line and apex" that was to arise, he should have gone further, and located claims covering the side line, on the back of the sloping limestone ridge, leading down into

Vallejo gulch. But again he might, like the original first discoverers, have become disheartened with his find on testing the outcropping ore by assay or mill run, and finding it so low grade near the surface. On general principles in this respect he would have been right.

Now, having thoroughly explored the little Aspen Mountain, he would observe that much the same formations crossed the creek and entered into Smuggler Mountain, though much obscured by heavy glacial drift. Here he might have located fresh claims on this hill, and become the owner of the celebrated Smuggler, Regent, and other mines, with their untold wealth. Thence he might have continued his successful trip, and followed the same so-called "contact" outcrop for miles, on to Ashcroft. It must be remembered here, however, that in locating all these claims, while the prospector may drive his location stake at every 1,500 feet, he is required, within sixty days after location, to dig a ten-foot hole in each location. As this may be a little difficult for him to do, he generally enlists others in his enterprise, to assist him, and enters some of the claims in their names, to prevent the discoveries being jumped by a horde of prospectors who press in as soon as anything is found. Good advice to a prospector is to keep very still and "mum" about his discoveries until he has well secured them, and to be very careful how he "opens his head" to any one. Commonly a prospector who has "struck it," comes into town, fills up with whiskey, "blows it in," and then "blows it off" all over town about his discovery, and is elated to find himself the hero of the hour. The result is, before daylight the following morning, a hundred men are chasing one another in the direction of his discovery, and before a day or more is over, the mountain is covered with locations as close as graves in a city churchyard, and in a week's time these locations are covered again by a second layer, as the saying is, "several feet deep."

A boom follows. The offscourings of the country pour in with the saloon, dance-hall, and gambling-hell element. A murder or two follows. Lynch law takes a hand. Then a horde of real-estate men come in, and lots are sold at fabulous prices, and the town is inflated with a population and everything else usually far above the capacity of the mines to support. A collapse follows, with a steady retreat of hollow-eyed, disappointed adventurers. In time the town and camp assume their lawful proportions, and business settles down to its lawful regime.

While all this has been going on, and amid all the fuss and bustle and "hooraying" of real-estate "boomers" and so forth, some prospectors have been quietly trying to follow up the first desirable indications into the neighboring region, resulting often in an extension of the ore-bearing region. Some of these locations are "bona fide" and valuable. Other "holes in the ground" are dug on the merest pretext of indications to catch the ignorant, adventurous tenderfoot capitalist purchasers, or "suckers." An investor going into the camp at such a time finds a fabulous price placed on every prospect, whether genuine or false. As a prudent man, he either beats down such prices, or concludes he will visit the camp a little later, when the excitement and inflation has gone down, and when things are on more of a business footing, and something like the real value of the camp has been found and proved. Of course in such a gambling speculation, by such prudence and delay he may lose a lucky chance, but he has preserved his prudence and escaped being wofully bitten.

Perhaps in a month's time the discoveries are found to be merely superficial, the boom utterly collapses, and the dreary sight is seen, a little later, of a desolate village, with frame houses and log cabins, and possibly a mill or two (for mills are sure to follow), lying in wreck and ruin, a home for the owls and the bats; or else the genuine discovery produces one or two mines and supports a handful of population legitimately.

Again, a region like Aspen may disclose a limited number of very rich ore deposits, but sufficient to support and sustain a fair-sized town.

But the most important and lasting discoveries of all are of areas producing an immense quantity of low-grade ore, such as Leadville. This gives an opportunity for a great number of mines and for the support of a large and permanent town.

CHAPTER XIII

EXAMINING AND SAMPLING MINING PROPERTIES, PROSPECTS, OR MINES

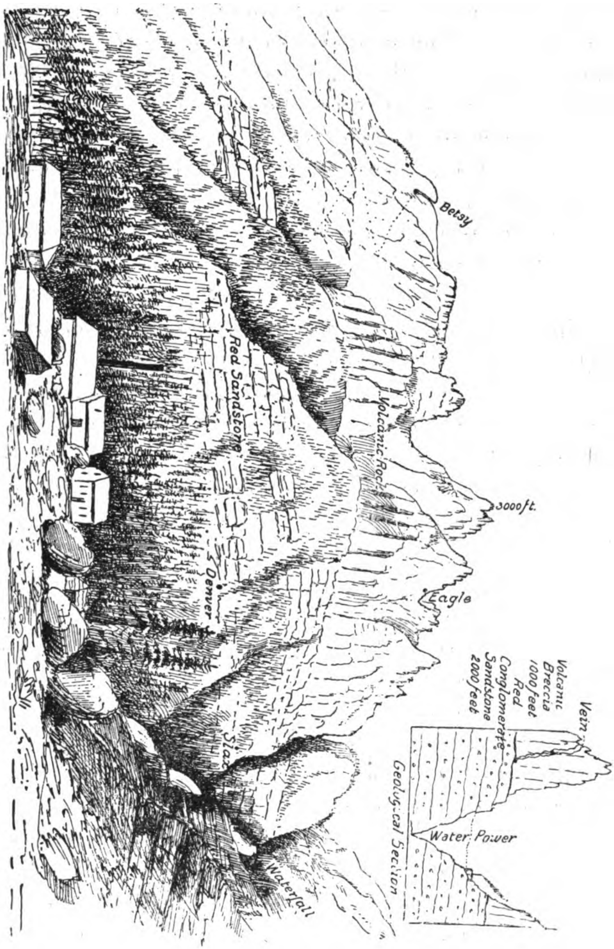
A PROSPECTOR may be, or may become, a "mining expert" and be called upon to make examinations of mining properties, whether prospects or developed mines, so a few suggestions may prove useful.

Mining properties of the precious metals are generally of two kinds, those containing ore deposits in place, such as fissure veins and blanket deposits and placers, the latter being gold-bearing. In both cases, and especially in the former, the character, position, and other relations of properties are infinitely varied, so that no hard-and-fast rule can be given to suit all cases; certain rules, however, will generally apply.

A mining engineer receives a letter from a company telling him to go to such and such a country or region and examine and report on a certain property that has been offered them. Such a mandate is usually accompanied by a letter or report from the owner or parties offering the property, giving the owner's description of the same, or else the report of some expert on it. As a general rule, such reports give the most favorable view, and in some cases must be taken "*cum grano salis.*" To the mining engineer they give some sort of an idea as to what the property may be like. As to its value, etc., that he proposes to find out for himself. The company sometimes asks him to examine with a view to verifying or modifying or contradicting such reports.

The region, the country, the character of the deposits, the local conditions, may in all probability be comparatively new or strange to him. Prior to starting he may make inquiries in mining circles if anything is known about the region or district. If there are any published mining or geological reports or maps, he will consult these. Finally he starts out, with as little baggage as possible, usually a small hand bag, containing a few necessaries; a tape line, geological pick, clinometer and compass, and note or sketch book. His dress is generally a suit of corduroys, leather gaiters, and strong boots.

As he enters the region by rail or on horseback he notices the main geological features, whether the rocks are granitic, sedimentary, or eruptive. Finally, he reaches the camp, calls on the owner or superintendent, and rides up with him to visit the



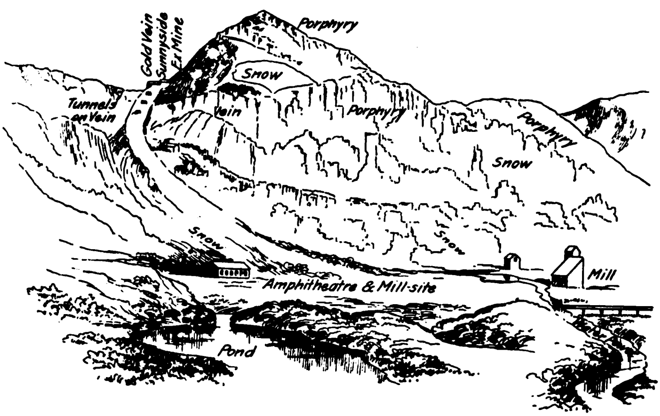
A Somewhat Inaccessible Gold Property (San Juan).

mine. If he should "lay over" for the afternoon in the village, he may as indirectly as possible try to pick up any gossip there may be afloat relating to the property. He is at once impressed with the accessibility or inaccessibility of the property, and estimates the probable cost of bringing down the ore to the mill or to the railway track, and observes the proximity or absence of timber and water-power. At last he reaches the mine, dines at the boarding house, and is then taken over the premises by the superintendent. His first attention is directed to the surface character of the property, its topography, whether rolling, smooth, or precipitous, whether it is high above the valley or down near to it, whether the mine is high or low as regards the water level or drainage system of the neighborhood, whether the property is conveniently situated for working the mine and transporting the ore, etc.

Accessibility is an important matter. In some regions, such as in the San Juan district (Colorado) for example, mines and prospect holes are sometimes on the top or sides of mountains or precipices, thousands of feet above the valley below, located at spots one would think only an eagle could reach ; prospect tunnels, too, are driven where there appears scarcely a foothold for a squirrel. No spot, however, seems too inaccessible for the prospector. At a glance the engineer sees that in a property situated in such a region, accessibility is one of the first and often the most formidable problem to be considered.

To some of these mines are long zigzag trails, cut in the side of the mountain. The engineer calculates how much the owners of the donkey, or "burro," train will charge to bring that ore down to the valley or mill. He argues that a mine at that almost inaccessible height ought to carry a good deal of pretty high-grade ore to pay even for transportation by the "burros," let alone the cost of freight afterwards to distant smelting works. On the other hand, a mine whose workings open out within easy access of the valley or railway track, could afford to carry less valuable ore. Then there is timber and water-power to be considered, the former for timbering the workings of the mine, the latter for running a stamp mill, or for supplying steam-power to the engines of the mine. If there be no water-power, and the vein carries free gold, the ore must be carried down to the nearest stamp mill. In a young or "virgin" property or prospect, the engineer will look out for a convenient site for such a mill, under a developed property ; if there be a mill on the premises, he will examine and report on its capacity and suitability for treating the ores. A mill site must, of course, be selected close to some water-power. In some districts there is a superabundance of water, in others a serious lack of it; or the supply is meagre at certain seasons, or is frozen up in winter. Some mines are quite dry, but generally they will supply enough mine water from their workings to afford steam power.

He observes the character and dip and direction of the veins, if exposed on the surface, examines any prospect holes on them, and takes a few samples for assay. He will consider the nature of the ore deposits, whether they are in fissure veins in crystalline rocks, or blanket deposits in sedimentary rocks, or contacts



SUNNYSIDE EXTENSION GOLD MINE, SAN JUAN.

Example of a Rough, Hasty Field Sketch of a Mining Property.

at junction with eruptive porphyries. A great variety of local and minor details have to be noticed which can hardly be specified.

Having looked over the surface, he enters the tunnel or workings with the superintendent. As he passes along, the latter is likely to call his attention to this or that spot, as especially good, and naturally he rather overlooks the poorer parts of the mine. He may suggest the advisability of taking samples from such favorable spots. The engineer, however, takes little heed, as, if he were to confine his attention to, and sample only these choice portions, he would obtain an incorrect estimate of the average run of the mine. Moreover, in some cases it is well to be on the lookout, lest these points, to which special attention is called by the miner, be previously "salted" or "put up" for the expert, and charged in various ways by rich ore.

Having traversed the workings and obtained a general idea of the position of the vein and ore bodies, and taken an inventory of the amount of development, length of drifts, shafts, etc. (the latter he can obtain from a map of the mine in the superintendent's office, a copy of which he will send to his company) he asks the superintendent to leave him and his assistant, and vacate the mine, as he does not wish any one except his assistant to be with him while he is taking samples for assay.

SAMPLING

Now begins his hard and most telling work, the time and labor depending very much upon the size and amount of development in the mine, or the degree of accuracy necessary. Taking a large strip of muslin, he cuts part of it up into small pieces about the size of a pocket handkerchief; these are to contain his samples for assay, when quartered. Then he takes the remainder of the muslin, or, better still, an ordinary candle box, to catch the mass of small fragments he detaches from the vein with his pick.

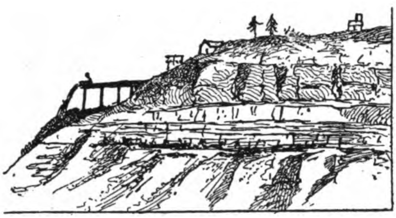
Expert Taking Samples.

Now with a light pick, or with a chisel and hammer, he begins, either from the entrance or end of the tunnel, to detach small portions of the rock, cutting a rough groove across the vein. Sometimes the tunnel occupies the whole width of the vein, in which case he will have to make a circular groove clear around the tunnel, across the floor, roof, and walls, as shown in the accompanying illustration; the fragments from his work drop into the candle box or on to the muslin.

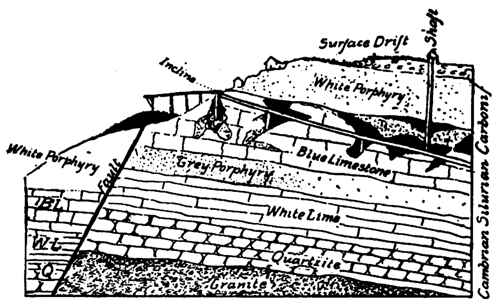
According to the length of the workings or the need for great accuracy, he repeats this operation at intervals, which may be every 5 feet, 10 feet, or 20 feet; at intervals of, say, 20 feet, he masses and mixes together all the samples, breaks them up as fine as he can on a shovel, and divides the result into four parts, throws away three parts and retains one. This he reduces to a fine powder and wraps up in the small muslin pieces, ties it up and seals with sealing wax, marking on it the number and other notes, such as 10 feet from entrance, etc., with an indelible pencil. This work he continues till he has reached the end of the tunnel, which, if it is 100 feet long, will give him, from 20-foot intervals, five little sacks of powdered ore for assaying. As a check upon this work, and for reference in case of any accident to or any tampering with his samples in transit, he will occasionally take a "grab" sample from his broken rock, before quartering it. Here and there, too, he may take a chunk of some peculiar rock, such as a porphyry or some peculiar streak in the gangue; these he will put in his coat pocket and keep on his person.

It is sometimes important in a vein to find out what rock or portion of rock carries the most value. For instance, on one occasion we examined a vein said to carry gold clear across its entire width of some 50 feet. Now this so-called vein proved to be a decomposed dike of porphyry impregnated with pyrites and free gold, and through the dike ran a network of little narrow quartz veins, or veinlets. On sampling, while we took samples clear across the whole width of the vein, we kept those fragments which came from the quartz veinlets apart from those which came from the porphyry gangue. The result was, we found the porphyry, constituting, of course, the main element, to be barren and the gold to be concentrated in the quartz veinlets constituting a minimum of the width.

So in a vein there will generally be parts richer than others, "pay streaks" as they are called, which it is important to distinguish, also certain metallic minerals in the vein carrying greater values than others. Thus, the pyrites, if undecomposed, may prove too poor to treat for gold; or, in a silver mine, streaks of gray copper may be very rich, while bodies of coarse galena may be very poor. In a gold mine it is important for the engineer, if he can, to find out to what depth surface decomposition or oxidation has penetrated, because in this brown rusty matter will likely be most of the "free gold"; while, when the unoxidized pyrites makes its appearance, the ore is no longer free ore, but must be treated by some process other than that of a stamp mill; and with the incoming of pyrite the palmy days of the gold mine may be at an end. Sometimes, however, though the oxidized brown gossan may play out and succeed to white quartz, the latter, if it be not too hard, white, and "hungry," may still continue to carry free gold in it. Again, in the veins, with their descent into depths, greater or less richness may occur or different varieties of ore set in, or absolutely barren quartz, so if there are shafts or tunnels driven on the vein a distinction should be noted with descent, as to values found at different levels, also



NATURAL APPEARANCE OF MINE ON A BLANKET ORE DEPOSIT.



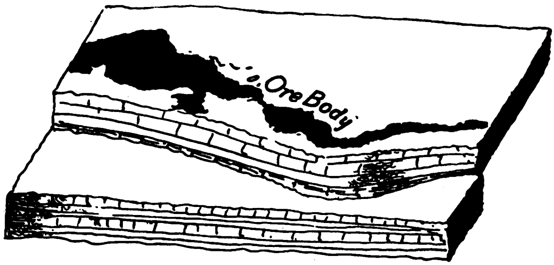
GEOLOGICAL SECTION SHOWING WORKINGS AND ORE BODIES IN CONTACT BLANKET ORE BODY.

Shaded Portions Are All Worked Out.

as to character and richness of the ore above and below water line; the latter corresponds to the average drainage level of the country.

This completes his underground examination. While in the mine he may make a rough sketch or two of the vein, showing the general disposition of the ore bodies or any peculiarities.

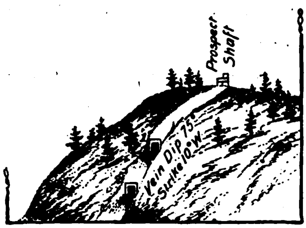
On emerging and carefully securing his samples beyond reach of their being tampered with, he selects a convenient point, possibly on a neighboring hill facing the property, and takes a general sketch of the property in pencil or water colors (see pages 179, 181, and 184) ; also makes a pencil sketch and ideal section of the hill, showing the position of the vein and its workings (see page 186), the amount of ore stoped out and the amount presumably in place intact. To estimate the latter is often a difficult and uncertain problem. He may



PLANO-SECTION OF A FLAT ORE BODY.

make some sort of estimate as to the reasonableness or not of the price asked, and give his estimate ; he can form, however, no true estimate of the value of the ore bodies till he has had time to assay his samples, for these are the crucial test of the value of the property.

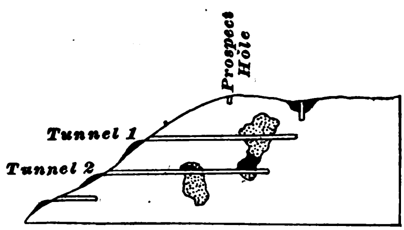
In writing up his report at his leisure, which will most likely be read at a general meeting of the company, he cannot be too clear, simple, and explanatory in his account and its details, as it is to be remembered that the company is likely largely to be composed of men unacquainted with mining and mining terms ; he must, therefore, not take it for granted that they know what "stopes," "adits," "gouge," etc. are, but should explain as he goes along, accompanying his remarks with rough sketches, to make his meaning clear, and put the members of the company as much on the ground as possible. We ourselves have found that it is not necessary generally to make elaborate notes in the field or to write pages of reading matter then, provided we make many sketches and on them put down items, such as length of workings, etc. The sketch is generally the notes, and when the engineer returns home, his sketches will recall vividly all he has seen, and from these he will write his report. Upon certain matters, however, such as involve numbers, he should be very accurate in writing notes, and not trust to treacherous memory for them.



FISSURE VEIN OUTCROP ON HILLSIDE, SHOWING SURFACE WORKINGS.

DESCRIPTION OF FIGURES

On page 179 we have an actual example of a rather inaccessible property in the San Juan, which, with the illustration on page 181, shows the kind of sketches to accompany a report. In the former, with its section, it will be observed how very high up the mining holes and prospects are perched, in most cases over 1,000 feet above the valley; and again, before the ore can be brought over to the mill, a ravine of a hundred feet deep, occupied by a boiling torrent, has to be crossed. Some of the properties might perhaps be worked by a suspension tramway thrown across the gulch. In another case a trail has had to be cut in long zigzags of some miles before the bottom could be reached. Another disadvantageous feature in this property is the number of scattered veins, none of them very rich by itself; this involves a separate plant or workings for each. One good vein would be better than all these put together. There is fine water-power on the property, and plenty of timber.



CROSS-SECTION OF VEIN, SHOWING WORKINGS.

Dotted Portion is Ore Body, Shaded is Ore Worked Out.

In the sketch on page 181 there is one fine rich gold vein, easily accessible and easily worked; below it lies a natural basin and abundant water, making it an admirable location for the stamp mill. This figure gives an idea of the rough kind of a sketch the expert makes on the ground, which he embellishes and elaborates on his return.

On page 182 is seen the expert taking samples in a tunnel driven in the vein. The vein in this instance, being a very large one, occupies the whole width of the tunnel; this is not generally the case—the vein and ore body are more commonly observed about the middle of the roof, i. e., if the vein is small.

On page 184, the first illustration shows the surface appearance of a "flat" or contact blanket deposit on the side of a hill, such as is met with at Leadville.

The second is a cross-section, showing the position of ore bodies, the portions worked out, and the portions probably left in reserve; also, the workings of the mine and the geological section, together with a prominent fault.

On page 185 is a somewhat ideal sketch of the probable relations of a flat ore body if the surface matter were removed, or rather if it were opened like a book.

On page 186 is shown the outside appearance of a fissure vein with three tunnels down in it, and also cross-section and profile, showing the tunnels and the ore bodies so far discovered in the quartz gangue, and how much has been worked out.

CHAPTER XIV

PROSPECTING IN VARIOUS REGIONS

THE GREAT NORTHWESTERN PROSPECTING FIELD

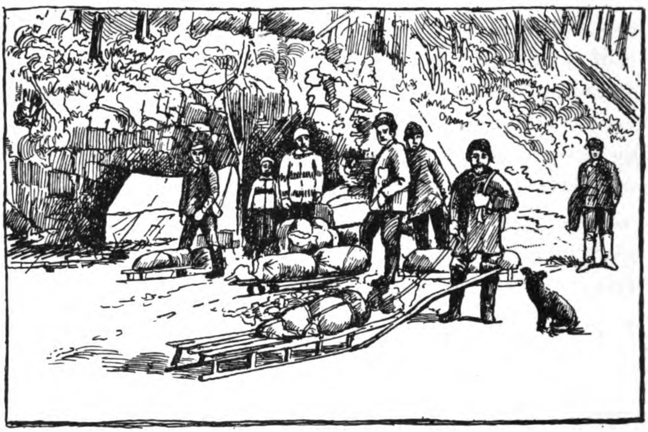
In previous chapters we have dwelt a good deal on prospecting in Colorado and the Rocky Mountains, considering that region as typical and comprehensive, and that, if a prospector knew experimentally that region thoroughly, he would be pretty well posted for tackling other regions of the West.

The main and general features of geology and of ore deposits are very similar throughout the Great West; the differences rather lie in exceptional cases.

Let us take a general view of the great northwestern prospecting field as a whole, before we take region by region. The features that most strike us are the comparatively light settlement of those vast areas, the chance of their being comparatively new and little tried, and certainly not exhaustively prospected regions; the vast areas that, for various physical reasons, have not been prospected at all, and in some cases not even entered by white men. These are alluring prospects for the daring young prospector who longs to enter some region in which he could say:

"I am the first that ever burst
Into this silent land."

We do not like going over old well-beaten tracks. We do not like to meet a prospect hole every few hundred yards, or after following up "float" and other signs, at last to come to the ledge in expectation of great things and find Bill Smith's



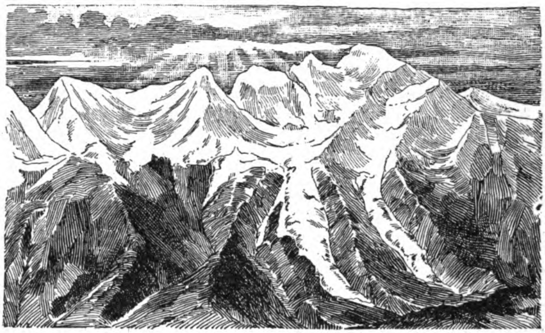
ALASKAN PROSPECTORS BREAKING CAMP AT FOOT OF CHILKOOT PASS.

ubiquitous stake staring us in the face. Much of the Northwest is a kind of untracked region. From the various accounts that reach us there is no lack of gold in those northern regions. The placer deposits are exceptionally rich and large, as we might expect them to be in such tremendously glaciated areas; and the finds remind one of the halcyon days of early California. But there are great difficulties to be overcome, not met with in Colorado or the Rocky Mountain region generally, necessitating great hardship and requiring lots of pluck. There are mighty glaciers to be encountered, networks of great and little rivers to be crossed, a very peculiar climate to deal with, plenty of mosquitoes, vast and almost impenetrable forests to be traversed, while a thick underbrush and profuse vegetation cover up large areas of unknown wealth. So, while the prospector of Colorado and Rocky Mountain experience may have found his pick and shovel and pan all that was hitherto necessary, in these new regions he must add to his outfit a canoe, a pair of snowshoes and a sleigh, and, in place of the "burro," a pack of native sleigh dogs, and, above all, he must carry a good axe, or even a long cross-cut saw, as often he will have literally to hew and saw his way to fortune.

A recent prospector in those regions has graphically stated the case as follows:

"Prospecting is hard; the country is heavily timbered, with much underbrush and fallen timber. The prospector has to pack his tools on his back and cut his own trail through the wilderness; when he finds a favorable location he makes his central camp, and works from that. Game is not plentiful. In the veins they find sometimes a 'cap' rock, rusty with oxidized iron, broken over and capping the veins. This cap is 2 to 4 feet deep. Then the rock passes down into hard unoxidized pyrites. Prospecting is hard and slow, for you have to blast from grass roots. Caps are poor. The best ore is found with depth. The veins in this region have not been much prospected, attention being confined mostly to placer and river deposits. Those veins I saw were rich and narrow, with free milling quartz, doubtless down to a limited depth below the surface. There are few, if any, large mines between the Selkirk Range and the Rockies. Veins may carry both gold and silver, but principally the former, and that mostly in arsenical pyrites. Galena and silver ores, however, occur locally. In Idaho, on the Snake River, placers are worked on bars at the surface line of low water. The gold is fine, light, and hard to save. At Spokane the river valley consists of barren wastes of sand. The soil is alluvial in this part, with no glacial matter. Various machines are used, and pumping plants are necessary, as there is no head or gravity line.

"In British Columbia gold can be found in nearly every stream. The Columbia River is 35 feet between high- and low-water mark six months of the year. Placers shift and change with every flood season. The first gold worked in paying quantities is forty miles north of Revelstoke, on small streams coming in from the East. Every stream running from the east side contains placer gold, as far north as Goldstream, 75 miles. The country has been worked and prospected for the last seven or eight years. The altitude of the Columbia is 2,000 feet above sea level and the higher ranges about 8,000 feet. Glaciers extend down to a level of 4,000 feet, and are still working and grinding down gold, and the best pay has been found late in the season of October, at the foot of the glaciers. The side



A GLACIAL REGION, SHOWING LIVING GLACIERS LEADING UP TO AMPHITHEATERS AND U-SHAPED CAÑONS.

streams, as well as the Columbia, are raging torrents from the first of June to September, but are worked about a month in spring, in April, and in the fall, in September and October, and between the thawing out in April and the floods of May. In the fall they are worked in September, after the floods have run off and before the hard freezing of October. This high water is caused by melting snows. Rain, contrary to what might be supposed, lowers the water in the streams because it makes the water so cold on the mountain tops that it checks the melting of snows, and the highest water is during clear, bright, hot weather. The snow, rather than the rain, is the cause of rise or fall of the rivers. The gold is fairly coarse, and found, as commonly elsewhere, mostly at bed rock and near the bed or channel of the present streams, also at the bottom of boulder and glacial débris to a depth of 20 to 80 feet.

"As an example of the richest of these placers, and the difficulty of working it, as well as of the pluck of prospectors, we may cite that of the Last Chance placer. The prospectors worked four years in an endeavor to dig down to bed rock, a depth of only 60 feet, but with a river of water to contend with, and only a few months in the spring and fall available for working. They were drowned out in summer and frozen up in winter. The prospectors made their wooden wheels and pumps, and packed everything over a rough trail, 75 miles, on mules. They had to make bridges across streams, which where liable to be washed away again before another trip. For supplies they would make two or three trips in the summer season. The first season they drifted on bed rock, hoisting the dirt to the surface and washing it in a common sluice box. In one short season, in this way, they took out $7,000, the following year $10,000, and the next year the same. On some of the streams they are hydraulicking, with an old-fashioned canvas hose with brass nozzle, like a fire hose, with 50 feet head of water-power, stripping the surface for some 20 to 30 feet. Some are working on benches, not in well-defined channels, and with glacial drift full of immense boulders to contend with.

"In places they work up almost under the present glaciers. The main aim is to get down to bed rock, often at considerable depth, getting a little pay gold as they go down. Prospectors go off in canoeing parties up the rivers, landing here and there, and prospecting the bars along the river reaches. The first glacier I met with was near Revelstoke. These glaciers are narrow necks of ice, leading up to big basins full of ice. One of these glaciers was 400 feet deep.

"The Kootenai country lies east of the Columbia, between the Canadian Pacific Railway and the boundary at the end of the Selkirk Range. Galena and silver ores are principally found north of the Spokane country. The region is steep and rugged, like parts of the Colorado Mountains. It is a great region for snow slides, another peril to the prospector, but an agency by which rich veins are often uncovered and float distributed. These snow slides cut long swaths through the thick timber and pile up a big bank of débris in the valley below. Several large mines are worked in this district, rich in silver, from 300 to 500 ounces to the ton. There is a smelter at Pilot Bay, on the Kootenai Lake, and another at Trail Landing, on the west side of the Columbia. Ores are hard, being arsenical pyrites, carrying gold and silver, 1 to 3 ounces gold and 10 per cent. copper and some silver. Bars of this ore occur in the granite, and the ore is 'frozen' on to the walls—that is, there is no parting selvage or gouge between the ore and the country rock. The War Eagle and O. K. are together shipping 200 tons per day, principally gold. The average is 2 ounces of gold or $50 per ton. Boundary Creek as well as Trail Creek report good prospects, and the mineral belt extends south into Washington, but is covered at present by Indian reservations, which precludes prospecting.

"The Fraser and Cariboo districts lie west of this region. There are some expensive hydraulic plants in the Quesnal and Horsefly, with 50 miles of ditch on each plant; and with several thousand feet of pipe and large siphons and storage reservoirs, preparing for next season. The gravel banks are 30 to 60 feet deep, and average from 50 cents to $2 per cubic yard, so it is said. The company must have good assurance of the great richness of the gravels to warrant so expensive an outlay. The main obstacle outside of the shortness of the season is from immense glacial boulders. These, in all placer mining, are obstructions, owing to the difficulty in handling them. They may have to be blasted or lifted out by derricks, and many an otherwise rich deposit has had to be abandoned, owing to the insurmountable difficulties from a preponderance of these boulders. On the Fraser River, Chinese and Indians wash bars every fall and spring, at low water, with rockers, sluices, etc., making a living. On the Middle Fraser, dredges are at work, costing $75,000 per dredge, dredging up sand and gravel 50 feet below the water surface. In the Horsefly country, worked successfully since 1860, they put down a 'wing dam,' or caisson, to bed rock, and clean up well. In parts of Alaska they work the gold gravel out in frozen blocks and pound it up in the spring, and work 'drift mining' in this way all the winter. The gravel beds never thaw out in Alaska. Throughout British Columbia transportation is by horse, but they use canoes where they have lakes or can go down stream. The streams are too swift to

ascend in that way. Leaving the traveled trail, you have to carry things on your back. Trails have to be made, and prospectors carry big cross-cut saws as part of their outfit, and saw through the timber and fallen logs."

Such is my friend, Mr. L. T. Preston's, comprehensive account of prospecting over this region, from his own personal experience of several months. Of course he did not go everywhere and see everything, but the general sketch will give us the best possible idea of what is before the prospector in the great Northwest, principally in Idaho, Oregon, Washington, and British Columbia. Alaska he did not penetrate far into.

PROSPECTING IN ALASKA

After our brief sketch of some of the leading features, from a prospector's point of view, of the Northwestern field, we will take up some of the prominent mining and prospecting areas in that vast region.

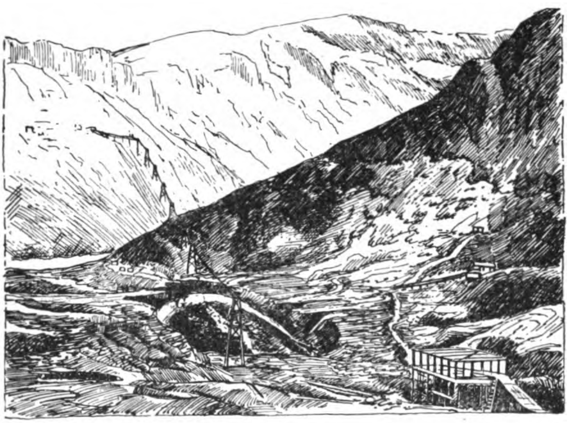
Beginning with Alaska, the most northerly, the least explored, the most attractive and unique: A glance at the map shows the outline of its coast to be the most ragged on the globe. The coast line is made up of an intricate network of islands divided from one another by a labyrinthine network of channels, which lead you so far inland that it is doubtful where the island zone and the true continent begin or end. These labyrinthine channels are only paralleled in their intricacy by the network of great and little rivers which seem to cover the surface like the ramification of ditches in a quagmire swamp. It is a land, too, especially near the coast, of great mountain ranges, which, like the other characteristics, are cut up *ad infinitum* by ravines and cañons; and lying in the depths of those cañons is the mighty glacier, the key to all this extraordinary sculptured and tattered and river-traversed and cañoned aspect of the region. Alaska, from its extreme northerly position, has been intensely glaciated both by the primeval ice sheet of the glacial epoch and by subsequent glaciers, many of which are still remaining in the mountain fastnesses, or running down into the fiords that open into the sea. These are still doing the work of their predecessors, viz., wearing down mountains, cutting cañons, exposing veins, grinding down gold-bearing rocks, and filling up ravines and valleys and river bottoms with placers and gold bars. Consequently the prospector will expect to find this country the paradise of placers. But, again, the mountains being a continuation of the Great Cordillera system, have the same crystalline granite core, the mother of gold, and this is traversed by many eruptive rocks, porphyries, and old lavas, and even overflowed in places by modern lavas from "craters" still in a state of active eruption. Here, then, are elements the readers of this book will have recognized as "good sign" to the prospector for finding gold veins and gold and silver deposits, viz., granite, eruptive and volcanic rocks, and much disturbance, heat, and metamorphic action. Like all pioneers in a new country, the prospector will most likely begin with placer mining, and end up, it may be, by the discovery of the lead or vein from which the gold came.

Vast areas of gold-bearing territory lie partly in British Columbia and partly in Alaska, known as the Yukon country. In 1887 coarse gold was found on tributaries of the Yukon. At low water these tributaries yielded large profits—from $50 to $100 a day—by sluicing. The rich spots on the low bars were worked out and led to discoveries on Forty Mile Glacier, Birch Creek, and others. High bars are also rich and untouched, owing to the difficulty of getting water on them and to the frozen condition of the ground. The largest nugget found was valued at $42. Some deposits are covered by 25 feet or more of loam before pay gravel is reached. Single clean-ups have been made of 55 pounds of gold and $36,000 in gold dust taken out in a season. On Glacier Creek pans of dirt run from a few cents to $4. On Birch Creek, remarkable for the number of elephant bones found in its gulches, very rich finds have been made. Prospectors have got as high as $13 to the pan. The gold is described as like pumpkin seed, yielding $3 to $10, and sometimes, under a big boulder or a little stone on bed rock, they could pick up from $15 to $20.

SILVER BOW BASIN

The first important discovery of gold in Alaska was in Silver Bow Basin, in 1880, in gravels of Gold Creek. The discovery and progress of this district is very instructive to the prospector.

The first prospectors came on the deposits on the hillside, and soon, as they supposed, cleaned out everything in the Basin. But a Mr. Nowell, quietly looking over things, decided to tap the bottom of the basin with a tunnel, to be used as a sluiceway, and so work the entire basin on a large and systematic scale. The first prospectors on the hillsides exposed numerous quartz veins, and stringers of quartz under the placers in bed rock. They located a few holes on these veins, but having nothing but an arrastra to work with, soon abandoned the vein mining. Several patterns of mills were tried on the flint-like quartz unsuccessfully, till a Webster mill with five stamps, and, later,



SILVER BOW BASIN LOOKING SOUTHEAST, SHOWING PLACER AND OTHER MINING OPERATIONS.

ten stamps, proved a success. The veins are called "contact vein fissures," the reef having a black slate hanging wall and a greenish gneiss foot wall. Between the walls of contact a space of several hundred feet occurs, filled in with schists, quartz veins, and vein matter. The filling is networked with veins from a knife blade to several feet in thickness, according to the "Alaska Record," which also says: "The ore in Silver Bow Basin is iron pyrites and galena with zinc blende, antimony, and copper pyrite, carrying gold and silver, but richer in gold. In some veins in this basin, now silver and now gold predominates. Milling consists in reducing their bulk by concentration, without free gold-saving appliances. Where the gold reef leaves the valley and climbs the mountain sides, veins outcrop on the surface. So there is not so much difficulty in tracing the reef through Silver Bow Basin to the summit of the divide, where veins were found cropping just beyond the upper break of the glacier. Some of these croppings showed upwards of 48.6 ounces of gold to the ton. The Gold and Curry mine lies north of the reef, and is a chimney or upshoot from the main mineral zone. It shows on the surface, for several hundred feet, a number of well-defined perpendicular veins, running high in gold. Great granite dikes cut through the slates east of Takon Inlet, and run for a long distance down the coast, from north to south, belonging to the same general zone of mineralized disturbance."

Sum Dum Bay, Shuck Bay, and Basin Reef have all their noted ore deposits, and along the mainland and numerous islands indications of mineral-bearing bodies exist in veins of quartz with "colors" in the streams, while in the limestone of Glacier Bay rich silver ores occur. In Admiralty Island, the Willoughby group of veins cut diagonally across a gneissic formation. The veins are from 1 foot to 10 feet wide, and entirely gold-bearing.

BEACH SANDS

Ruby and black sand are found along the beach at the foot of the Fairweather Range, for many miles up the coast. They are rich in fine gold, but heavy and bright, amalgamating readily by sluicing. The deposits come from grinding glacial action in the ranges back of them ; streams carry the sand to the sea, and the surf rocks and pans and separates the heavy material, leaving it in alternate layers and windrows along the beach. The black and ruby sand and gold, being the heaviest materials, naturally affiliate.

COPPER RIVER

The Copper River section is one of romantic interest and speculation. Natives living at the headwaters used copper implements and brought down to the coast chunks of native copper to the Russians, who were thus tempted to explore the source, but ill-treating the natives, after their wont, the exploring party were brained when asleep. Prospectors, since, who have tried to ascend, have been intimidated by glaciers, swift currents and rapids, high precipitous banks, and other almost insurmountable difficulties. So the upper Copper River is still an unsolved problem.

At the head of Cook's Inlet, Russians placer-mined for years. Rich digging and much coarse gold were found lately at Turnagain Arm. Both silver and gold are mined in Unja and Unimak Islands, the ore running from $24 to $143 to the ton. A stamp mill here, high above the mouth of the Yukon, is the most northern mill in the world.

DISCOVERY OF THE TREADWELL MINE

The discovery of the Treadwell, the most noted mine in Alaska, as told in the "Alaska Mining Record," is another instructive lesson to the prospector.

Like many other instances, the discovery of gold in placers led to the discovery of the renowned Paris or Treadwell mine.

On the 27th of January, 1882, prospectors from Juneau crossed Gastineaux Channel to Douglas Island and found pay dirt upon the beach, and the following March they washed on ground called Ready Bullion, and in three days washed and cleaned up 27 ounces of gold dust. This led to finding another deposit of gold dirt and decomposed quartz, and in washing the gravel from the bed rock, the great Treadwell ledge was exposed. Peter Erussard, or "French Pete," located the ledge, calling it the "Paris." Placer miners, however, by right or might, held the surface for two years, and washed out amounts estimated at $50,000 to $100,000. Nothing was done by "Pete," as he considered the ore too low grade to work profitably. Then came along one of those characters so often figuring in the history of great mines, a far-seeing man, named John Treadwell, who made a thorough examination of the ledge, its facilities for working and opening up, as well as the character of the ore by assaying, and opened negotiations for purchase. French Pete was glad to let "the worthless thing" go for $400. Treadwell organized the Alaska Mill and Mining Company, and began driving a cross-cut prospecting tunnel towards the veins, and erected *a 5-stamp mill* (not a 100-stamp mill, as is often so foolishly done at the outset) to test by mill run the true value of the ores before he went further, and while the tunnel was being driven in towards the ledge. When the cross-cut reached the opposite wall, it showed up, instead of the obscure veins on the surface, a ledge of 400 feet in width of nearly solid quartz! And the little stamp mill proved that the average value of the ore was sufficient to make the mine pay if worked on a large systematic scale. In 1883 a 120-stamp mill was erected, and in 1890 they added chlorination and doubled the stamp capacity. More claims were purchased, and wharfs and railway tracks and the largest works in the world soon showed that this mine, from the little beginnings of the prospector, had assumed the rank of one of the foremost in the world. The power that drives the great machinery is an 18-mile ditch, extending along the mountain side, applied to a Pelton waterwheel under a head of 520 feet, with Corliss engines also added. The 240 stamps weigh each 850 pounds, with 96 drops per minute. The mill has a daily capacity of 700 tons of ore, and chlorination of 18 tons of pyrite. The average grade of ore is only $2.75, carrying 2 per cent. sulphurets; and the expenses of reduction are at the extraordinary low figure of $1.35. Formerly the ore was quarried out in great pits, dropped down ore shutes into cars, and conveyed through a tunnel by steam and dumped into bins, thence into crushers and batteries; but with deeper working a shaft was sunk 250 feet below the tunnel, and immense hoisting works put in, to raise the ore to this level. Two hundred men are employed daily, at $3 to $7.

Mr. H. P. Cushing, speaking of the Treadwell mine vein, says: "The gangue is for the most part white transparent quartz, which has been considerably crushed, and thereby rendered granular and opaque. A peculiar greenish rock is also found, poorer in gold than the quartz. Pyrite is evenly, but sparingly, distributed in small crystals. Occasional streaks of quartz free from pyrite occur, and at times pyrite alone constitutes the mass. "Horses" of slate were occasionally met with, which were taken out with the ore and sent through the mill. The quartz carries a certain amount of free gold, but the main portion is enclosed by pyrite and cannot be amalgamated. Streaks of molybdenite (like graphite) occur, running high in gold. The Treadwell is an example of an ore body in which the percentage of the precious metals is low, yet the property a good paying one, on account of the vastness of the deposit and the ease and cheapness with which it is worked. It is close to water and steamships, plenty of mountain water-power, and abundance of fuel and timber. Six hundred tons are pulverized daily, by 240 stamps, in the enormous stamp mill. The outcrop of the vein stood up to the prospector's gaze, owing to its hardness relatively to the enclosing slates, as a considerable peak, and the first mining done was simply the working off of this peak. Later a tunnel was run into the mountain side, cutting the vein, from which the ore is dumped into cars below."

CHAPTER XV

GEOLOGY AND MINERALOGY OF ALASKA

From what we can gather from Mr. Cushing and the "Alaska Record," the following appears to be the general geological features of this region:

Along the headwaters of the Yukon are high ranges, with lofty snow-capped peaks and many chains of lakes. In the gravel, along the sources of the streams, gold is found, and bars have paid fair wages. In the ranges, veins of silver, copper, and lead exist, but, their location being somewhat inaccessible and remote from any ore market, are passed over by the prospector, who seeks for placer digging only. Bed rock is mostly granite, together with some ancient limestones and crystalline slates and schists. Serpentine also appears (usually a green or purple-streaked rock), showing a continuation to the north of the celebrated serpentine schist and slate belt of California and the Kootenai, Caribou, and Cassiar districts. Some ranges are like the highly colored mineral belt of Red Mountain in Colorado. Placer mining on the Yukon is probably still in its infancy.

According to Mr. H. P. Cushing: "The geological structure of this region is very complicated, due to the disturbances which have taken place. There have been two or more different periods of crust movements. The original shales and limestones have been shattered, fissured, faulted, and metamorphosed, and at certainly two different periods outflows of eruptive rock have taken place. Great numbers of these fissures have been filled with metalliferous matter. Small veins abound, carrying gold-bearing pyrites, generally in a quartz gangue or silver-bearing galena, and silver sulphurets in a calcite gangue. These veins are found both in metamorphic slates and limestones and in eruptive rocks. In the large majority of cases the deposits are of no value, due to their small size and prevalent leanness of ore. When they hold out promise for the future, it is more often from the size of the deposit than from its richness."

VEGETATION OBSTACLES TO PROSPECTING

"Owing to heavy precipitation and hot summers," says the "Record," "the region is covered by a dense mantle of vegetation of almost tropical luxuriance, and forests cover the land from water's edge to timber line, save where cliffs are too steep for a seed to lodge, or a glacier fills a ravine.

"No forest fires have devastated these shores. The scars of winter avalanches are quickly covered with a mantle of living green. For the first 1,000 feet above sea level the forests are choked with densest undergrowth. A jungle of bushes covers the mossy pitfalls of decaying logs beneath. Above that zone is a belt where ferns and mosses riot, and trees spring up slender and straight as columns in a vast cathedral, where there is ever a somber green light, and dew and damp moisture left by tangled clouds.

"The foot sinks in a thick carpet of moss, and one treads with muffled steps in deference to the somber silence and solitude that reign in an Alaskan forest."

"At altitudes of 2,000 feet above the sea there are the wildest fantasies in trees—wind-swept, gnarled, and crouching hemlocks, borne down by the weight of winter snows (like the stunted spruce at timber line in Colorado) until what should be a lofty tree spreads out flat like a mat, the stump growing only a few feet high, its limbs elbowing out in all directions and the whole tree covering several square yards of ground. In places these dwarfed forests cover the surface of the country, and the traveler, at times, has to crawl and wind his way, by lying flat on his belly, under the low spreading branches, or clambering up through an opening finds a sudden seat astride a limb or in some other awkward position among the boughs, in this novel mode of traveling over the top of these singular Alaskan forests."

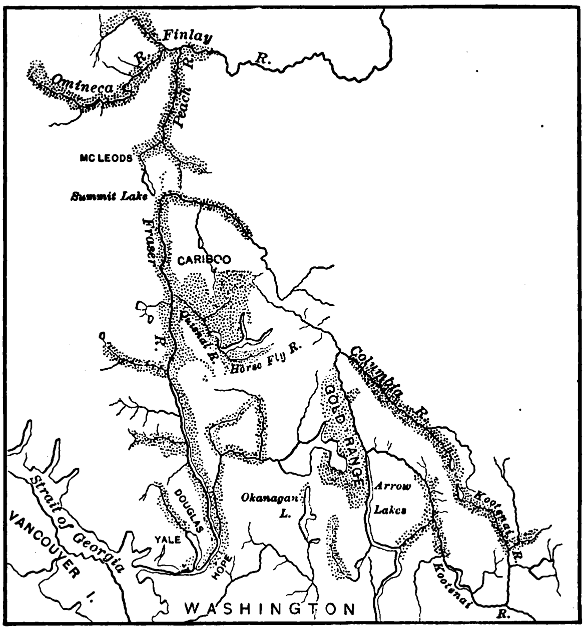
A picture of every-day life of the pioneer prospectors is thus drawn by the "Record":

"Imagine a group of bearded, roughly clad men, squatted under a brush, spruce or hemlock, around a cracker box, with a pot of steaming mussels between them, with French Pete's Siwash sugar and blackstrap molasses as dessert, and later in the evening gathered around a roaring log fire, discussing the results of the day's 'run' in the diggings, or spinning yarns of the huge nuggets they had taken in the Caribou district, or of the extreme cold in the Cassiar region. A devil-may-care life was led by the pioneers, with many a hardship, yet through it all they thrived, growing strong, and enjoying the hard knocks incident to a prospector's life. Nor were these hardships and dangers confined to land in this semi-aquatic country. In trying to reach the coast, parties were blown ashore and their canoes wrecked. The sole resources of many of these men consisted of a sack of flour, a side of bacon, a few pounds of beans, a pick and shovel, and a canoe. But they were not discouraged, for they knew that gold lay in the basin above them, and they set to work cutting down the monarchs of the forest and building cabins for their shelter during the long months of approaching winter."

CHAPTER XVI

BRITISH AMERICA

THE MOST reliable account we have of this great region is from the Canadian geologist, Mr. G. M. Dawson, and in it we shall see much that will remind us of Alaska and of other regions of the Northwest, as well as those bordering on the Pacific coast. There is a family likeness between all these, owing to the comparative similarity of their geology. British America, like Alaska, is traversed by the same Cordillera system of mountains, and in the second place has been glaciated like Alaska. Hence it is a region of fissure veins and of placers. There is scarcely a stream in British Columbia that will not show "colors." The variability of the product depends on the season; the great winter snowfall or heavy rainfall retards work in clearing deep claims from water till late in the spring.



BRITISH COLUMBIA GOLD FIELDS. (AFTER LOCKE.)

The general distribution of alluvial gold indicates that several rock formations produced it in greater or less quantity, though it is only where coarse gold occurs that the original gold veins may be supposed to exist in the immediate vicinity of the deposits.

Colors travel far on beds of rapid rivers before they are reduced to invisible shreds. Glacial drift also distributed the gold widely. The formations are talcose and chloritic (i. e., greenish) or blackish-gray slates and schists, much altered by heat; they appear to be the prolongation north of the richest gold-bearing rocks of California. Denudation of these veins concentrated the gold in placers.

The noted Caribou district is a high plateau cut by V-shaped cañons, whose lessening slope is concealed by gravels which increase in thickness till the valley becomes U-shaped or flat-bottomed, through which streams flow tortuously and gently. The banks are densely clothed with firs and the country covered with drift.

Shallow placers, as usual, first attracted attention, and, later, deep diggings in due order were attacked and found most profitable. Williams and Lightning Creeks yielded the greater part of the gold of Caribou, being well suited for deep work, having a hard deposit of boulder clay beneath the beds of the present watercourses, which prevents the access of much of the superficial water to the workings below. The rocky bottom of the valley is followed beneath 50 to 150 feet of overlying clays and gravels, the course of the ancient stream being traceable by the polished rocks of its bed, and coarse gravel and boulders filling its channel. The richest lead of gold is found in the hollow of the rocky channel, but following the rock surface laterally, side ground rich enough to pay well is found for a greater or less width. Old stream courses of Caribou pursue the same direction as the modern rivers, crossing often from side to side of the valley, with different flexures, but never leaving the line of the old and modern valley, or crossing it, as in California. We may take the Van Winkle mine as a type. On reaching the buried channel a shaft is sunk on the down-stream end of the claim, in the sloping side of the valley, to bed-rock slate. The shaft is continued to a certain depth in this, and then a drift is started at right angles to the course of the valley. The right depth is estimated by that found in other workings. The old channel is struck in such a way as to enable the subterranean water collecting in it from the whole upper part of the claim to be pumped to the surface by the shaft. The old channel, once reached and cleared of water, is followed up its slope by the workings to the upper part of the claim, and where paying side ground occurs it is also opened. The richest pay is obtained in the rock channel of the old stream, but where this is much contracted the force of the water has swept the gold away to those places where its width is increased. The hard rocks retain their polished water-worn forms, but *the slates are rotten* to a considerable depth, and on cleaning up on the bottom a thickness of 1 to 2 feet is taken out with a pick and shovel and sent up to the surface with overlying gravel for treatment.*

In the central channel most gold *lies directly on bed rock, and only occasionally in pay streaks or gravel above it, for a few feet.*

The side ground is worked up from the channel in successive breasts parallel to it. The lowest layers of gravel contain many boulders of quartz and slaty fragments fallen from the hillsides. Water is the main difficulty met with, the workings being annually filled by spring floods. In working over the deep ground in early days in the Caribou district much was left that would even now pay handsomely, but cannot now be found on account of the treacherous nature of the moved gravel (a lesson, first, that old carelessly worked placers may pay to work over again; secondly, the difficulty of working old ground, new firm ground being far easier; and lastly, for prospectors to work a placer scientifically and exhaustively before they abandon it).

In this, as in most other gold-bearing countries, the placers have led later to the discovery of veins. Several of these veins have been traced for miles. The gold occurs associated with iron pyrites and galena, through crystalline masses of which the gold is sometimes strung.

KOOTENAI DISTRICT

This district is rugged and mountainous, comprising the south portion of the Selkirk Range and the Columbia, or Gold, Range. Between these ranges is a string of lakes. The ranges are not very continuous. The rocks are mainly massive granite, in places overlaid by stratified rocks. The ranges average 8,000 feet above sea level. The country is densely wooded. Two long deep valleys traverse the district north and south, one occupied by the Columbia River and Arrow Lake, the other by the Kootenai lakes. The lake discharges into the Columbia.

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*Rotten rocks, especially slates or schists below placer gravel, are favorite repositories for gold in placer mining, and the prospector should never stop his search till he has dug down well into this rotten bed rock.

GEOLOGY

The oldest stratified rocks are mica schists and gneisses, and some crystalline marbles and quartzites of the Archæan age. Overlying these at Hot Springs are gray and green schists, unconformable and newer than the Archæan. Over these are massive gray limestones, changed locally into white marble, with conglomerate below. The green schists are composed of volcanic detritus made schistose or slaty by pressure. The thickness of the series is 32,000 feet.

West Kootenai is of massive granite, with many eruptive dikes. The granites are of intrusive eruptive origin, and later than the stratified rock which they have altered by their heat at the contact. They are closely connected with metalliferous veins or stratified rocks deposited at the time of their intrusion. These new eruptive granite dikes, of a reddish color, cut the older gray granites, as at Cripple Creek, Colorado. Most of the mines are in the stratified rocks. A few veins traverse a hard, dark-gray mica syenite (a rock not unlike granite), and are gold-bearing associated with iron pyrites in quartz. Those in stratified rocks carry galena, blende, and pyrite, and are low grade in silver. Such are the Hendryx and Hot Springs mines. The richer ores at Hot Springs are in green and gray schists and limestones. The richness is due to the influence of country rock and proximity to granite. Stratified rocks, containing the ore deposits of Toad Mountain, are surrounded by granite. Alteration of rocks is due to the heat of the granite. So the country rock consists of altered old volcanic material, derived from the detritus of an eruptive porphyry. Greenish-gray rocks, spotted over with coarse porphyritic white crystals of plagioclase feldspar and black augite crystals, are characteristic of the ore-bearing zone.

The Spokane mine occurs near a wide belt of quartz and a dike of eruptive andesite lava. In the "Number One" the rock is limestone, with veins cutting across it north and south, and veins traceable for miles. Ores range from 20 to 300 ounces in silver. The richest deposits are in limestones and black clay slates. The ore is principally silver-bearing galena, decomposed in the limestones to carbonates for some depth, together with native silver and gray copper, occurring in irregular pockets and impregnating the limestone by substitution, as at Leadville, Colorado.

The Cassiar mines are worked at great disadvantage in an Arctic climate, with the soil permanently frozen, with a short season of floods disastrous to mines.

THE PECULIAR GOLD-BEARING ROCKS

On Leech River are some persistent gold-bearing rocks found through British Columbia, showing a great area and extent of these peculiar rocks. In the southern part of British Columbia these rocks are black slates and schists, traversed by quartz veins. It is from these, mainly, that the placers derive both their material and gold. In prospecting, the extent and distribution of these slaty areas is important, though only a portion of the streams flowing over them carry gold in paying quantities. Still, when the prospector has once become familiar with these rocks, he keeps to them and avoids other and barren regions.

The slates are sometimes calcareous, micaceous, and graphitic. Probably a small quantity of organic matter, in the sediments from which these rocks were made, may have aided in precipitating metalliferous matter, and accounts in part for their richness. Their fissile character later rendered them easily permeable by waters which have concentrated the minerals of economic value with quartz and other crystalline minerals of secondary origin in the veins. Geologically this set of strata appears to lie between the Carboniferous and Mesozoic rocks, and may be metamorphosed Triassic or Jurassic strata. The group runs all along the west coast, from California to Alaska, and a knowledge and recognition of them as the gold-bearing series is of great importance to the prospector. The rapid character of the Fraser River has distributed the finer particles of gold throughout its entire course, though the heaviest, coarsest gold is found in that part of the river occupied by the slates. Where the slates are absent, it is derived from the igneous Tertiary rocks, volcanic tuffs, breccias, and lavas, which often yield gold placer matter, just as certain volcanic andesites and breccias carry gold in Colorado, and are worthy everywhere of examination. Fine gold also was carried far by the ice and currents of the glacial period. On the Tranquille River the gold is scaly, and with it are particles and scales of platinum, of the same shape as the gold; the same metal occurs in the beach sands and some of the placers of California, though no platinum in place has been found on the Pacific Coast. Besides the gravel in the bottom of the stream, an older series is exposed 100 feet above it, interstratified at the top with a white silt deposit. This deposit is a delta formed by the Tranquille, when the water of the lake was at a higher level, in times following the glacial epoch.

The gold is derived from eruptive rocks and slates, and the best paying ground is *where the creek crosses a belt of soft slates.* In some cases the pay is derived from a cement consolidated by calcareous matter resting upon rotten slate. Gold is found in gravels resting on the surface of the older rocks, in irregular pockets and uneven hollows; and again, it is not till these gravels are found spreading more widely and in thicker masses over the Tertiary beds that the richer gold deposits occur. The rocks underlying the Tertiary formations are decomposed and shattered and pass upwards into a clayey breccia, followed by clays and shales.

The natural history of Cherry Creek is instructive, as typical of how placer valleys and deposits are formed.

The actual valley of the stream is, at the productive part, a narrow depression scoring the bottom of a deeply rounded valley. This valley existed and carried a stream like the present in preglacial times. When the glacier from the Gold Range retreated, leaving the valley blocked with morainal matter and boulder clay, the stream again began excavating its bed down the valley. Soft materials were rapidly removed. The stream at first changed its bed frequently, but at last subsided into the deep narrow valley in which it now flows, cutting a new course in the rock of the wide valley and leaving the old channel yet buried with drift on one side of the present valley.

The best paying claim is situated on a little bench 30 feet above the stream. Indians obtained gold from the veins by lighting fires over them and dashing cold water on the heated rock, thus disintegrating the rock and exposing the metal.

Placer grounds extend over 100,000 square miles of Lower Canada. The gravels are generally covered by a layer of vegetable earth or by a bed of clay. They lie on Lower Silurian diorite and serpentine gold-bearing rocks, as in the Ural Mountains of Siberia; hence Russian engineers consider that the gold originates from the rusty quartz of the crystalline schists in the vicinity of serpentines and diorites. Diorite in appearance is commonly a greenish-gray rock, speckled over with little white crystals of feldspar, and often, too, with crystals of hornblende or mica. From the alteration of the hornblende it derives its greenish-gray color, and hence it is often called "greenstone," while its speckled character would name it by miners as a porphyry. Diorite is in many countries an accompaniment of gold, or gold-bearing, particularly in Northwestern America, where it is often associated with serpentine. The latter is commonly a green streaky rock, like green marble, and is often the result of alteration of volcanic rocks and others containing magnesian silicate minerals; hence the frequent association of serpentine with eruptive rocks. Both serpentine and diorite are important factors in the gold-bearing zone of the Northwestern and Pacific Coast areas.

Where the Chaudiere River makes sharp turns, gold is found in cavities and fissures of the clay slates, which run in parallel ridges and are uncovered at low water, when miners break it up and search the slates to a depth of several feet. The fissures are filled with a clay gravel which carries the gold. Many hundreds of dollars have been extracted from between the layers of slate. The gold is sometimes tarnished by a black coating of manganese. At Devil's Rapids, the gold lies in a bed, 200 feet thick, of a hard alluvial conglomerate cemented by clay. The Des Plantes River runs over serpentine, diorite, and schist, yielding grains of gold mingled with black sand. The gold occurs in the reentering angles and cracks of the diorite. In some streams in Lower Canada, most of the gold is extracted from fissures in the sandstone bed rock, to a depth of 5 or 6 feet. In the joints and lamina where gravel has penetrated and indurated, gold is found in the largest masses in abundance. The worn appearance of the gold implies that its source is remote. When gravel lies on blue clay, with boulders in it, in this region, it is poor, but becomes richer when resting on bed rock. In two layers of gravel, separated by a stratum of clay, the lower only is gold-bearing. These clays are barren but contain cubic pyrites, pebbles, black sand, and garnets. The layers of gold-bearing alluvion are not continuous, but occur in sheets or belts of variable extent and thickness. The gold, too, occurs in patches, isolated or remote from one another. A week's work at a good spot is often better than months in poor ground. Quartz veins in Lower Canada run in the direction of the stratification, northeast by southwest, often obscured by vegetable soil, and require prospecting by trenches, as at Cripple Creek, Colorado, and many other regions.

The veins contain pyrite, zinc blende, galena, and native gold. The pyrite and blende carry the gold, which is derived from lower Silurian rocks. These veins occur in soft blackish schists and greenish-gray rocks, or in fine-grained felsite trap or indurated volcanic ash, with seams and stains of green epidote. The latter is a grass-green mineral often found associated with quartz and mineral veins, and with iron, garnets, and hornblende. It is a secondary mineral, derived from iron-bearing minerals, such as hornblende, etc. Sometimes it occurs in distinct crystals, but more commonly as a grass-green staining to the rock. The prospector is likely often to come across this mineral in his searches among the crystalline rocks and veins. It is no particular sign of the presence or not of precious metals, but a common accompaniment of them; it is much lighter—more grassy-green—than copper carbonate.

GOLD IN SLATES

In all parts of the slaty belt, quartz veins abound. A band of slates is often characterized by small thin streaks of quartz and lenticular bunches through all its layers, without showing any well-defined large veins. The quartz holds little pyrite. Good pay is obtained by cleaning up the bed of the river itself and by crevicing in potholes, pockets, fissures, or slates, or sides of the valley. In Leech River, the gold was generally diffused in small quartz seams through certain parts of the slaty rocks, of which a great mass was worn down in excavating the valley, leaving the heavy gold by natural process of concentration in a narrow line on the bottom of the excavation. Copper ores and gold in some localities are associated, especially where diorites, green slates, and dolomites are extensively developed. Gold has been obtained from "gossan," or surface float, filling the crevices in a cavernous, rusty dolomite.

Dolomite is a magnesian limestone, the carbonate of lime of an ordinary limestone, replaced in a great measure by carbonate of magnesia. As magnesian carbonate takes less place or volume than carbonate of lime, the replacement often gives, by shrinkage, a minutely cavernous incoherent structure to the dolomite limestone. And just such a structure is that of which metal-bearing solutions are liable to take advantage and to deposit in it their metals, as, for instance, the silver-charged dolomites of Leadville and Aspen, Colorado. A gold-copper vein at Palmerston carries much copper pyrites; it is associated with dark-greenish hornblende rocks and slates, and the gangue is a translucent quartz, divided into layers, or ribbons, by strings of iron and copper pyrite and calcspar. The last mineral is sometimes, but not commonly, a gangue of metalliferous veins.

Gold veins occur near Lake Ontario in fissures in syenitic granite, that is, in granite containing a good deal of hornblende as well as mica, with micaceous and talcose slates forming the walls and horses in the veins. The talcose, or soft, greasy, greenish soapstone-like slates, result from chemical decomposition of the syenite along the sides of the fissure, apparently a sort of indurated gouge or selvage to the quartz vein containing gold-bearing arsenical pyrites. These veins are irregular in thickness and quality, the fissure opening out wide in some places and pinching in others, and the ore richer in places than in others. Diorite is associated with some of these veins, like the "porphyry contacts" of Colorado. All over the glacial drift of the plains, from Lake Manitoba to the Rockies, gold is more or less present, and appears to have been washed from the shingle terraces along the eastern base of the mountains, where it is believed the precious metal is most abundant. On the Saskatchewan small red garnets, and black, or magnetite, sand form the bulk of the residue of the pannings. The gold is not derived so directly from the mountains themselves as from the drifts of granitoid pebbles spread over the face of the country, derived from the denudation of the great belt of Laurentian rocks extending from the shores of Lake Superior northwest to the Arctic Sea. In New Brunswick, gold is found in the pebbles composing the Carboniferous conglomerates of the coast. Gold veins also occur in diorite; some are short gash veins.

NEWFOUNDLAND AND NOVA SCOTIA GOLD

In Newfoundland quartz veins occur in serpentine of the Lower Silurian, and where serpentine is absent there is no ore. It occurs in pockets rather than veins. Small veins intersect one another, forming a knot or bow, at point of intersection, often rich in gold. The rock is a dark-green chlorite schist. In Nova Scotia the gold-bearing series is in Cambrian greenish-gray grits and sandstones, with bands of shale overlaid by black earthy pyritous slates and sandy beds, much crumpled and contorted. The lodes are in the most metamorphosed quartzitic rocks, and in soapstone with rutile and garnets. These strata are thrown into waves, the elevated points of which having been planed off, show the gold-bearing quartz lodes in the form of irregular ellipses. Gold occurs as spots and bunches up to 60-ounce nuggets. The leads conform with the stratification. It is alleged that much of the gold drift of Nova Scotia has been carried into the Atlantic to form the submarine banks of the coast. Copper Lake is a curious instance of gold occurrence. The lake was drained. A layer of tough clay and glacial drift was met underneath the mud and vegetable matter, and in this underclay small round nuggets were often found. Irregularities in veins sometimes disappear with depth. Lenticular veins may die out before reaching the surface, but with depth may resume.

CONTORTED GOLD VEINS IN THE CARIBOU DISTRICT NOVA SCOTIA. (LOCKE.)

CHAPTER XVII

CALIFORNIA

CALIFORNIA has many characteristics common to the Northwestern field—the same general mountain features, the same peculiar set of gold-bearing strata, and the same characteristic placers, some of which are a little different from placers in general by being covered with heavy flows of lava. The country is divided into three great belts : One, the Sierra Nevada Range, a second 50 miles west of this main axis, principally including the great valley system, and the third the Coast Range. The Sierra is the belt of intrusive granite and of Mesozoic strata intensely altered by heat. The great valley is the belt of alluvial deposits, and the Coast Range is a fold of Tertiary and Cretaceous rocks, also much crystallized and altered by heat. The Sierra is the belt of the origin of the precious metal in place in veins; the Coast Range, of quicksilver, cinnabar, asphaltum, etc.; the great valley, of gold-bearing alluvia which also cover portions of the Sierras. In the Sierras volcanic activity has ceased, but on the Coast Range solfataric action is still apparent. The Coast Range is of shales and sandstones, and limestones altered by metamorphic heat into crystalline quartzites, slates, and sometimes serpentine and marble; volcanic rocks appear often, and granite but rarely. The slates are changed into jaspers and serpentines, which carry the cinnabar.

In the Temescal Range, which is composed of granite, porphyry, and metamorphosed sandstone of Cretaceous and Tertiary origin, is one of the few localities in North America where tin has been discovered. Large areas of the Coast Range are covered with lava, pumice, and obsidian. Hot springs and sulphur beds occur.

The geological structure of the Sierra Nevada, according to Bowie, is:

1. A central intrusive core of granite, flanked by
2. Metamorphic slates of Triassic and Jurassic age, composing the gold-bearing slate formation, overlaid by
3. A covering of Cretaceous, Tertiary, and Post-Tertiary

deposits, which are either river deposits forming the gold placers, or sedimentary volcanic layers, or lava, or marine formations.

Granite occurs in the northwestern part of the State, disappearing in the northeast under great lava beds, and reappearing in Butte and Plumas Counties, increasing in mass and importance to the south.

The gold-bearing slates are metamorphic, crystalline, clayey chloritic, and talcose slates, occupying the western slope of the Sierras, with occasional areas of granite enclosed in them. In this slate occur the veins of quartz, carrying gold. Some veins are very large and traceable for vast distances ; others are small and short lenticular bodies.

Diorite and serpentine, as throughout the Pacific Coast field, are often associated with gold-vein deposits. Basaltic tufa is generally of a light-greenish or yellowish color, or rusty, and contains angular quartz pebbles. The gold deposits of sand and gravel rest upon the tufa, and in Stanislaus County are not capped by lava. Bones and teeth of the elephant are found. An average section of a placer in this district is as follows :

1. Top soil, red sand.
2. Coarse red granite gravel and sand.
3. Red cement (hardpan).
4. Sand and pebbles.
5. Loose yellow sand.
6. Dark-colored gravel, containing fragments of slate, granite porphyry, greenstone, serpentine, quartzite, diorite—materials derived from the Sierra Nevada.

Total, about 50 feet.

The greater part of the gold is confined to the lower stratum of gravel, next to bed rock, associated with magnetic iron (black sand) and platinum.

Lava covers many thousands of square miles of Northern California and Southern Oregon, and buries up many a valuable area of gold-placer ground. The latter are limited to the North in accessibility by the overwhelming shell of lava. Sedimentary layers of fragments of lava, carried to a distance by water and deposited as breccia or conglomerate of volcanic ashes, are found interstratified with the gold gravels or covering them. The gravel deposits vary in texture from a fine pipe clay to sand and coarse gravel, and from that to boulders weighing tons. These deposits were laid down by the action of Tertiary rivers, which had the same general course as the present streams on the west slope of the Sierras, but whose channels were wider and slopes greater. These rivers eroded the gold-bearing slates with their quartz veins, and concentrated the gold in deposits, often 300 feet wide at bottom and several thousand feet wide at top, with a depth now varying from a few inches to 600 feet. Volcanic eruptions have in places covered these deposits with lava and tuff hundreds of feet deep. Quantities of fossil wood and remains of land and water animals found in these deposits attest their river fresh-water origin.

The top gravel sometimes pays, but not generally. Gold may also be found at times literally in grass roots, entangled in the roots of the plant. But the best pay is generally near or at bed rock. Where bed rock is of slate, upturned on its edges, gold frequently permeates it a foot or two, so a miner does not stop till he has dug up some bed rock. Fine sand is generally poorer than coarse gravel. Deep pot holes filled with sand are often, but not always, rich. All this goes to show that, to prove a placer, a system of sluicing should be adopted which bottoms the entire deposit.

BEACH MINING

Beach mining is carried on in various places along the coast, especially between Cape Mendocino, in California, and the Umpqua River, Oregon. The beach sands contain gold in a finely divided state in layers (1 or 2 feet deep) of magnetic-iron sand, which by concentrating action of waves and tide is separated from the lighter quartz sand. By the wash of the water the gold layers are sometimes exposed and sometimes covered by the non-auriferous material. With the gold, and like it only more compact, flakes of platinum are found. As the tides continually alter the position of the gold-bearing layers, it is necessary to prospect daily for the richest spots, which are generally covered at high water. The sand assays from $5 to $30.

DEEP-LEAD MINING AND MOTHER VEINS

Gold, in this State, is often mined in deep deposits overlain by lava, by tunnels and by drifts. Where a pay channel has been found or is supposed to exist, a prospecting tunnel is driven in to find and develop it. Whenever the nature of the deposit admits it, hydraulicking is the best method. The great mother veins, or congeries of veins, of California are extraordinary phenomena. That of Nevada and Amador is an irregular disjointed outburst of quartz, extending 80 miles, from Mariposa to Amador. In a series of lenticular bodies separated by barren intervals, it occupies a width of 12 miles, and the mines are located on intermittent outbursts of quartz. One of these veins, 8 to 40 feet wide, suddenly pinches out in 500 feet. Free gold, averaging $10 to $15, and pyrite are the constituents. These veins are in slate. In the higher portion, near the junction of slates and granite, are isolated patches of ancient gravel, capped with lava. Some of these veins change with depth into tellurides, as at Cripple Creek, Colorado. In El Dorado, the belt of gold-bearing slates, etc., is 30 miles wide. Some mines, noted for free gold near the surface, ceased at 250 feet, passing into barren, poor quartz. Diorite, slates, schists, greenstones, syenite, and serpentine make up their gold formation. The greenstones seem responsible mainly for the gold here. Gold is generally sparingly distributed in the gangue, but rich in the pockets at intervals. Veins are commonly narrow, though plentiful, and demand economic management.

The dolomitic or magnesian portion of the great mother lodes decomposes readily, and becomes a rusty cellular "gossan," traversed everywhere by seams of white quartz which carry the gold values. The rich gravel belt is coextensive with the gold-bearing slates and is derived from them. The coarse gold lies nearest the place where it originated. The lenticular veins are rather intercalated beds or bodies, between the stratification, than true fissure veins. The rocks in many localities are penetrated in every direction by little irregular veinlets. Spots are rich even where not more than one inch thick.

The character of the gold varies in form and value. It is coarse and in flat grains on bed rock ; in the upper part of the bank, "flour" and scaly, and 50 cents purer than the coarse. Lumps occur, coarse and scraggy.

Coarse gold is generally well rounded and smooth ; the finer, more flaky, with quartz occasionally adhering to it. If coarse gold is worth $17, fine gold is worth $18 per ounce.

A system of mining is carried on called "seam diggings;" this is on decomposed bed rock, filled with irregular seams of quartz containing gold. These rocks are commonly soft slates or sandstones, filled with iron pyrites, traversed by little quartz veins and serpentines. These veins are, like the German stock-works, a multitude of little veins ramifying in all directions, with gold far from uniformly distributed in them, mostly in pockets. In these a miner may make nothing or a fortune, or strike, as one did, a $4,000 nugget. When these quartz seams leave the soft decomposed matrix and pass into hard rock, they run out or disappear altogether, and gold invariably gives out. Veins occur as bunches of quartz, quite thick or split into eight or ten strings, which disappear before reaching the surface. Quite a number of quartz seams found below do not extend to the surface. On the other hand, the great mother lode of California outcrops in places, like an immense white wall, 60 feet wide. The likeliest veinstone is seamy, oxidized, rusty, mottled, and marbly. The gangue of some veins is crystalline quartz, semitransparent and ribboned in such a way as to present the appearance of a succession of layers parallel to the walls, one of these layers or lamina being more productive than another. These bands may be separated from one another by thin layers of quartz differing in color from that forming the seams themselves ; or again, laminæ of slate may divide the vein into bands no thicker than paper. Very crystalline, pure, transparent quartz is "hungry," or poor, while if oxidized and showing the square little hollows left by the cube of pyrite that has oxidized out, it is liable to break. Below the drainage line of oxidation, the ore is liable to be hard of treatment.

Flakes of gold are distributed in the veinstone, in the vicinity of certain dark-colored streaks parallel to lines of deposits of quartz. When the gold lines a crystalline cavity, it is in well-formed crystals. In narrow fissures the crystals are flattened to plates. Besides quartz, semiopal and chalcedony occur interleaved between layers of quartz, showing clearly their origin from hot-spring action. Some California lodes have been worked to a depth of 1,500 feet without impoverishment. Bodie, in Mono County, is an isolated mass of porphyry, the center of a great eruption. There are evident traces of igneous action, comparatively recent, in Mono Lake, with islands of lava. The surface of the mountain is covered with an ocherous earth, derived from decomposing poryhyry, and containing fragments of quartz, jasper, and chalcedony, derived from the breaking up of various veins and lodes which intersect the mountain, while parallel veins of hard, compact, uncrystalline "hungry" quartz occur on the surface of the hill; at a depth of 50 feet they become softer and are productive. The veins show a fine parallel-ribboned structure, indicative of their deposition by hot springs, like those at Steamboat, in Nevada.

YUBA AND OTHER PLACERS

The Yuba placer is a good typical one of a certain kind of placer. It is composed of 250 feet of gravel, protected by lava and cemented into a hard conglomerate. The colors of the upper and lower portion of the mass differ, due to oxidation of iron pyrites by surface waters staining the gravels red and brown in undulating lines, contrasted with the blue color of the unoxidized detritus. The "blue gravels" are highly impregnated with iron pyrites, forming a cement. Isolated patches of fine sand, exhibiting false bedding, occur in the upper portions, and contain much fossil wood, flattened by pressure and blackened to coal. When covered by lava this wood is beautifully agatized. On bed rock, the grains and scales of gold are very conspicuous and are inlaid so firmly upon the hard, smooth granite bed of the ancient river as to resemble a gilt mosaic. Beneath the lava of Table Mountain, Tuolumne, is a fine-grained sandstone interstratified with seams of clay and argillaceous shale. With these are beds of strongly cohering conglomerate or cement, at the bottom of which is the pay gravel.

DEEP PLACERS

Professor Eggleston, writing on California deep placers, says: "The great lava flow filled the deep channels and covered elevations also. The Yuba cuts cañons through the volcanic flow to a depth of 3,000 feet, showing in sections, first, lava; second, gravel; third, slate. The deep leads were found by miners who could not get hold of the open, easily worked placers, and so were driven to prospect up hill till signs led them to a point underneath the lava. Deposits are sometimes found in basins formed by swelling of the bed rock. The ancient rivers were on a much larger scale than now; they had "bars," eddies, rapids, waterfalls, with gold deposited in crevices. There were long barren stretches, and pockets of richness. Sometimes there was more than one channel. The problem of drift mining is to find the channels. Some of the best drift mines have been found by following surface placers up to the line of disappearance of gravel and gold; at this point is a channel and place to prospect. Sometimes a depression in the line or under edge of the country rock indicates an old channel and probable presence of gold. Gravels are not confined to definite channels, but old streams sometimes overflowed, as modern ones do, carrying gravel and gold with them. In some localities two distinct sets of ancient river channels have been found, one cutting across the other, very different in character, showing they were formed at different periods. Gravels sometimes cover the whole surface of the country without any apparent defined channel. Channels are subject to irregularities and are sometimes abruptly cut off by faults caused by a movement of the underlying pipe clay or by erosion of ground beneath the flows."

PROSPECTING IN IDAHO

The southern portion of Idaho is a continuation of the sagebrush and alkaline deserts of Nevada and Utah. The Snake is the principal river. The valley of the Snake River is a plain 50 to 100 miles wide, covered by flows of recent basaltic lava (page 219). From Wyoming County to Owyhee County north of this plain the country is mountainous. This northern region is well wooded and watered and good for mining. The winters are long and severe. A large granite area occupies part of Southwestern Idaho, which has been greatly disturbed by eruptive action at a comparatively recent date. Dikes of basalt occur and hot springs abound, issuing sometimes from the granite, at others near volcanic rocks, showing that volcanic heat still remains below the surface. The numerous veins in the granite strike significantly in the direction of the ranges in the flanks of which they occur. The fissures containing the veins were made by the upheaval of the range. The movements in the ground, the fissures, and heat action probably belong to the Snake River eruptions.

The ores were probably deposited by solfataric hot springs accompanying the eruption of basalt. The living hot springs

GREAT BASALT PLAIN OF SNAKE RIVER, IDAHO, WITH RECENT CONES. (AFTER LOCKE.)

in the granite are charged with alkalies and sulphohydric acid, and may be called modern solfataras. These occur in the immediate neighborhood of the mines. As we have often before said, solfataric action, whether modern or extinct, is associated with ore deposits, and Idaho seems to be a region of past as well as present vein formation due to its volcanic character. Some of the veins are faulted and their walls slickensided, showing that movements have occurred even after the veins were formed and filled. And veins, like old healed wounds, being weak places, the fissuring again took place along the old breaks.

BOISE BASIN

The gravels of the Boise Basin cover an area of 30 square miles and to a depth of about 12 feet, representing an extensive erosion of the upper country by streams far greater than those of the present limited rainfall admits. They date from a time prior to some of the basalt eruptions, for locally the gravel is covered by a basaltic cap. Some veins are later than the basalt itself.

The mines are mostly in the granite or veins between granite walls, which are numerous, rich, and narrow. Some, like the celebrated De la Mar mine, are nothing more than rich impregnations of decomposed porphyry dikes. The ores carry both gold and silver, the gold being generally free or in pyrites or zinc blende.

Prospectors should carefully observe the float, the character of the croppings, evidences of disturbance, and especially the decomposition of the country rocks, particularly if that rock happens to be a porphyry dike. The granite masses are, for the most part, the mother of the gold. The veins here frequently grow less rich as their depth increases, though the strong veins may continue rich to a very great depth, and decomposed gold-impregnated porphyry dikes, like the De la Mar, are liable to continue rich to as great a depth as the decomposition lasts.

In Wood River district, ores occur in granite and slate. The placer-gold gravels are of great volume and extent and have yielded some thirty million dollars. There are three classes of gravel. The bars of Snake River are gold-bearing, but the gold is very fine, or "flour."

Rich, but small, placers occur along the Salmon River; small placers are found near the croppings of gold veins, and these veins have been discovered by following up placers.

The deep gravels of Boise Basin are surrounded by mountains, and receive no drainage from beyond the basin's own limits, yet it contains 125,000,000 cubic yards of placer material 250 feet deep.

Gravels are spread over the whole basin, and occur even on the tops of high hills, and are at times capped by heavy flows of basalt, as in California "deep leads." The pay dirt is generally on bed rock. Large boulders and fossil wood are abundant here as in California placers. It is evident that a great river once flowed through the basin and transported the gold-bearing gravels.

CHAPTER XVIII

MONTANA, DAKOTA, ARIZONA, AND NEW MEXICO

MONTANA is a region of granite mountains and the sources of many great rivers. The geology is an Archæan granite core, with patches of ancient Paleozoic sedimentary rocks. A large portion of this so-called granite is really an eruptive diorite—that peculiarly gold-bearing rock. It is composed of augite, hornblende, and plagioclase feldspar, with grains of magnetite. The more modern eruptive rock, called rhyolite, usually a light-colored gray or white rock, occurs, as well as porphyries. Rhyolite breaks through the diorite granite at Butte City. The prospector sees here the usual good signs for a mineralized region, viz., plenty of eruptive rocks. The vein material is simply an alteration of the country rock along certain places in which calcite quartz and metallic minerals have replaced portions or all of the original constituents. There is no definite wall generally to the ore deposit, at least on one side only. There was no preexistent open fissure of the same width as the present vein. Gold at times seems merely to impregnate the country rock. A considerable portion of the ores consists of gold-bearing pyrites and quartz sufficiently oxidized to mill freely; others require smelting. A good deal of copper ore is present.

The placers have produced richly. The deposits are mostly in open valleys comparatively high up on the mountains, and consist of coarse gravel varying from 5 to 65 feet in thickness. Bones and tusks of elephants have been found in the placers of the glacial epoch. Bed rock is not always reached, but a clayey seam or false bed occurs, below which the gravel is barren. Alder Gulch is the most noted placer; it has yielded upwards of thirty million dollars. For a distance of 15 miles, from the summit of the mountains to the Ruby River, the pay has been continuous and rich. The ground is worked to profit along the banks as high as the water can be carried, and is known to be rich still above the highest elevation to which the water has reached. In Deer Lodge County, where the first discoveries of gold were made, the ore is in diorite granite. The butte of Butte City is a rhyolite lava dike. The ore is not confined to veins, as the county rock often yields pay material for a varying distance from the main ore body. At Helena the ores are mainly gold-bearing in veins in granite and in slates. The veins are segregations of quartz and metal, in bodies lying parallel with the formation. At Big Hole, the river for ten miles runs through a cañon cut in gneiss in which are abundant gold-bearing quartz veins.

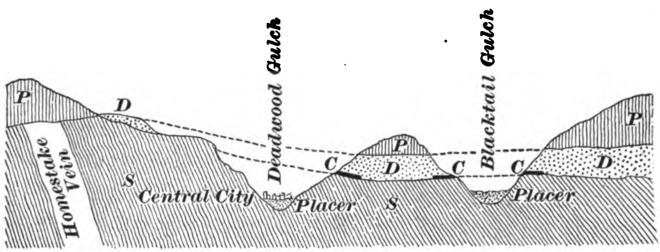
PROSPECTING IN DAKOTA

The Black Hills, of Dakota, are in many respects geologically an epitome of the great Rocky Mountain system. They are a wooded island, rising 3,000 feet above the ocean-like prairie, being an independent uplift 100 miles distant from the Rocky Mountains. The uplift is oval, about 120 miles long by 50 miles wide. The central mass is granite, with sedimentary rocks of all ages, from Cambrian to Tertiary, dipping away from it on all sides. Large veins of coarse pegmatite granite occur in the granite; and eruptive rocks, porphyries, etc., are intruded between the sedimentaries. The hills contain iron, copper, tin, gold, and silver. The deposits in the granite and schists are lenticular in shape and composed of gold-bearing pyrites.

There are placers of stream tin, and also of gold, and a remarkable ancient consolidated placer, found at the base of the Potsdam or Cambrian rocks, and of Cambrian age. This was formed by the ancient ocean advancing upon the slowly sinking granite island, sorting over the material washed from the land and depositing it as sand, gravel, and pebbles, as the basal member of these rocks. The particles of gold were derived from the granite veins; it was a very ancient primeval gold placer, now consolidated into hard rock, as shown at the Homestake mine. It forms the hard cement beds of the miner and is stamped as an ordinary free-milling proposition. We have called attention to this before as an instance of what we call conglomerate rock, rather than an orthodox modern placer, producing gold.

HOMESTAKE MINE

In the sketch (page 223) the porphyry cap of the Homestake vein is shown. The porphyry flowed sometimes beneath the Potsdam, sometimes on it and beneath the Carboniferous, sometimes it lifted up the overlying strata by a thick intrusive sheet. The lower contact line is the old Potsdam beach. The gold in these ancient placer conglomerates is finer than that in the veins, as is commonly the case with placer gold. The Homestake property, or a section 6,000 by 2,000 feet, constitutes the gold belt. The deposits were of course originally laid down as beds, but have since been much altered. The beds contain a good deal of carbonaceous and graphitic material, which were doubtless relics of organic substances in the placer, which may have helped in precipitating the gold and chemically changing the iron that carried it. The ore is not continuous,



THE HOMESTAKE MINE, DEADWOOD, BLACK HILLS.

P, Porphyry; *D*, Potsdam Conglomerate; *C*, Cement Mines; *S*, Schist.

but in great "shoots" or "pipes" of a lenticular shape; in cross-section the shoots cross the dip. In the Homestake are sheets of porphyry cutting across or parallel with the stratification. The influence of this porphyry on the lode is good, enriching the bed and by oxidation rendering the ores more free milling.

Mr. W. B. Devereux gives a very interesting and instructive account of these peculiar gold deposits, which he aptly calls "a fossilized placer."

"The underlying rocks are metamorphosed crystalline Paleozoic schists, which contain the gold-bearing quartz veins. Resting unconformably on these is a sedimentary formation, composed of débris derived from the schists containing fossils of the Potsdam period. The base of this formation is a conglomerate. Gold in early days was found in the lowest stratum of this conglomerate. It was obtained by horizontal drifts, and many hundred thousands of dollars were taken out in a short time. The mines were called 'cement' mines; the conglomerate needed the stamp mill for reduction. This conglomerate merges upwards into sandstone or quartzite. It is a mixture of quartz boulders, pebbles, and worn fragments of schist with pebbles of hematite. Gold occurs in this, both as mechanical and chemical constituents. The horizontal character of the sediments, and the fact that their fossils belonged to salt-water types, shows that they were ocean sediments, formed in shallow water, where there was strong wave action. These deposits were later overlaid by the porphyry. Ore mined from this ground milled $50 per ton, and the stratum lying next bed rock was exceedingly rich. Small channels and depressions caused local concentrations, and these channels were followed in mining. The ore was hard and required blasting.

"There were the same variations of quantity as in ordinary placer gravels. Local channels showed alternations of rich and poor material, due to different conditions of current, and the occurrence of the greater part of the gold at bed rock; about 6 feet in thickness as a rule paid. The gold was like placer gold, in shot gold, or smooth rounded grains slightly flattened. The cementing material was iron oxide, and bed-rock gold was often attached to the overlying boulders by this medium. The gold was most abundant with large quartz boulders or pebbles of hematite. The latter nearly always carried gold. Each grain of gold is generally covered with a thin coating of iron oxide which needs a blow to loosen it. The richest ore is not always found in the deepest portion of the channel, but sometimes upon one slope. Basins occur in these channels that are rich. They seem to have been formed by whirlpools."

Where the slate was soft cement, gold worked down into the crevices for several feet. The history of these singular deposits appears as follows:

"The gold veins were in existence before the Potsdam period. The Potsdam seas washed away the débris resulting from the disintegration of the quartz veins and deposited it in deeper water, according to its specific gravity; at the same time gradual wave action carried the gold to bed rock in the same manner as it settles in a miner's pan. The Homestake vein was a hard reef, or low island. In time the sediments became an island, gradually cementing into rock, until later eruptions of porphyry caused great local metamorphic action. The gold now became partially dissolved, and was again precipitated as thin films in the schists below. A period of rest ensued until fresh-water streams cut through the upper strata and disintegrated the matrix of the gold and afforded material for a new concentrating process. This disenveloping process has continued to the present. Gold from the conglomerate found its way to the bottom of Deadwood Gulch and was joined with supplies from the Homestake vein and formed the great Deadwood placer."

The gold belt is a zone of slates and schists, with many lenses and shoots of ore. Zones impregnated with pyrite pass into quartzites, forming foot and hanging walls. Such deposits have to be worked on a large scale to pay, and concentration and chlorination are necessary.

The "contact" gold deposits carry silver also, and vary in thickness from a few inches to 10 feet, averaging $15 to $60 in value. They are in connection with igneous intrusive rocks. In the Potsdam placer conglomerate, the gold occurs along the bedding planes of the rock and in vertical joint planes, or impregnating the quartzite and replacing the cementing material of the original sandstone in close connection with igneous rocks. On the surface the iron is oxidized. In the deeper workings, a bluish quartzite constitutes the ore, containing minute pyrites occupying spaces between the grains of sand, like a cement. The ore also occurs in large bodies, replacing beds of loose shales which occur in the Potsdam. The porphyry eruption gave rise to hot solutions necessary to collect and redeposit the gold in an available form. The Oro-Fino mine is a crater in Archæan granite, with vertical walls filled with breccia. The diameter of the crater is 150 feet. The breccia consists of angular, worn fragments of slate, quartzite, and porphyry, cemented together by pyrite, galena, and blende derived from hot ascending solutions. The prospector may notice here certain good concomitants for a rich lode, viz., the presence of eruptive porphyry, and close to it a loosely compacted rock or breccia, supplying good places in its interstices for ore solutions to circulate.

The outcrop of the galena deposits is lead and iron carbonate, but with depth, sulphides.

TIN DEPOSITS

The Black Hills of Dakota have long been noted for the occurrence of that metal so very rare in America, viz., tin. Miners in 1875, working for gold, found a troublesome heavy black sand in their sluices. Some of this was sent to Prof. Richard Pearce, of the Argo Works, Denver, and found by him to be tin. The veins carrying tin in the igneous and granite rocks of Harney's peak also carry gold and pyrites. It is probable that both gold and stream tin were derived from the Potsdam sandstone. The veins in the granite are a chain of lenses. They vary in width, some being upwards of 100 feet. When tin is present, one of the mineral constituents of the granite is generally wanting. The vein matter is composed of quartz and mica alone, or of soda, feldspar, and mica, or of pink feldspar and quartz.

MINERALS ASSOCIATED WITH TIN

The Etta tin vein is columnar and oval, 150 by 200 feet. The minerals in it are arranged concentrically. The central portion, or core, is quartz and feldspar, surrounded by albite feldspar and mica carrying tin. Another zone surrounds this with large crystals of lithia mica. The interstices between these crystals are filled with an aggregation of albite feldspar also carrying "tin stone," but in more massive form. Tourmalines or "schorl" also occur as in tin-bearing rocks in Cornwall. Tourmaline is a long, jet-black crystal, not unlike hornblende. The common mica associated with these tin deposits is of a light greenish-yellow color and the feldspar is white. When mica, quartz, and feldspar are all present in the granite, tin is absent; when only mica and quartz, tin is present. If the vein is of feldspar alone there is no tin. The quartz is usually banded. If the crystals of the rock are large, the tin crystals are large also. Tin occupies interstices between crystals. Apatite, columbite, beryls, garnets, barytes, zircon, corundum minerals also occur. Stream tin is not so pure as the vein tin. The yield is about 74 per cent. tin.

For our knowledge of the deposits of the Black Hills we are indebted mainly to Prof. F. C. Carpenter's admirable report.

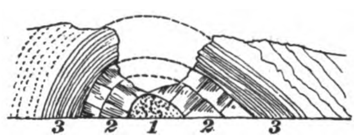
PROSPECTING FOR PLACER DEPOSITS IN DAKOTA

Experiences in this region with the gravels, as related by Jenny, are very suggestive to the placer prospector.

"The placer gravels result from decomposition and erosion of the rocks, and these included gold deposits in Tertiary times. The gravel deposits of French Creek show a local rich concentration of gold on the outer edge of the bed rock. Though very encouraging at first, on driving an open cut into the bar where the gravel was undisturbed, the richness of the pay dirt rapidly decreased and soon became uniform, showing the result first obtained was only a superficial rim rock 'prospect.' The richest layer was rarely on bed rock, but 10 to 20 feet above it, in a sort of false bottom of compact clayey gravel, which had retained most of the gold. The gold was in flattened scales, free from black sand but associated with little-worn garnet crystals. The gold is derived from quartz ledges in schists, rather than from the intruding granites, as shown by the fact that the gulches paved wholly with granite were barren. Pay gravel is of heavy pebbles, clayey sand, and many garnet crystals derived from the schists. It is soft, rarely cemented to a conglomerate, and easily washed in a sluice. There was a general diffusion of gold in the creek beds, but little concentration in rich deposits, due to slight denudation of the ledges and want of sufficient grade in the valley to cause a concentration of gold into a paying channel. Down Spring Creek, where a large quartz vein crosses the gulch, gold is found in the stream bed, derived from a decomposed stratum of clay slate which retained the gold swept over it from the quartz vein. It is noticeable that enormous quartz ledges carrying gold in place are in the vicinity, and these have made the placers. In another locality, the richest layer was the lower part of the red-garnet gravel resting on the surface of blue plastic clay. Where the bed rock is soft and decomposed it is liable to be rich, but when hard and smooth, poor. Large placer flats and elevated bars occur at bends of the stream, and are rich. The region is just such as would lead the prospector to expect rich placers. The source of supply is great, the side valleys are excavated for miles along the outcrops of gold-bearing veins, slates, and quartzites, all contributing to the placer of the main valley. Gold has been partly retained in the gulches, and then carried out and scattered far and wide in the drift. In flats and creek beds, where a stratum of soft slates is found crossing the gulch below, a high and hard bar with rich deposits may be sought for. Pits were sometimes sunk in the flats near the channel of the stream, but failed to reach bed rock, owing to uprising springs of water which could not be controlled. Panning has varied from 1 cent to the pan to 10 cents, on an average. On Bear Creek one pan yielded $27, and a rocker in 8 days took up $165. On Deadwood Creek gold is derived from igneous rocks, and the gravel is of the same material, yielding 12 colors to the pan. Manganese and limonite iron were found associated with the gold sand, showing the gold came from a heavy manganese and iron ledge in the cliffs. The gold being entirely free from quartz, appears to have been derived directly from the igneous rock itself, not from quartz veins. A gravel wash from the Black Hills is found all over the surface of the plains, made of every kind of rock found in the hills, and doubtless carrying a certain amount of scattered gold. Miners prospecting up a dry gulch of Whisky Creek, obtained 25 colors from dirt shaken from the roots of a small bush growing in a crevice in the bare sandstone bed rock at the bottom of the ravine; hence the locality is called the Rosebush diggings, which derives its gold from the washing down into ravines, by occasional heavy rains, of gravel deposits capping the hills; such a sudden stream would sluice the gravel accumulated in the gulch, the gold being caught in the crevices of the bed rock. It yielded 5 cents to 15 cents to the pan. The gold was in fine particles, associated with garnets which came from the schists of Harney's Peak. The ravine is hollowed out 200 feet, through red sandstones. Its bottom is paved with Carboniferous sandstone, and the hills on both sides are covered with deposits of slate and quartz which furnished the gold. The supply of water was so small, though the deposits were rich, that the miners waited till the spring rains filled the water holes and made it possible to work the pay dirt in rockers in rich spots. Most of the streams sink in their beds among the foothills miles from the placers. In dry ravines, cutting through gravel deposits, miners can make wages by washing the earth from the bottom of the gulches, during early spring months, when there is water enough."

PROSPECTING IN ARIZONA

Arizona is in the southern portion of the great plateau system. We visited Prescott some time ago and the mining region around the Hassyampa Creek. Between the Union Pacific and Prescott the country is very sterile, composed mainly of contorted granitic schists and lavas. About Prescott we come into massive granite and syenitic rocks, traversed by dark greenish-gray dikes of diorite. These dikes are in places gold-bearing, especially in the oxidized decomposed surface, yielding a good deal of free gold over a considerable width of the rotten dike, which at the time of our visit was being treated by an arastra in the creek below. At a little depth, however, we found the free character of the ore changed to rather rich gold-bearing pyrites requiring smelting. On examining a cross-section of the dike, which was upwards of 100 feet wide, we found it traversed by numerous little veinlets, which assays showed to carry the gold, the diorite matrix being poor or barren. The main difficulty in this region is the general lack or uncertainty of water, the creeks being liable to dry up at certain seasons and to boom at fitful intervals. Arizona is noted also for its rich copper mines. In the southern part of the State, near Tombstone, you rise from Post-Pliocene gravels to a granite plateau of gray, crystalline eruptive granite, weathering in gigantic rounded blocks lying on one another. Near Tombstone stratified formations overlie the granite, consisting of quartzites, limestones, and slates of Lower Carboniferous and of Paleozoic age, dipping at a low angle towards the east. The Toughnut



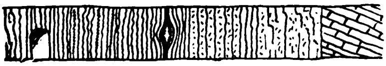
ARCHED FOLD, TOUGHNUT MINE, ARIZONA.

1, Novaculite under Limestone; *2*, Limestone bending over the Novaculite; *3*, Shales bending over the Limestone.

mine, described by W. P. Blake, is an instructive one to the prospector.

"Here porphyry dikes cut through the strata, following the general faulting lines of the country, the veins also following the same general course. The stratified rocks are shales and quartzites, very fine-grained, the latter rock changed to the variety called 'novaculite' or whetstone rock. Abundance of iron pyrites occur in the layers of quartzite. Above the quartzite are dark-blue limestones and black shales. The black limestones above the novaculite are silver-bearing. These beds are folded into arches. The Toughnut is on the anticlinal of one of these arches. The ore was discovered cropping out in the soil and vein stuff. The rich ore lies in the folds. The folds have also broken into faults. The Grand Central Chief mine is located in the outcrop of a dike of diorite porphyry which carries ore in, through, and alongside it. The prospector found the outcrop obscure, being a confused mixture of porphyry, flints, quartz, and porous quartzite. None of the outcrops rise high above the soil. He was led, however, to the spot by a considerable stain of iron, and a little digging revealed good ore near the surface.

"The dike varies in thickness from a few feet to 70 feet, dipping west 55 degrees. It cuts through the shales, quartzites, and limestones. The dike is vertically laminated, or divided from top to bottom by layers or cleavage planes filled with thin veins of quartz (in this respect as in many others resembling the phonolite dikes of Cripple Creek with their cleavage zones produced by shearing or slight faulting movements and filled with rich ore). Large portions of the dike are so penetrated by quartz as almost to consist of that mineral. The dike itself is much impregnated with pyrites in cubes, many of which having dropped out, leave square cavities and produce a honeycombed structure of the quartz. Though it has been worked 600 feet deep, and there are 12 miles of workings, undecomposed ores below water



CROSS-SECTION OF THE MINERALIZED DIKE, CONTENTION LODE, ARIZONA.

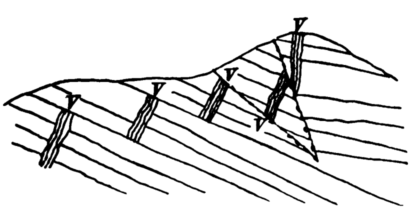
Showing vertical laminated structures with seams and cavities of quartz crystals and ores.

level have not been reached. The minerals are oxidized and so red with iron oxide that miners emerge from the mine like red men.

"Along the upper 300 feet of the dike extensive decomposition of porphyry has produced pure white or stained kaolin, or china clay. This kaolinization extends to the adjoining shales. The ores are gold and silver, the gold being free, the silver as chlorides with carbonate of lead. Metallic gold and silver chloride are disseminated through the mass of the porphyry, while portions of the porphyry carry quartz veins. The porphyry also passes into soapstone and serpentine.

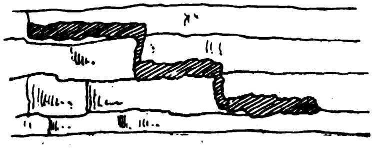
DIKE MATTER PENETRATED BY VEINLETS OF MINERAL-BEARING QUARTZ. BLACK, QUARTZ VEINLETS. LIGHT SHADED, FELDSPAR.

"Gold occurs in crystalline flakes and scales, chiefly in and along thin seams and cracks in the mass of the rock, as if infiltrated and deposited from solution. Free gold is found in the quartzite. Both dike and strata have been moved and faulted, as shown by breaks in continuity and by brecciated cross-courses, seams traversing both igneous and stratified formations. This breaking up of the dike and fracturing and brecciating of the country rock, accompanied by the movement of the dike upon itself and the formation of heavy clay seams, provided suitable places for the accumulation of ore found in the softer, more broken portions of the dike. Bedded ore deposits are associated with bedded dikes and vertical fissures parallel with the Contention lode. One lode is traceable for two miles, till it passes into underlying granite.



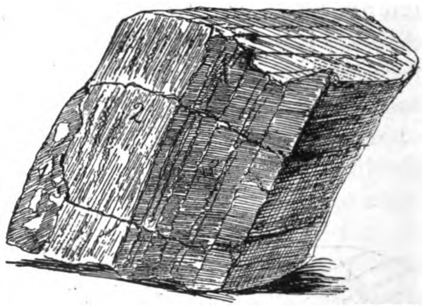
FAULTING OF ORE BODY OR VEIN, CONTENTION MINE, ARIZONA.

"A line of fissures cuts across the arch of the Toughnut, which has been followed in ore and is connected with the side bedded deposits. This lode is marked by heavy outcrops of quartz and by flinty boulders lying above the limestone, on the surface. The bedded deposits fill irregular cavernous spaces eroded in the strata by metalliferous solutions without definite boundaries, and are apparently explained by the metasomatic or substitution theory.



BEDDED DEPOSITS OF LEAD PASSING FROM STRATUM TO STRATUM, THROUGH JOINT CRACKS. (ARIZONA.)

"There have been shearing movements of the dike upon itself, resulting in heavy clay seams from attrition, also lateral and vertical displacements from west to east and downwards, the top of the dike having been carried off in successive blocks by the sliding of masses of the stratified formations upon the planes of deposition of the beds, and partly on steeper planes of fracture. These movements have been accompanied favorably by ore occurring in the softer, most broken portions of the dike, coincident with great original metallization and subsequent movement attended by clay seams. The fragments are not cemented by quartz, but loosely by clay, showing mere mechanical force.



SECTION OF MOOSE MINE VEIN, CRIPPLE CREEK, COLORADO.

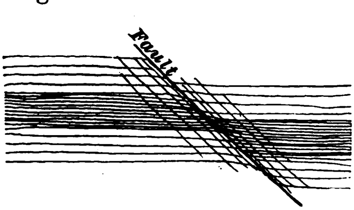
1, Country Rock Breccia; *2*, Yellow Jasper with Cavities of Quartz Crystals; *3*, Blue-Gray Jasper with Seams of Quartz and Iron Containing Gold.

"The vertical lamination of the dike by shearing, and the filling of the interstices so caused with quartz and mineral, is like to what we find so often at Cripple Creek, Colorado, in the mineralized dikes of phonolite forming the lode of many of the mines, such as the Moose, Elkton, Raven, and others—phenomena to which the prospector's attention is particularly called, as he is likely again and again to meet with it. Mr. Penrose, in his description of the veins of Cripple Creek, gives a very clear account of these peculiarities in ore deposits.

According to him, 'the nature and mode of occurrence of ore deposits at Cripple Creek depend on the character of the fissures containing them. Fissuring occurred before the formation of the dikes which filled the fissures. Sometimes veins alone occupied these early formed fissures, sometimes dikes. Generally, however, the veins were formed at a late date, long after the fissuring and dike filling, as the veins intersect the dikes and follow the course of preexisting fissures, which intersect the dikes longitudinally or cross them diagonally. There are sometimes two systems of parallel fissures. The fissures are very numerous and their course follows that of the veins and dikes, viz., northeast and northwest, or generally north and south. Fissures were not open gaps, but closed lines of fracture, and veins in them are due to replacement of country rock along these courses. These fissures were at times held open by loose fragments of rock broken from the walls or by protruding parts of the walls brought opposite each other by movements along the fissures. The course of fissures is sometimes a clean-cut break, but usually with parallel cracks on either side, so numerous as to give the rock a banded, sheeted, or slaty structure, sometimes not parallel but intersecting, producing "linked fissures."' Outside this fissured zone, fissuring becomes less and less and farther apart, with receding from the main zone. This parallel fissuring is due to strong compressive stress, in which dislocation is spread over a series of parallel surfaces, instead of confined to one fissure. The distribution of these lines of dislocation in a homogeneous mass follows definite mathematical laws. Fissures occupied by veins result from movement and faulting, as shown by presence of breccia, groovings or striæ, and slickensides. These movements were of

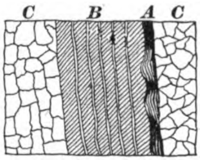
SECTION OF THE ZENOBIA VEIN, CRIPPLE CREEK.

Example of a Clean-Cut Fissure Occupied by a Brecciated Vein.
a, Vein.



SHEARING PARALLEL FISSURES PARALLEL TO A FAULT. C. O. D. MINE, CRIPPLE CREEK.

the nature of earthquake shocks. The character of fissures depends on the nature of the rocks they intersect. In massive, hard rocks, the fissures are sharper than in soft, plastic ones, like breccia. In one case, force causing a fissure overcomes cohesion of hard rock, making a sharp break; in the other, only to the extent of faint fractures without any one well-defined break. The ore deposits are bodies of secondary minerals filling the fissures, sometimes a single fissure, sometimes a number of thin parallel seams filling a fissured zone. Ore deposition was a sequel to dike action, depending on heated rocks for its effect. Dikes may have cut water channels in country rock, and water from these channels forced up the sides of the dike caused ore deposition. Shrinkage cracks, also found in the dikes at their contacts with country rock, may have offered favorable places for ore deposit. Hence the connection between veins and dikes."



SECTION OF ELKTON VEIN, CRIPPLE CREEK.

Showing Relation of a Vein to Sheared Phonolite Dike. *A*, Vein; *B*, Sheared Dike; *C*, Country Rock.

PROSPECTING IN NEW MEXICO

This is a region characterized by great flows of basalt and recent lavas, so recent that they often cover the placer grounds and modern river deposits. Old craters occur here and there, and the foothills and prairie border are studded with lava-capped mesas. To the west the country is a continuation of the Rocky Mountain system, with many rocks and formations similar to those in Colorado, and producing much the same ore deposits and in much the same geological relations. Thus, there are contact deposits between porphyry and Carboniferous limestones, as at Leadville, and fissure veins in granite, as in Clear Creek County, Colorado, and mineralized dikes, as at Boulder. The Rocky Mountain system is lower and more broken up into individual ranges than to the north. Besides the veins of gold and silver in place, there are vast areas of gold placer ground; but the prevailing feature is a lack of water to work them. The great Rio Grande system, it is true, traverses the region, but the fall of the river is not sufficient in most part to bring its waters out of its bed for mining operations.

Gold occurs in the Jicarilla Mountains, but no water, and the gold ores in the veins distribute their wealth in beds of dry gulches furrowing the sides. In Grouse Gulch, a placer occurs resting on hard red clay from decomposition of red granite bed rock. At Santa Fé, the gold placers lie in the Placer Mountains, for the placers in this region are true "hill deposits" on slopes and ridges of the Rocky Mountains, carrying coarse gold like those of the high plains of California. Pay gravel lies deep below the surface, and is generally very rich. Absence of water leaves many of these untouched. Mexicans sink well-like shafts, according to Locke, through the soil to the gravels, and tunnel upon bed rock, and take the richest gravel to the surface in sacks, cart it two or three miles to water, and pan out the gold in wooden bowls called "bateas." In winter they obtain water by melting snow with hot stones.

Gold occurs locally in quartzose sandstones of Carboniferous age, and in rusty beds rather than in veins. The sandstone appears to have been charged with gold-bearing pyrites, by decomposition of which the gold has been liberated. In localities there are regular quartz veins, bearing gold pyrites, which have been worked for twenty years. The erosion, or breaking down, of a bed of sandstone would supply gold to a stream or deposits without it being accompanied by beds of quartzose gravel. So rich deposits may exist on the hillsides without indications of their presence by beds of rolled gravel or broken fragments of veins on the surface.

Professor Silliman, speaking of the great placer deposits in New Mexico, says:

"Here are countless millions of tons of rich gold quartz reduced by the great forces of nature to a condition ready for the hydraulic process, while the entire bed of the Rio Grande, for 40 miles, is a sluice on the bars of which the gold derived from the wearing away of the gravel banks has been accumulating for countless ages, and now lies ready for extraction by the most approved methods of river mining. The thickness of the Rio Grande gravels exceeds often 600 feet, or three times that of the like beds in California, while the average value per cubic yard is believed to be greater than in other accumulations yet discovered."

The area, according to him, covered by these gravels, is 400 square miles; only three portions of this area are available or within reach of the Rio Grande waters, and the lava circumscribes much of the river frontages. Nothing corresponding to the "top dirt," "pipe clay" or fossil wood of the California gravel beds occurs. The gravel for many miles is unbroken except by valleys of erosion cut down 200 feet deep in them, with yet 400 more before bed rock is reached. The gravels above the second "malpais" will be of less value than the under bed, and zones of poor gravel may occur. Over limited areas, beds of fine yellow sand occur, which are poor and barren, but the great mass of these heavy beds are compact gold-bearing gravels, and contain boulders of quartzite with blue or gray

THE ORTIZ MOUNTAINS AND GALISTEO RIVER.

stains and seams of magnetic iron and rusty quartz, stained by decomposing iron pyrites, with but few pebbles of granite, syenite, porphyry, or greenstone, characteristic of the mountain ranges, and with no volcanic débris or ashes. Quartz and quartzite pebbles form 80 per cent. of the gravel in these beds; the source of the material is from corresponding beds of the Sangre de Christo Mountains, north and east. Prospectors claim that the gravels will average 50 cents to 75 cents to the cubic yard. An artesian well was sunk at the Ranches de Taos 425 feet, and through the entire depth only gravel was met and the material showed the presence of gold for the whole distance. Along the Rio Grande, mining operations by ground sluicing have been carried on ever since this locality was first possessed by the Spaniards. Dredging is being carried on in some parts of the Rio Grande on the bed of the stream itself.

CHAPTER XIX

THE GOLD OF THE ORTIZ MOUNTAINS AND GALISTEO AND RIO GRANDE PLACERS, N. M.

IMPORTANT mineral deposits and placers lie at the base of the Ortiz Mountains and along the Galisteo and Rio Grande Rivers. The placers are being worked by dredges by the Santa Fé Placer Mining Company, to the chief engineer of which, Mr. F. E. Nettleton, and to Prof. E. Walters (geologist), we are indebted for our information on this region, as published in the "Southwestern Manufacturer."

The Ortiz Mountains are 25 miles from Santa Fé city. The elevation of axis of this mountain is 10,000 feet above sea level; the valley of the Galisteo River at its foot is 5,674, at Los Cerillos railroad station. Along this axis are granite, syenite, and porphyry. East and west of the axis, paralleling it, are black trap rock, volcanic dikes extending across the country indefinitely, from 3 to 5 miles from the axis of the range. Between the axis and the dikes, about three-fourths of the distance, are well-defined lodes parallel to the axis of the range. At right angles to these lodes are secondary lodes reaching from the primary down to the dikes, especially on the east side of the range. The great western primary lode extends south to San Pedro. On the secondary lodes are fine bodies of low-grade ore, such as Cunningham Hill, near Dolores.

The main western lode is rich in copper and copper mines, as the San Pedro copper mines. Others, such as the Gipsy Queen and "Lincoln-lucky," are gold producers. The main primary lode on the eastern side of the range has been worked at intervals since 1711, soon after the second conquest of New Mexico by the Spaniards. Señor Ortiz located on this lode the celebrated Ortiz gold mines. The vein matter of the Ortiz lode is decomposed quartz, carrying free gold, with depth changing to sulphides or pyrites. The Spaniards worked out great quantities of this ore by means of old-fashioned stopes and inclined galleries, but owing to their crude methods they could not successfully work the mines below the depth that yielded the free milling ores.

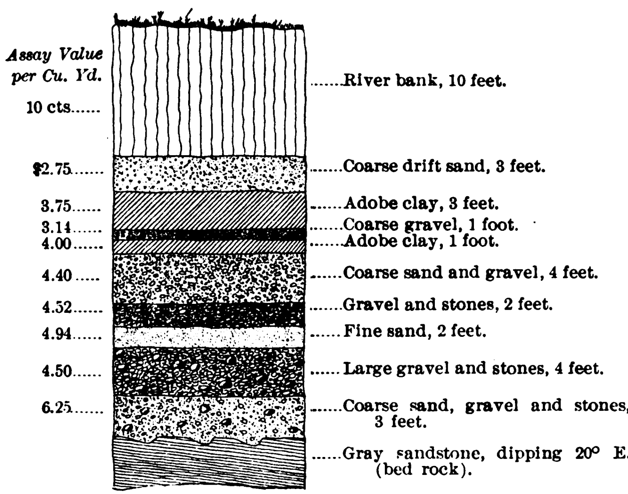
The axis of the Ortiz Mountain range is in close proximity to the newer formations closely flanking its slopes. This uplift came, as in the Colorado range, after the Cretaceous period. The axis is raised some 2,000 feet above the sandstones flanking the mountain, which contain both anthracite and bituminous coal. The green trap-rock dikes were thrust up through the newer formations. These Cretaceous sandstones are soft and easily eroded, and form the country rock that usually includes the gold-bearing veins, hence a large quantity of gold is freed and carried to lower levels by each rainy season. The slopes of these mountains are so steep and the sandstone so soft, that erosion is extraordinarily rapid.

On the eastern side of the range are large fields of rich placers—decomposed quartz in sand and gravel which have inundated the entire eastern slope. Here are millions of cubic yards of gold-bearing material resting on soft sandstone. These deposits were made in a past age, after the mountains uplifted and had afforded great quantities of gold-bearing material, freed by the rapid erosion of the country rock. Above the main eastern dike, and paralleling it for several miles, is probably the richest "dry placer" in the entire field. The geology of the region is simple: the strata rise from the Galisteo River, at an angle of 10 degrees, up to the primary main eastern lode. Between that and the axis of the mountain the incline is much greater. The lode is in a true fissure into which the vein material has been injected.

The sandstone constituting the general matrix of the country rock is so soft and porous that the vein matter lying near the surface rapidly oxidizes. The oxidized honeycombed quartz remains, with its vast supply of free gold that erosion is gradually freeing and carrying down the slopes to feed the placers below.

The great trough that affords a line of rest for these enormous placer deposits is the bed of the Galisteo River. This river is 4 to 10 miles from the main eastern lode, and close to the dry placers, which are from hundreds to thousands of feet higher than the river, though the deposit extends in more or less richness down to the banks of the river. There is considerable uniformity of values throughout the field. Placers of workable richness are found almost anywhere where there are drift deposits on the entire eastern slope of the range.

Water supply is the most difficult problem. The Cunningham mesa, or "old placers," on the eastern slope, has been worked for hundreds of years by ancient Aztecs and later by Spaniards, yet it is said by experts that if water could be brought to bear, the placers could yield a million annually for twenty-three years, despite the hundreds of past years they have been worked. These dry placers have only been worked hitherto by the Mexican dry washer and by "batea" and dry panning, and hauling the material to the nearest water on the



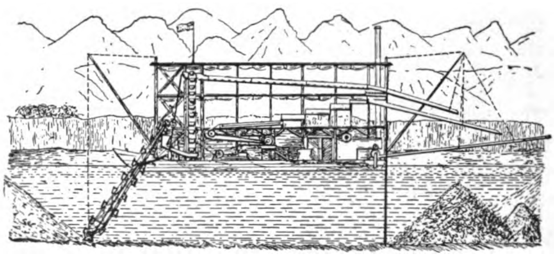
SECTION OF RIO GRANDE RIVER BED, SHOWING STRATA VALUES.

backs of burros. Hundreds of thousands of dollars' worth of gold have been extracted, and still but a minute fraction of the deposit has been touched. For 5 miles from Los Cerillos to Ortiz station the bed of the Galisteo River is a rich placer, and will pan well wherever samples are taken. The sandstone bed rock is 15 to 35 feet below the surface. There is not enough fall and pressure power in the river for hydraulicking the dry placer above. The next nearest is the Rio Grande. The water in the river is mostly "subflow," penetrating the deposit from top to bottom, hence all the material is in a partial state of suspension, so that any particle of gold lodging on the surface finds its way to the bottom, where it remains. Thus the material near the surface shows $2.46 and at bedrock $6.42 a cubic yard.

The Santa Fé Placer Company used the air caisson for making tests of the materials, the strong subflow prohibiting the use of the ordinary cut and pumps. The stratification of the matter penetrated is shown in the sketch, page 239.

MODE OF WORKING PLACER

The process proposed for extracting the gold is by the Nettleton placer machine, a powerful steam-bucket dredge of a capacity of 1 cubic yard of material a minute, having as an auxiliary a 6-inch centrifugal pump, whose suction pipe will



THE NETTLETON PLACER MINING MACHINE FOR RIVER WORK. CAPACITY, 1,000 YARDS A DAY.

extend down the dredge ladder to within 12 inches of the lowest point reached by the buckets. This pump will not only bring up the necessary water for sluicing, but such loose material as may be left by the buckets, and in a great measure clear the bed rock of gold. The product of dredge and pump is deposited in a sluice box 25 feet above the deck of the barge, from which elevation the work is done by gravity until the material and water is disposed of. Passing down the first sluice of 30 feet, a grizzly or grating is reached, removing stones over 3 inches in diameter, finer material passing through screens which reduce it to ½ inch. So the non-productive material is removed at once and deposited behind the barge.

Having passed through the screens, the material and water fall into a box containing quicksilver and thence flow into table sluices, giving an additional length of sluice of 70 feet, by which time even the freest gold has gravitated in the riffles of the sluices and been held there by quicksilver, with which they will be charged. The percentage of fine flour gold being very large, the material is passed over a burlap sluice, the fibers of which arrest and hold the gold. The usual accompanying "black" or magnetic-iron "sand" carries a great deal of gold, as high, so it is reported at times, as $2,000 per ton, the gold probably in sulphides. To save this, after passing the burlap, the matter comes in contact with strong magnets placed in the circumference of a cylinder, the iron adhering to the magnets, from which it is removed by a revolving brush, the non-magnetic matter passing on to a revolving screen, where it is reduced to $\frac{1}{16}$ inch, preparatory to being run over amalgam plates, such as are used in stamp mills, or into a series of boxes filled with quicksilver. By this time all collectable gold will have been saved, and, after being run through traps to save any stray amalgam or quicksilver, the now unproductive material will pass into a tailings well and be taken up by an 8-inch centrifugal pump and deposited far behind the boat. Fine sand settling in the riffles of the sluices or burlap will be treated with cyanide. Depressions in bed rock the dredge cannot reach will be reached by the air caisson and bed rock thoroughly cleaned.

Another plan suggested is to raise the material and water for sluicing with a centrifugal pump to the amalgamating plant placed on the bank. Large stones and gravel from the screens will be deposited in the excavation back of the workings and the fine tailings, sluice, and surplus water will be conducted down the river by flume a sufficient distance to prevent its return. This plan will enable the bed-rock depressions and crevices to be cleaned by hand at less expense than by dredge or caissons. The water flow of the river will not exceed 10,000 gallons per minute during 10 months of the year. So no great capacity of pumps will be needed. The natural conditions have made the Galisteo River a promising placer proposition. The extent of its gold deposits can only be conjectured.

CHAPTER XX

THE GOLD AND SILVER ORE DEPOSITS OF THE MERCUR DISTRICT, UTAH

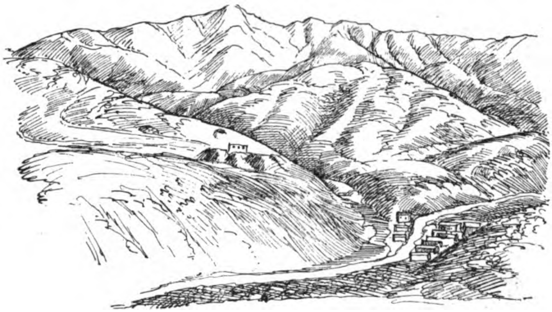
For our information on this district we are indebted to the valuable reports of the United States Geological Survey, by Mr. S. F. Emmons and Mr. E. Spurr. From the base of the Wahsatch Mountains on the east to the Sierra Nevada on the west, is an arid region called the Great Basin, because it has no external drainage to the ocean. This was once occupied by two large fresh-water seas, represented now by only small salt lakes. The Basin consists of broad level valleys 6,000 feet above the sea, intersected by mountain ridges called the Basin Ranges. The Oquirrh Range, in which is the Mercur gold-mining district, is the first of these ranges west of the Wah-

Mercur Basin, Looking South, Mercur Hill on the Right.

satch, about 13 miles from them. The Great Basin is an arid, sage-brush desert. A few small streams are in the Oquirrh Range, but insufficient for mining purposes. The range is 30 miles long, culminating in Lewiston Peak, 10,628 feet above the sea.

Utah has hitherto been celebrated more for its silver than gold products. Hence the importance of the gold-mining district of Mercur.

Bingham Cañon, Ophir, Stockton, Camp Floyd, and Tintic have all been noted more for their silver than their gold. The Oquirrh Mountains are composed of Carboniferous limestones and quartzites, compressed into a series of complicated folds, accompanied by metamorphism and injection of porphyry sheets and dikes, with subsequent mineralization in the more disturbed districts. The Lower Carboniferous limestone of Lewiston Cañon is the ore-bearing horizon of the Mercur district. On the north side of Ophir cañon an arch of Cambrian quartzite has been uplifted by a fault. There are no large exposures of eruptive rocks, such as result from eruptive overflows, but rather narrow dikes and intrusive sheets. In

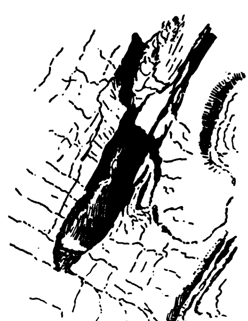


MERCUR BASIN, LOOKING NORTH, MARION HILL IN LEFT FOREGROUND.

Bingham Cañon the ore occurs only in the vicinity of porphyry bodies that occur there. In the Mercur district the igneous rocks are in thin sheets, parallel to the stratification, and beneath these sheets the ore deposits occur. There have been two distinct periods of mineralization. During the first the silver ledge was formed; during the second the minerals of the gold ledge were deposited. In both cases the ore was deposited along the lower contact of a porphyry sheet, where a porous or brecciated zone has been formed by intrusions of igneous rock, which the mineralizing solutions reached through fractures or fissures extending downwards from the respective sheets. The principal vein materials of the silver ledge are silica, barium, antimony, copper, and silver, brought up by ascending hot solutions as sulphides and sulphates. They were deposited in the contact zone below the lowest porphyry sheet, and occasionally above it. The limestone in this zone is replaced by silica. The fissures through which the mineral solutions ascended have since been filled with calcite.

There are two kinds of quartz porphyry. The Eagle Hill porphyry is a light, white rock, like Leadville white porphyry; the bird's-eye is gray, and speckled with hornblende, mica-quartz, and feldspar crystals. Two ore-bearing beds or zones 100 feet apart occur near the middle of a great series of limestones. The lower bed is of a dark silicified quartzose limestone, brecciated and porous, carrying silver, copper, and antimony, but no gold. It is called the Silver Ledge. The upper zone, called the Gold Ledge, is of decomposed, bleached red or yellow limestone and shale containing realgar and cinnabar, with low but uniform percentage of gold.

The Silver Ledge, owing to the hardness of the rock, causes it to stand out as a distinct ledge, and is easily followed, but the Gold Ledge of softer material could only be traced by a slight ocherous appearance in the rock. The gold is invisible. Certain beds supposed to be clay or shale in the mine proved to be altered sheets of white porphyry. Three of these were traced on the ore-bearing zone, and revealed the oft-observed connection of igneous rock and ore deposit. The vein materials of the gold ledge are realgar (sulphide of arsenic), cinnabar, pyrite, and gold; with these are barite, calcite, and gypsum. The deposits occur at the intersection of zones of fracture with the lower contact of the middle of the three porphyry sheets, reaching a thickness of 20 feet. Some of the fissures are still open, showing no evidence of filling or erosion by circulating waters. (See illustration of Silver Cloud Mine.) These fractures cut across the Silver Ledge and, as a rule, do not extend above the Gold Ledge.



NATURAL OPEN FISSURES IN THE FACE OF THE DRIFT OF THE SILVER CLOUD MINE, IN SILVER LEDGE, MERCUR.

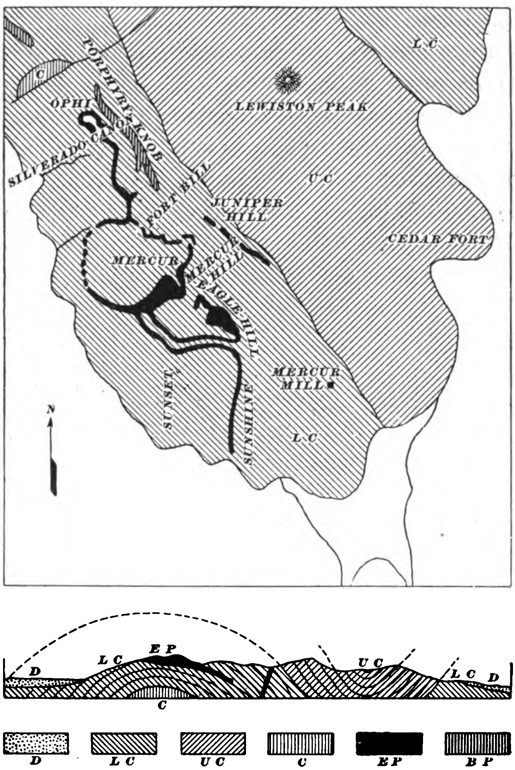
The section of the region is as follows:

1. Blue-gray, Lower Carboniferous limestone, occupying the bottom of the cañons, 200 feet thick.

2. Interbedded limestones or calcareous sandstones, 600 feet.

3. Thick blue-gray limestone, 5,000 feet thick, containing thin strata of water-bearing shale, and in its lower portion it carries the ore horizons.

4. Above this again, more limestones and sandstones, 5,000



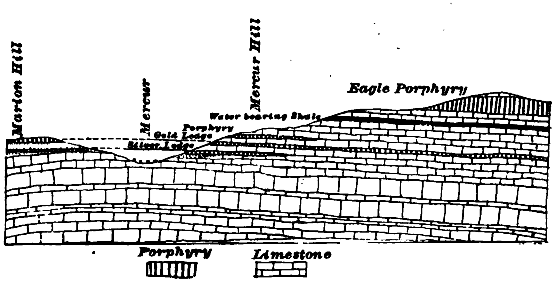
MAP AND SECTION OF THE OQUIRRH MOUNTAINS.

D, Drift; *L C*, Lower Carboniferous; *U C*, Upper Carboniferous; *C*, Cambrian; *E P*, Eagle Hill Porphyry; *B P*, Bird's-eye Porphyry.

feet thick. So in Mercur Basin a total thickness of 12,000 feet of strata is exposed.

As the hills around Mercur are not covered by drift, it is easy for the prospector to trace the line of contact between the eruptive porphyries and sedimentary rocks. The zone can generally be identified by fragments lying on the surface. In the weathered limestone rock, chips are of the typical dark-blue color, while those of porphyry are yellow, brown, or green. On a bare hillside the line separating the two can be easily traced. The bird's-eye porphyry weathers an olive-green color and the eagle porphyry generally breaks up into small blocks and chips.

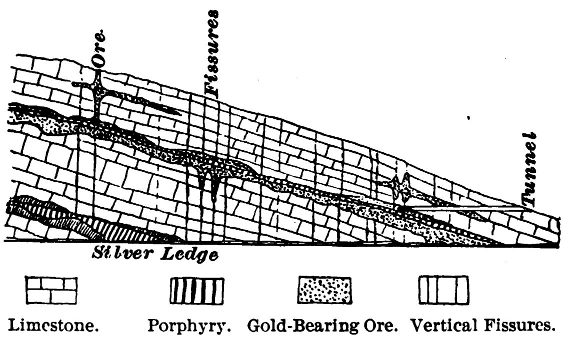
Most of the rocks in the Mercur Basin show traces of gold like at Cripple Creek, Colorado, suggesting a widespread mineralization. The porphyries showed the highest traces and the limestones the least. Pure white calcite veins, unconnected with the main mineralization, showed small quantities of gold. Certain localities are so greatly mineralized as to furnish profitably-worked bodies of gold and silver ore. These localities are at



GEOLOGICAL SECTION OF MERCUR BASIN.

the contact of porphyry sheets with enclosing limestone. In localities only is this contact line rich. In one group the limestone is hardened at contact with the porphyry into what miners call "black quartz," showing silver chloride, antimony, copper carbonate, and barite. In the other groups, limestone and porphyry are decomposed into a soft black shaley substance. The first group contains silver, the second only gold, together with arsenic and cinnabar. The one is the Silver, the other the Gold Ledge. The rock forming the contact of the Silver Ledge is much broken or brecciated, the fragments composed of cherts and silicified limestone, inclosed in cement of white calcspar and barite. The greater erosion of the softer porphyry leaves a distinct shelf or ledge 20 feet wide.

In the limestone below the ledge are many vertical calcite veins, formed by the intrusive action of the porphyry, as was also the breccia or broken element in the ledge, and the interstices were healed by solutions of calcite. Hardening and darkening of the limestone are noticeable at this upper contact for 3 feet. Three sheets of porphyry are developed on the hill, one 20 feet thick, associated with the Silver Ledge, and the lowest; above this a smaller sheet, much decomposed, associated with the Gold Ledge; and above this a third unmineralized. At the bottom of the Silver Cloud mine are many open fractures without vein filling, indicating the action of faulting. They were later than the vein filling of the Silver Ledge. Large geode cavities lined with calcspar crystals occur in the vein, together with a network of calcite veins; bunches of barite, stains of green malachite and azurite copper occur, and a good



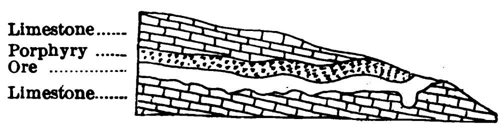
GEOLOGICAL SECTION OF PART OF THE MERCUR MINE.

deal of kaoline in crevices. The open fissures show their later origin by cutting through all these. The softer and decomposed porphyry is actively prospected for gold.

A black, flinty, impure quartz accompanies the ore. Changing of the limestone into a quartz-like condition was one of the first stages of metamorphic action. The quartz is generally this "horn," or flinty amorphous quartz; crystals are rare. The latter occur in irregular cracks and cavities produced by solutions. The honeycombed nature of the rock is what mainly shows the intensity of the action accompanying mineralization.

The calcite veins are generally barren. Baryte or heavy spar is closely associated with the ores, occupying irregular spaces in the rocks, and is a sure sign of considerable mineralization. Baryte often forms the gangue in which the ore is imbedded. Antimony occurs in radiating crystals and bunches. Copper stains are associated with the silver. "Chinese talc," or gouge, a clay resulting from decomposition of the porphyry, occurs, as at Leadville. The silver ore consists of small films of chloride of silver, disseminated through altered silicified limestone.

Mineralization has taken place at the contact of porphyry and limestone. From this it extends into the limestone, away from the porphyry, mineralization decreasing in force as it recedes from the line of contact. (See illustration below and on page 247.) The mineralizing agents were heated waters, circulating along the contact, containing silica, barium, antimony,



SECTION ALONG GEYSER TUNNEL, MERCUR.

copper, and silver. The work of these solutions was the leaching out and removal of lime and replacement of it by silica, without destroying the original features of the rock. Quartz in the vicinity of eruptive rocks is apt to accumulate in compact, crystalline masses, or in a flint-like jaspery or chalcedonic condition, and the silicifying of the limestone at contact with porphyry at Mercur is only a natural and common result of metamorphic action.

Water contained in lavas is not given off till just at the moment of solidification of the lava, when it is separated out and appears as a fluid. When this solidification takes place at the surface, it forms clouds of steam, so generally visible on cooling lavas, but when the lava is forced in, in a molten state, underground between strata, the water is still under sufficient pressure to keep it in a liquid state. From this result, intensely heated solutions arise, capable of much corrosive effect on the rocks and of aiding ore solution. These solutions act most violently at the contact, and become rapidly cooled on penetrating the adjoining rock.

The phenomena at the Silver Ledge indicate brief intense action, highly heated waters, with great metamorphosing and corroding power. The mass is full of cavities showing this. The barium found in the Silver Ledge was derived from the porphyry, as probably were the metals, which were deposited, as at Steamboat Springs, Nevada, by ascending hot solutions. These exuding at every point in the cooling porphyry, found in the limestone a zone where the passage of solutions was easy by opening of fissures and formation of breccias. The heated waters under great pressure would move along this broken weak zone, as also occasionally in an upward direction. Where porphyry sheets cut across the strata, water would rise rapidly. Where circulation was retarded, accumulation and mineralization would be greatest. In the case of the Gold Ledge, the mineralizing agents were probably more in a gaseous than a liquid condition. The various metals, antimony, cinnabar, etc., found associated with the gold, are such as would easily pass into the state of vapor and be the last deposited. After the eruption of the porphyry, a disturbance brought about a set of vertical fissures establishing a communication with a body of uncooled igneous rock at an uncertain depth, affording a vent for moist volcanic vapors ; and along the porous zone at contact of porphyry and limestone, and in the brecciated limestone, the vapors spread out, and, becoming cooled, deposited the gold and associate minerals.

The Gold Ledge is a mineralized zone in the lower part of Mercur Basin. It consists of an altered limestone following the under contact of a thin sheet of altered porphyry. The thickness of the contact zone varies from 20 feet down to nothing. The lines of greatest mineralization coincide in direction with a set of vertical fissures forming shoots or channels.

The ores are oxidized or else sulphides. The former are extracted by the cyanide process, the latter by roasting. The zone is soft and pulverulent, and full of cherts. The amount of gold in the ores rarely exceeds 3 ounces to the ton. Silver is absent.

CHAPTER XXI

SALTING MINES

IN THESE days when, owing to the depression of silver, so much attention is being turned towards gold and gold mines, too much care cannot be taken by those investing or acting as examiners or experts in gold mines, that there are no tricks played upon them by the astute miner; for "for ways that are dark and tricks that are vain" the Western miner is at times "peculiar." One of these tricks is what is known as "salting" mines or ledges; that is, by various means and ways introducing into the mine, or into the samples taken from it, certain rich minerals that do not rightly belong by nature in the mine or property, in order to raise the value of the mine in the eyes of the investor or expert. When samples are taken from such a tampered-with mine, the values and results must be accepted *cum grano salis*—indeed, with a very large grain of salt. Whether this classical allusion is the origin of the word "salting" we do not know.

"Take care you ain't salted," is the advice to the inexperienced investor or novice expert. So clever are the miners that cases are on record where even a most experienced expert has been taken in, and comparatively or wholly valueless properties sold for large sums, the purchase followed later by woful dismay and surprise when dividends were called for and did not appear.

Gold mines, of all others, are the most easy to salt, hence the precaution in these days is timely.

While a mining engineer or expert can hardly prevent salting, with care he can and ought to be able to avoid being taken in; to be forewarned is to be forearmed.

On entering a mining camp in the far West, especially in the more remote outlandish districts, an investor or an expert may consider that the whole village, from the hotel bell boy to the mayor (who, by the way, may be the principal saloon keeper), is in league against him. Directly he arrives, everybody in town wants to know his business; on this he should keep as mum as possible, and, if he can, throw impertinent inquirers off the scent. The idea is, "Here is a capitalist to fleece and an expert to delude." Every one, too, has a "hole in the ground" of his own to present. Should they get wind of the particular property in view, there are confederates and middlemen anxious to share the spoils. Moreover, it is considered to the general credit of the camp to sell a mine, be it whose it may, good or bad, and if you mention any property, you will invariably hear it "cracked up." The Eastern "tenderfoot" is somewhat of a "sheep among wolves" in such a camp. The expert, too, is at a certain disadvantage on entering into a strange mining camp, not being familiar with the local conditions. Ores, for instance, in one section or region are not always of the same value as similar ores in another; the rocks may look new and strange to him, and there are a hundred local conditions known only to the resident miner. It would be well, when possible, for an expert, before passing a decided opinion on an important property, to stay around in the vicinity for a while, till he knows the "hang of things."

On his way to the mine there will be plenty to fill his ears with the untold value of the property he is about to examine; this friendly duty is not unfrequently performed by an officious middleman. To favor and "soften up" the expert's mind and heart, and make him "feel good" towards the property, attentions of all kinds are showered on him. He is driven about town like a nabob, and if he shows a weakness for a "wee drappie," champagne and whiskey are at his service *ad libitum*, as judicious preparation for the coming examination. It may be observed here that attempts are made sometimes to "salt" the expert as well as the mine, not merely by befuddling his brain with intoxicants, but by offering bribes, and as an expert is often not too well off, the latter is a great temptation.

We will now suppose, after this ordeal, he goes to the mine with the superintendent or miner. All may be, and we may say generally is, honest and square, or it may not. The expert looks over the exterior and surface signs of the property, studies the outcrop of the vein on the surface, its probable surface continuity, the advantages and disadvantages of the situation of the mine, its proximity to railroads, smelting works, markets, etc., and then enters the mine in company with the miner. As a rule, the latter will naturally point out to him the richest portions and ignore the poorer; sometimes he excuses himself from taking him down into the latter because it is dangerous or full of water. If full of water, the expert, if possible, should have it pumped out. He may suggest, here and there, that such and such a spot would be a good one for the expert to take his samples, and so forth. The expert of course assents to all he is told, but with both eyes open, and does not stop to take any samples for assaying until he has seen the whole of the mine; then he requests his companion to go out on the dump and smoke his pipe there, as he insists upon having no one with him in the tunnel when he is taking his samples for assay. He will be inclined to rather avoid those particularly favorable spots suggested to him by the miner, as probably giving too rich an average for the general run of the mine, or as not impossibly being "fixed" for him. If he suspects the latter, he will take a sample or two to see if the mine has been tampered with, taking a little of this out on the dump, crushing it, and washing it in an iron spoon. If a very astonishing amount of gold colors show up, his suspicions are aroused. The judicious miner does not generally want to salt too heavily, for fear of the enormous results exciting suspicion, but despite his care, he nearly always salts a little higher than he intended. In a mine where the rock is hard, a miner may salt by drilling holes and inserting mineral or ore and disguising the hole. In loose ground, or one full of cracks, a shotgun loaded with a moderate charge of gold dust will do the work. The skill of the miner in this case lies in his choice of a spot where he thinks it probable the expert will take samples, or in coaxing the expert to take samples from such ground. In hard ground, the expert may avoid such salting by having the work blasted out in his presence till a purely fresh, virgin face is shown, and then taking his sample. These precautions are not necessary under all circumstances, but only in cases where the expert has a suspicion that there is an attempt to "put up a job" on him.

After getting his samples, and as many as possible, he will sack and seal them then and there in the mine, and never lose sight of them until he has expressed them to his own home.

Sometimes a mine is so timbered up that sampling is difficult. Now, as they go down the shaft, it may be the expert remarks, "I should like to take a sample in this shaft, but it is so timbered up that I don't see how we can do it without ripping out some of these boards." "Why, of course, so you oughter," says the miner, "and see here, I think this board is loose." Now beware lest that board was purposely loosened and that behind it the ground is salted.

By taking a great number of samples at comparatively close intervals, provided afterwards the samples are not tampered with, the expert is less liable to be deceived by salting than if he took very few. A mine cannot be salted all over from end to end if it is a large one, but only at judicious intervals, and it will be hard if the expert does not escape some of those intervals and get some true samples.

Besides taking his regular assay samples by cutting all around the walls, roof and floor of the tunnels, at intervals of 5, 10, or 20 feet, according to circumstances, crushing and quartering the débris, and finally sacking and sealing his sample bags, he should occasionally take a "grab sample," or a bit of rock at random, or a small sackful from the great mass of his samples, and put them in his coat pocket, and keep them on his person, to act as a reference in case of any possible tampering or accident to his samples while in the vicinity or in transit. He should also take bulk samples, good-sized chunks of uncrushed rock, which should agree with the assay results of his quartered samples.

A disadvantage an expert is under in a strange camp, if he cannot take his own assistant with him, is that he is very much at the mercy of the miner, if any hard work has to be done, such as blasting or hard digging. While engaged in such work the miner, if he pleases, has many chances of scattering around a little gold dust on the rock of the vein or the loose dirt of a placer.

While gold dust is the favorite medium for salting a gold mine, chloride of gold is sometimes used. The latter, however, is rather a dangerous and barefaced trick to try on a competent expert, as its quality can readily be detected by the chemist, it being soluble in water. In a case of this kind that came to our knowledge, an experienced expert had examined a certain mine and condemned it. Later, the owner, who was an honorable man, asked him if, as a special favor, he would reexamine it, as in his absence the assay values from the mine had of late shown much better results. The expert reluctantly consented to do this, though contrary to his general rule. In going along the workings, he noticed here and there on the walls certain patches and streaks of clay or mud he had not observed on his first visit. Guessing what they were, he casually observed to the miners, "Seems to have been raining in the mine since I was here." However, to the great delight, doubtless, of the miners, he took several samples of these, and forwarded them to a reliable chemist. The latter pronounced them chloride of gold. This of course gave the salting scheme away, as chloride of gold does not occur free in nature, much less in a mine. The owner of the mine was exceedingly angry when he learned what the miners had done without his knowledge or connivance. The men themselves being commonly more or less interested in the sale of a mine, are apt to try and salt it without any connivance of the owner or superintendent. We heard of a case in the San Juan district where a mine that was fairly good was about to be examined. This mine carried occasionally specimens of the very rich ore called ruby silver. Not satisfied with the fair, natural richness of the mine, the miners must needs import into the hole quantities of ruby collected from other mines in the district, whose men were of course in sympathy with the scheme and probable sale. This was acting without the knowledge of the owners.

SALTING GOLD PLACERS

Although a gold placer usually covers a very large area of ground, it is possible to salt it. Usually a miner shows up his placer by opening up pits at convenient intervals, so as to cover the property. Nothing is easier than to salt these pits with gold dust. Consequently, while an expert will examine these holes and pan the dirt, he should be on his guard, and insist, where possible, on holes being freshly dug in his presence. Even then he is not safe. Generally in a placer, by the cutting of a stream, sections are shown sometimes from grass roots to bed rock. From such he should take and pan samples at different levels in the exposure; this, too, privately, and without too much supervision of the interested miner.

SALTING ASSAY SAMPLES

This may be done in several ways. If the expert is imprudent enough to allow a miner to accompany and assist him in breaking down or crushing samples or panning them, then the infusion of a little gold dust is easy. Again, after the expert has made up, sacked, and duly sealed his samples with wax, should he leave them anywhere within reach of the miners, they are not wholly safe, for the miner may insert the point of a fine syringe containing gold dust into the bag, or he may make a bread mold of the wax seal, open the sacks, and either change the ore for richer, or infuse some gold dust. Changing of samples for others is not an uncommon trick. The expert cannot watch his samples too closely. He should sack and seal them on the ground, sleep with them under his pillow, if need be, at night, yet even then cases have been known when the wary miner has succeeded in extracting and changing them for bags to all appearance exactly similar. The samples are never safe till boxed up and expressed and on the way to the city address. He should never fail, as we have said, to have partial duplicates of these about his person.

If the expert wishes to assay the ore at a friendly assay office near the mine, while he is grinding down his sample to dust, an innocent looking miner may loaf in, and while watching the operation, accidentally upset the ashes in his pipe over the sample. Probably these ashes contain gold dust, and we might here observe that a single grain of gold smaller than a pin's head may materially alter the results of an assay.

Some years ago an individual, who had succeeded in booming a certain placer district and getting up an excitement and a rush, constituted himself as a referee and professor; and when miners brought samples for his inspection, they were always found to be very rich in gold. But similar samples from the same spot, if uninspected, were somehow invariably barren. The wizard's mere look seemed to change the sand into gold, until it was found that he concealed in his finger nails "which were taper" not wax, but fine particles of gold. Hence, Midas-like, whatever he touched he turned into gold. While the salter may lay traps for the expert, the expert may sometimes lay traps for the salter. An expert, who had reason to suspect a certain mine he was examining had been tampered with, and guessing there was a likelihood of an attempt on his samples, after securing himself with duplicates, left his samples exposed on the floor of his room at the hotel, then went out and hired a reliable Mexican boy to watch his room and report to him immediately if he saw any one enter it. He had not long to wait. At dinner the boy tapped him on the shoulder, and he went to his room and caught the miner in the act of tampering with his samples.

Sometimes miners, if wealthy enough, will go to great expense to salt a property. Some miners took a couple of well-to-do eastern capitalists to a certain placer, panned the gravel before their eyes and showed up wondrous colors. The investors having been warned of miners' ways, refused to entirely swallow the bait, but told the boys to go ahead and develop the property, and if, at their next visit, it showed up as well as the pans did on this occasion, they would buy it. When the easterners were gone, at a cost of several thousand dollars they built a flume, put in a hydraulic plant, and gathered a pile of loose dirt to wash down the flume, where the gold is gathered upon quicksilver. The "sharks" raised $50,000 for a gold dust fund. This dust was run evenly over the quicksilver, so that when the capitalists returned, there was everything to show an enormously rich placer ground. The capitalists insisted upon a clean-up after the first fortnight's run, which added so much more joy to the sharks. This time the bait was swallowed whole, string and all. The capitalists paid down, promptly, $250,000 for the ground. The sharks left the country. In a few weeks nothing could be found but the amalgam of the sharks.

An ingenious trick once baffled some experienced experts and came very near selling a mine. The mine was a well-developed one and had done great things in its day. It was claimed that at the face of the tunnel, or where the workings left off, there was still a fine showing of ore in place to go on with. The experts found it as stated; on the face or end of the tunnel there was a fine showing of ore, and the probable amount in place and for the future was duly measured up and estimated. It leaked out later that this block of ore was only a thin screen purposely left, all back of, and behind it, having been carefully worked out and the opening for the miners' ingress and egress skilfully concealed. The mine was reexamined, the cheat discovered, and the reputation of the experts saved as well as many thousands of dollars from the pockets of guileless investors.

This brief sketch of some of the ways of some miners, for some regions and properties, would give an unfair idea of mines and miners as a whole, if it were supposed that all miners are given to salting, and all properties for sale are beset by a network of dishonest devices. On the contrary, many, very many, miners are "as straight as a string," and hundreds of properties are to be examined without fear of tampering. But it often happens that a miner, who in every other relation of life is as honest as the day, draws a line, when it comes to selling a mine to what he considers "fair game."

But, as elsewhere the world through, honesty pure and simple is the right policy, and in the end would be found the best paying one, for the notorious dishonesty connected with mines (much more common in the past than in the present) scares away capitalists from investing, while if truth and honesty were maintained, money would roll in freely.

One lesson at least may be learned from what we have said, and that is, that if in some cases a professional expert even is taken in, what chance has a capitalist, ignorant of mines, to buy a mine on his own examination? What man, ignorant of horse flesh, would venture to buy a steed from a professional horse jockey, without taking with him a friend who is knowing about horses?

How much more so in such a difficult and delicate problem as that of purchasing a mine, is it the duty of an investor never to purchase or induce his friends to purchase a mine, until he has employed the services of a competent expert to previously examine it. If the expert's fee should amount to a few hundreds, and after all he should decide on condemning the property, it is far better for the company to entail this expense, and perhaps lose this small sum, than to involve themselves in the loss of thousands of their own as well as other people's money in a bogus, worthless, or "wildcat" scheme.

CHAPTER XXII

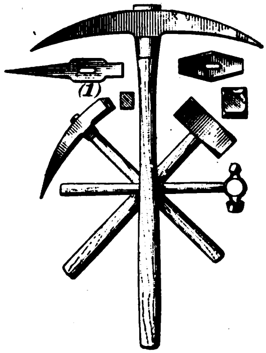
PROSPECTORS' TOOLS AND HOW TO SHARPEN AND TEMPER THEM

THE principal tools a prospector takes into the field are picks, drills, hammers, and shovel.

A prospector, especially when climbing mountains, likes to be as light-handed and unencumbered as possible.

For his trip as a whole, he may carry several different tools packed on his donkey, but when he has arrived at a locality, the vicinity of which looks likely, he leaves most of his heavier tools in his temporary camp, or near to where he pickets his pack animal. He makes a short excursion up the mountain for a general reconnoiter, armed with nothing more than a light prospecting pick, weighing not more than three or four pounds. This little pick is about 10 inches in length, with a handle about 15 inches long; the longer portion is sharpened into a pick, and the shorter ends into a square-faced hammer. We recommend a square, sharp-cornered face to the hammer, in preference to the beveled face, as the sharp edges and corners are better adapted for breaking rock than the rounded or beveled ends. This prospecting pick, or geological pick, and hammer, should be all of good steel, with a good-sized eye, to admit a springy handle of hickory. (See *1*, *1*, *1*, page 259.)

Armed with this little weapon he climbs the hillside, hunting for "float" or for rusty outcrops of ledges. Loose pieces of rock he cracks open with the hammer end, softer rock in place he explores with the pick. "When I am climbing over the hills," said an old weather-beaten prospector to me, "I want nothing but my little pick; then if I find anything likely 'in place,' I mark the spot, and go on, and at noon I come down to camp, or to where the 'burro' is feeding, and take up my heavy digging pick and shovel and 'open up.' This will occupy me till evening at least; then if I find there is a ledge worth more thorough exploring, I leave my tools by the hole, and next morning bring up the drills, hammers, and blasting outfit. But the first thing I would advise a tenderfoot, is to *get his eye trained*, trained to looking for float and observing mineral signs—trained to the whole business of close observation. Why, I myself, old hand as I am, after being away for some months about town, or looking at other things, can't get my eye in and down to it for two or three days; then it kind of comes natural.



PICKS AND HAMMERS.

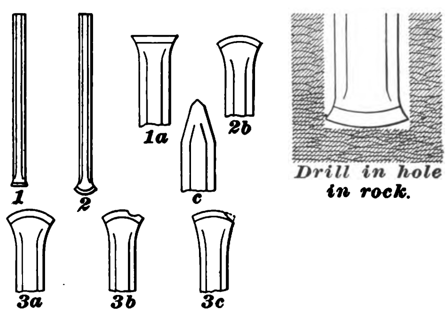
"You must have an eye for float and rocks like an artist has an eye for color, and a musician an ear for music. A tenderfoot had better go along with an old hand for a few days, to get into training."

DESCRIPTION OF TOOLS, PICKS, AND DRILLS

Picks and drills are the main tools that need sharpening and tempering. The kind of sharpening and nature or degree of tempering depend upon the kind of work or kind of rock to be worked, whether hard or soft, loose-grained or fine-grained, silicious or clayey. Drills, for example, would have to be differently sharpened and tempered for hard vitreous quartzite than for soft sandstone or hardened clay. The same remark applies also to picks. Picks may be double or single pointed, or with a hammer head called a poll, if it is to be used for breaking rock. The main points of a pick are, strong cutting tips, stout eye, and a tight handle. The little prospecting pick is made of the best steel throughout, but in the heavier pick, the wearing parts are the tips, which should be replaceable. An all-steel pick is liable soon to be shortened up and useless, while the iron pick eye, a 14-inch length of best iron, gives long service by welding on tip ends, whenever desired. Professor Ihlseng, in his "Manual of Mining," as also Mr. George Andre, in his book on "Rock Blasting," gives excellent descriptions of tools used, as well as the mode of sharpening and tempering them; to them we are indebted for many of the details of this article, and to their works we refer the reader for further information on this subject. "The picks are sharpened to form on an anvil, and commonly drawn to a four-sided pyramidal point, for hard rock, and a slim taper for fissured rock, and a bluff taper to cut crisp ground, and to a chisel end for chipping the ground. The eye is oval and well surrounded with metal. All the strain of the prying falls on the eye, which must be true and stout.

DRILLS

"The drill is a bar which has one cutter end and one hammer end. It is of round or octagonal steel. Drills may be of various lengths, from 1 foot to 4 or 5 or even more feet. For prospecting purposes two or three medium short drills, from 2 to 4 feet, are generally enough, as the prospector's business is rather to find than to develop. In beginning to drill, it is common to use a short, thick drill, with a stout 'bull edge' rather than a thin, tapering one, especially in hard rock; smaller sized, i. e., narrower drills, may be used for increasing depth.



FORMS OF DRILLS.

"The rock drill consists of chisel edge, bit, stock, and striking face. To allow the tool to free itself readily in the bore hole, and to avoid introducing unnecessary weight on to the stock, the bit is made wider than the latter. In hard rock, the liability of the edge to fracture increases as the difference of width; the edge of the drill may be straight or slightly curved—a straight edge cuts more freely than the curved; a bull bit for hard rock is generally curved—a straight edge is weaker at the corners than the curved. The width of bits varies from 1 inch to $2\frac{1}{2}$ inches. On page 260, *1*, *2*, *1a*, and *2b*, are the straight and curved bits and angles of cutting edges for use in rock. The stock is octagonal in section. It is made in lengths varying from 20 inches to 42 inches. The shorter the stock, the more effectively it transmits the force of the blow. To insure the longer drills working freely in the hole, the width of the bit should be very slightly reduced in each length. Diameter of stock is less than the width of the bit, generally by $\frac{3}{8}$ of an inch.

"The smith cuts up the 'borer' steel bars into desired lengths to form the bit; the end of the bar is heated and flattened out by hammering to a width a little greater than the diameter of the hole to be bored. The cutting edge is then hammered up with a light hammer to the requisite angle, and corners beaten in to give the exact diameter of the bore hole intended. The drills are made in sets, and the longer stocks will have a bit slightly narrower than the shorter ones, for reasons already given. The edge is touched up with a file. Heavy hammering and high heats should be avoided. The steel should be well covered with coal, in making the heat, and protected from the raw air. Overheated or burned steel is liable to fly, and drills so injured are useless until the burned portion has been cut away. Care is required to form the cutting edge evenly, and of the full form. If the corners get hammered as at *3a*, in the figure, they are said to be 'nipped' and the tool will not free itself in cutting. When a depression of the straight or curved line forming the edge occurs, as at *3b*, the bit is said to be 'backward,' and when one of the corners is too far back, as at *3c*, it is spoken of as 'odd-cornered.' Either of these defects causes the force of the blow to be thrown upon a portion only of the edge, which is thereby overstrained and liable to fracture."

SHARPENING TOOLS

Professor Ihlseng, in his "Manual of Mining," says: "The best fuel for blacksmithing may be a slightly caking coal, giving flame and high heat. Coke is hotter, but harder to keep fire in. The fuel should be as free from sulphur as possible. White-ash coal is better than red-ash; sulphur makes the iron "hot short," and tends to produce scales. The coal should be clear of shale or slate, for they fuse and make a pasty cinder that is annoying."

A prospector away from civilization may have to use wood; in that case he should use chips, and blow them with a portable bellows.

The prospectors who try to get along on as small an outfit as possible usually take one to three blasting powder cans and cut the heads out of all but the bottom one, and one head of that must be cut out; these they place one on top of the other, to make a furnace. They punch an inch and a half hole in the side of the bottom one, at the bottom, for a draft, and to put in the points of the tools to heat them.

They use charcoal for fuel, and a chunk of steel or railroad iron about 6 inches long serves for an anvil. Some take a small bellows and anvil with them. For tempering drills they give the drill, when red, a plunge in water. After two or three rubs on wood, to brighten it, they hold it up to the light and watch it until it takes on a straw color. Then they dip it in water again. For picks, a blue color is the most satisfactory in general.

"Steel is a compound of iron and carbon, and its homogeneity and presence of carbon impart to it a capability of hardening and tempering to a degree depending on the temperature of the heating and subsequent cooling. As the amount of carbon increases, the melting point of the iron decreases, and this greater fusibility reduces its welding quality.

"A steel is called 'hardened' when it has been suddenly cooled and thereby become as hard as possible. This is owing to the presence of carbon, for pure malleable iron is not affected by the operation, while both steel and cast iron are to a marked degree.

"The operation consists in heating the steel to a certain degree of temperature, and then plunging it into some fluid which abstracts the heat from the tool. The quicker it is done, and the greater the difference of temperature, the harder is the tool. Either water or oil is used; both volatilize at a temperature much below that of the immersed tools, so the hardening takes place in a vapor; oil generally produces the best effects.

On the first plunge the metal is chilled and coated with soot, after which a slow process of cooling takes place.

TEMPERING

"Tempering follows hardening, whereby the steel is subjected to a subsequent lower heat, which softens it, and removes its brittleness. When the hardened steel is slowly reheated, its surface gradually assumes phases of color, beginning with a light straw, passing through shades of yellow, brown, purple, blue, and red. At a cherry-red heat, the original color before hardening, the effects of the chilling are practically removed.

"Tempering consists in carrying the second heat to one of the above mentioned colors, according to the amount of the brittleness to be annealed. This depends upon the use to which the article is to be put. A second stage of the operation finishes the job. The aforementioned reheat goes on a little way beyond the desired color. The tool is carefully plunged part way into the water or oil, till the disappearance of the steam indicates that it is cold, when another portion of the tool is further immersed for a moment. The tool is withdrawn, the scales rubbed off and the heat of the remaining portion draws to the edge, until it has assumed the proper tempering color. It is then thoroughly cooled. The idea that the steel is cooler at a blue, than at a yellow, in final drawing, is erroneous, for more of the heat is conducted from the red portion to the point than it radiates to the air, and the first heat to the edge only gives a yellow; with more, it becomes purple, and so on. Hardened drill and pick points are treated in this way, 4 inches of the end being heated to a yellow; and, in thirds, the tempering is proceeded with as above.

"Care should be taken that the plunged tool, while tempering, be not held too long a time at a certain color line, as it has a tendency to break at that point. The tool should be slightly waved in the water. 'Pieces' which are to be tempered throughout, must be allowed to soak, i. e., become uniformly hot, before plunging.

"The proper color for a given ground is only ascertained by experience. Generally speaking, the picks and drills are stopped at a 'straw,' if intended for hard ground; at a blue, for mild ground. The toughness of the steel should be preserved as much as possible; therefore select the lowest color compatible with the service to be performed. A high carbon steel is given a lighter color than steel of low carbon.

"A pick is made of a square iron bar 14 in. × 1¼ in., heated at the middle, and then struck endwise, till about 1½ inches across. This spot is softened, and at red heat cut open, and swelled by a drift to form the eye. It is then slit at the ends, and softened, while a 6-inch length of pick steel is being heated. When ready, this steel is tongued into the iron, and hammered. A reheating with borax, and a hammering, complete the weld, after which the picks are sharpened and tempered; no signs of the weld should be visible."

"Pick steel" is a special steel that can be had in bars 1¼ in. or 1½ in. × ⅝ in. or ¾ in., and is used only for tips.

Steel bars for drills come in lengths of about 14 feet each, and from ⅝ inch to 2 inches in diameter. The American "Black Diamond" brand is a favorite. The bars are cut into pieces as long as can conveniently be used, e. g., 30 inches and 36 inches. The bits are wider than the tool, to prevent it sticking to the hole. They are widened according to pattern, so they can "follow" well. The first drill has the widest bit; the followers narrower ones. In hard rock, the flare is smaller than that in soft rock.

"The temper is a lighter color for hard than for soft rock. If the edges of the returned drills are cracked or broken, the steel is too brittle, and should be made softer or other coal used. If the edges blunt much by wearing round, they are all right, though a harder temper may give them a longer life. Cast-steel borers are never heated above a cherry. They are annealed at the striking end."

PRACTICAL SUGGESTIONS AND POINTS BY A BLACKSMITH

A prospector must have something to act as an anvil; a hard pebble won't do—he can carry a small anvil or a chunk of railroad iron. A small hand bellows, or even a portable forge, worked with a crank, will make his outfit complete. The following practical hints I picked up from a blacksmith while watching him at work tempering both picks and drills for some prospectors. He said: "You must temper your drill according to the character of the rocks.

"For hard rock, use a short, thick-edged 'bull bit,' which will stand a high, brittle temper, such as 'straw.' For picks, a light-blue color is a good temper, rather than 'straw,' which is too brittle. Cherry-red is the heat of your bar, not hotter; laying this on the anvil and hammering it well, all over, gives it toughness. If blisters show on the steel, you must hammer it over again. By occasionally dipping your hammer in water and then striking with it, you get the steel down to a fine grain. When you are dipping for tempering, put the point in the water; that cools the point, and the heat runs the color down to the cool point; when the color reaches the tint you want, then is your time to cool off quickly. The color progresses from a white or pale-straw to copper color, to blue. Copper tint is a good one to stop at for a drill; blue, for a pick. The right moment to stop and cool is just at the turning point from one color to another."

He took a piece of steel, heated it to cherry red, laid it on the anvil and pounded it lightly with his hammer all over, to toughen it by blows, occasionally dipping his hammer in the water to "water temper" it; this further toughens it, by partially cooling it. Now the bar was again put in the fire and heated to a cherry red, care being taken not to keep it too long in the fire, as that would tend to take its toughness out, or produce blisters. The bar was plunged about an inch into the water, and then rubbed against a brick, to show the colors plainer. These passed from the point upwards, gradually, through the colors we have mentioned. To arrest it by suddenly cooling off at "straw," would make it too brittle for ordinary drills, except a "bull drill." Now the "straw" turns into a copper hue, a good point to cool off for a *drill*. Now it passes into a blue; at this point it would be well to cool off for a *pick*. The edge of a drill is almost of secondary importance to the *sharpness of the projecting corners;* when these are gone, the drill is used up, and clogs in the hole. Some rocks, like sandstone, will, by reason of the quartz in them, wear off the corners very rapidly, others, like limestone or granite, less rapidly.

Another blacksmith advised me not to dip (as is commonly done) the point *only an inch* in water as it is apt in use to break at the water line, but plunge it *all over* in the water. "Who shall decide when doctors disagree?"

A prospector should take with him a regular blacksmith's hammer for sharpening, as well as the 4- or 5-pound hammer he uses for striking the drill or the rock.

CHAPTER XXIII

SOME ELEMENTS OF MINING LAW RELATING TO PROSPECTING

A PROSPECTOR would do well to acquaint himself with a few elements of mining law, so we will give a few samples of Colorado mining law for his benefit.

Extent of Lode or Claim.—The length of any lode may equal, but not exceed, 1,500 feet along the vein.

Dimension.—The width of lode claims in Gilpin, Clear Creek, Boulder, and Summit Counties, shall be 75 feet on each side of the center of the vein or crevice. The maximum width of lode claim allowed in other localities by United States statute is 300 feet on each side of the center line.

Certificate of Location.—The discoverer of a lode shall, within three months from the date of discovery, record his claim in the office of the recorder of the county in which such lode is situated, by a location certificate, which shall contain :

1. The name of the lode.
2. The name of the locator.
3. The date of the location.
4. The number of feet in length claimed on each side of the center of the discovery shaft.
5. The general course of the lode as near as may be.

Discovery Shaft.—Before filing such location certificate, the discoverer shall locate his claim : *first*, by sinking a discovery shaft on the lode, to the depth of at least 10 feet, or deeper if necessary, to show a well-defined crevice ; *second*, by posting, at the point of discovery, on the surface, a plain sign or notice containing the name of the lode, the name of the locator, and the date of the discovery ; *third*, by marking the surface boundary line of the claim.

Staking.—Such surface boundaries shall be marked by six substantial posts, hewed or marked on the side or sides of which are in towards the claim, and sunk in the ground, to wit, one at each corner, and one at the center of each side line. Where it is impossible, on account of bed rock or precipitous ground, to sink such posts, they may be placed in a pile of stones.

Open Cuts.—Any open or cross-cut tunnel, or tunnel which shall cut a lode at a depth of 10 feet below the surface, shall hold it, the same as if a discovery shaft were sunk thereon, or an adit of at least 10 feet along the lode, from the point where the lode may be in any manner discovered, shall be equivalent to a discovery shaft.

Time.—The discoverer shall have 60 days from the time of uncovering or disclosing a lode, to sink a discovery shaft thereon.

Construction of Certificate.—The location certificate of any lode claim shall be constructed to include all surface ground within the surface lines thereof, and all lodes and ledges throughout their entire depth, the top or "apex" of which lies inside of such lines extending downwards vertically, with such parts of all lodes or ledges as continue to dip beyond the side lines of the plane, but shall not include any portion of such lodes or ledges beyond the end lines of the claim, or at the end lines continued, whether by dip or otherwise, or beyond the side lines in any other manner than by the dip of the lode.

Cannot be Followed.—If the top or "apex" of a lode in its longitudinal course extends beyond the exterior lines of the claim at any point on the surface, or as extended vertically downwards, such lode may not be followed in its longitudinal course beyond the point where it is intersected by the exterior lines.

Proof of Development.—The amount of work done, or improvements made during each year shall be that prescribed by laws of the United States.

Placer-Mining Claims.—The discoverer of a placer claim shall, within 30 days from the date of discovery, record his claim in the office of the recorder of the county in which said claim is situated, by a location certificate, which shall contain :

1. The name of the claim, designating it as a placer claim.

2. The name of the locator.
3. The date of the location.
4. The number of feet or acres claimed.
5. The description of the claim by such reference to natural objects or permanent monuments as shall identify the claim.

Before filing such location certificate, the discoverer shall locate his claim:

1. By posting upon such claim a plain sign or notice, containing the name of the claim, of the locator, the date of discovery, and number of acres or feet claimed.
2. By marking the surface boundaries with substantial posts sunk in the ground, one at each angle of the claim.

On each placer claim of 160 acres, not less than 100 dollars' worth of labor shall be done by the first of August each year, and upon less or more ground a sum in proportion.

TESTING GOLD ORES

—— FOR ——

TREATMENT BY CONCENTRATION

—— AND ——

AMALGAMATION

TESTING GOLD ORES FOR TREATMENT

BY

CONCENTRATION AND AMALGAMATION.*

BY H. VAN F. FURMAN, E. M.

The various processes for the extraction of gold from ores have previously been described in detail in "Mines and Minerals."† In the present article the writer proposes to explain how a gold ore may be tested in the laboratory so as to determine whether it can be treated successfully by amalgamation or concentration, or by a combination of the two methods.

The great majority of the gold ores of Western America, and various other gold-producing regions, can be successfully treated by these methods; but the average mining man seems to have the idea that the process to be adopted can only be determined after many tons of ore have been shipped to some working mill and there treated. This method of testing an ore by a mill run presents certain advantages and is to be recommended, where it can be economically and successfully carried out, but it necessitates the mining and shipment of a considerable quantity of ore, as it is impossible to make a reliable quantitative test in this way on a few tons of material, on account of the difficulty of making an accurate "clean up." It also involves the careful supervision of an expert at the mill during the test, while the nearest available mill may be far distant, in which case the expense involved will be considerable. The nearest available mill may be totally unsuited to the proper treatment of the ore, and a mill adapted to this purpose may not be obtainable within hundreds or thousands of miles. By this method a great deal of time and money may be wasted in making an

* Reprint from "Mines and Minerals" for June, 1899.

† "The Metallurgy of Gold," by H. Van F. Furman, "Mines and Minerals," September, 1896, to June, 1898.

unnecessary test; on the other hand, the results obtained are actual working results, obtained in a working mill, and hence appeal to the uninitiated.

It is the opinion of the writer, after many years of practical experience in testing ores both in the mill and in the laboratory, that the laboratory method is preferable in most cases. It can be carried out on the ground; it involves less expense; it does not involve the actual mining of tons of ore with which to make the test; the results may be obtained quickly, and the conditions essential to the successful treatment of the ore may, in most cases, be determined more accurately in the laboratory than they can be in the mill.

No matter how much engineers may disagree with the above statements, they might all well agree that preliminary laboratory tests should always precede the actual mill tests, in the examination of any mining property. Many mining districts contain the ruins of reduction works, which were erected to treat ores that were either wanting in quantity or were totally unsuited to the method of treatment adopted. How much wasted money could have been saved by a little preliminary testing? Want of intelligence, or care, in the sampling and estimation of ore bodies, and a disregard of metallurgical principles, and economic conditions, are responsible for a majority of such failures.

CONCENTRATING TESTS

The method to be pursued will depend largely upon the appliances at hand, and whether this is to be a preliminary or a final test. It may happen that the only apparatus attainable is the hand mortar, bucking plate, gold pan, and a few sieves, in which case the tests are made by hand. These hand tests can hardly be taken as a criterion of what may be actually accomplished in a properly constructed mill, but they are, nevertheless, extremely valuable as an indication of what may be accomplished and are frequently all that will be required.

HAND TESTS

The first step in all tests is a critical eye inspection of the ore, in order to determine its mineral character and approximately the percentages of its various mineral constituents. Sometimes this is as far as the investigation need proceed, as the inspection may show the ore to be unsuited to concentration. If the character of the ore, and the percentages of the gold-carrying minerals, appear such as to lead one to believe the ore may be concentrated, the next step is to determine how fine the ore should be crushed. This may be settled, in a preliminary way, at least, by crushing typical pieces of the ore and examining the different sized particles with the aid of a magnifying glass. It must be remembered that fine crushing is nearly always a disadvantage; but, on the other hand, it is necessary to crush the ore sufficiently to liberate, or separate, the valuable minerals from the gangue.

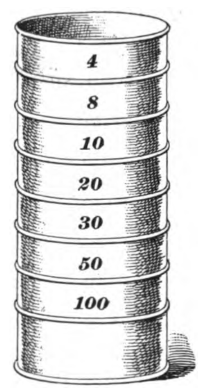


FIG. 1.
NEST OF SIEVES.

Having settled the point as to how fine it is desirable to crush the ore, a sample of, say, five pounds, is crushed to this size. The sample should be crushed in successive stages, the fines being screened out as the crushing progresses, in order to avoid an undue amount of slimes. The hand mortar and a nest of box sieves will serve for this purpose. The sieve frames and box, of the nest shown in Fig. 1, are of tin; the sieves, except the 4-mesh, are of brass cloth, and the pan box is 12 inches in diameter. These nests of sieves can be purchased of dealers in assay supplies, or can be made by any first-class tinsmith. For these hand tests it is not desirable to make a number of different sizes, as only comparatively fine material can be treated in the pan. Consequently the ore is crushed to pass a certain mesh sieve; generally 20- or 30-mesh will prove to be the proper size. After the sample is crushed and screened it is dried on a steam drier, the dried pulp is spread out on a piece of rubber cloth, or heavy paper, and a sample for assay (about 6 ounces) is carefully taken. The assay sample is pulverized on the bucking plate to pass a 100-mesh sieve. From the remainder of the material a sample of, say, 4 pounds, is weighed out and concentrated by panning in the gold pan illustrated in Fig. 2. The tailings from this panning operation are caught in a large tin milk pan, or other suitable vessel, and allowed to settle. The concentrates remaining in the gold pan are examined from time to time to see if they are sufficiently free from gangue and are washed off into a small tin sample pan. When all of the 4-pound sample has been treated in this way, the tailings are settled and examined with the magnifying glass. Should they be found to contain much valuable mineral they are repanned, the resulting concentrates being added to the first batch. This operation may have to be repeated once or twice in order to obtain clean tailings, and even then the tailings may show considerable valuable mineral in the finer sizes, or adhering to the larger particles of gangue. In this case, the tailings are dried and crushed to pass a finer screen, say 50- or 60-mesh. This material is mixed with water in a large tin pan and is carefully washed on the vanning plaque or vanning shovel, illustrated in Fig. 3. The concentrates from this operation are washed into a small sample pan and dried, while the tailings are added to those resulting from the panning. Each sample of dried concentrates is weighed, and a small assay sample is carefully cut out of each lot. The assay sample is ground on the bucking plate to pass a 100-mesh screen, and assayed. The

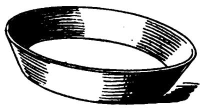
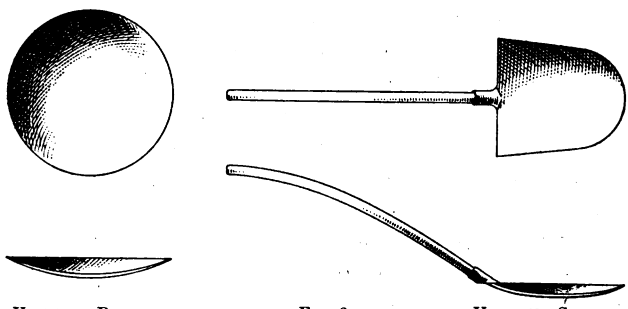


FIG. 2.
GOLD PAN.



VANNING PLAQUE. FIG. 3. VANNING SHOVEL.

tailings are also dried and weighed, and an assay sample is cut out. The tailings should be retained for further tests, by amalgamation or other methods, should such tests be considered advisable after the various samples are assayed.

The method of calculating the results is illustrated in the following example: ore, iron pyrites, gangue quartz.

Assay Samples.	Weight. Ounces. Avoir.	Assay. Ounces per Ton of 2,000 Pounds.		Percentage of Total.		
		Gold.	Silver.	Mineral.	Gold.	Silver.
Ore taken	50.0	1.2	6.0		100.00	100.0
Concentrates from panning	6.5	7.0	21.0	13.0	75.83	45.5
Concentrates from vanning	1.0	7.9	46.0	2.0	13.16	15.3
Tailings	40.6	0.12	2.0	81.2	8.02	13.5
Loss (fine slimes)	1.9			3.8	3.09	25.7
Saved in concentrates	7.5			15.0	88.99	60.8

Such tests are, of course, only approximations, and while they are not sufficiently thorough to enable one to plan a mill for the proper treatment of an ore, they are extremely useful in out-of-the-way places, and will serve as a guide as to the proper method of treatment to be adopted. Before the engineer can make a report as to just how an ore should be concentrated, what machines should be used, how the machines should be arranged and adjusted, what the probable cost of treatment will be, and many other details, several points in the treatment of the ore have to be determined.* Assuming that the preliminary tests were satisfactory, as in the case of the above example, to determine these points a large quantity of the ore should be shipped to some concentrating mill and treated, or the following machine tests should be made.

MACHINE TESTS.

For testing small quantities of ore the writer knows of no apparatus which is better adapted to the work than the Vezin Laboratory Jig, for treating the coarser sizes, followed by the Richards Tube for classification of the finer sizes, which are then treated on the jig, vanning shovel, or vanning plaque.

*The reader is referred to the writer's article on "Concentration of Gold Ores," published in "Mines and Minerals" for April, May, June, July, and August, 1897.

The Vezin Jig, illustrated in Fig. 4, was designed by Mr. Henry A. Vezin, of Denver, Colorado, for the purpose of making concentrating tests in the laboratory. Mr. Vezin has also designed a jig with a bed 6 by 12 inches, having six times the capacity of the smaller one, and being also arranged for hand power, though it was found best to use a 2-inch belt and

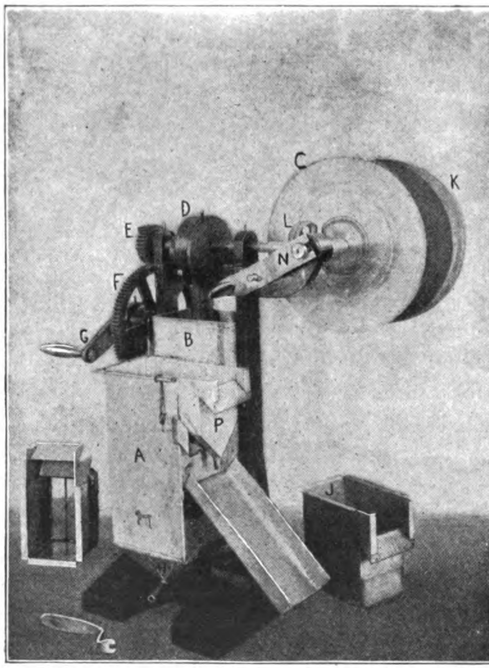


FIG. 4

VEZIN JIG.

power for driving it. This jig is useful for treating samples of ore from 600 to 1,000 pounds in weight; but the small jig will generally be found most convenient. The jig consists of a screen compartment *A*, connected with the hutch, as in the ordinary large jig. Into the compartment *A* is fitted the screen box *J*. In the illustration, one of the screen boxes is shown in place in the machine and two extra boxes are shown on the table. The screen box in place is provided with a stay-box *P* and is used when fine material is treated, or where it is desirable to jig under water. The screens and plunger are 3 by 4 inches, and the plunger has a clearance all around of $\frac{1}{32}$ inch. In a later machine the screen boxes are dispensed with, the screens being held in place by brass collars attached to the jig compartment and held together by means of clamps. The screen compartment, hutch, plunger compartment, and screen boxes are of No. XXX tin or No. 22 brass. The screens are of woven brass wire. The plunger compartment, shown at *B*, is provided with a brass piston with rubber packing. The plunger rod is operated by an eccentric *D* arranged so that the stroke can be readily varied from 0 to $1\frac{1}{4}$ inches. The machine may be operated by hand by means of the crank *G* and the gear wheels *E* and *F*, geared 3 to 1, so that without moving the hand very quickly, a speed of from 200 to 240 revolutions can be attained. The machine may also be driven by power by means of the small wooden pulley *K* and the friction gears *C* and *L*. This friction gearing is thrown in or out by the spring *N*, and the small wheel *L* is adjustable on the shaft so that the number of strokes can be readily varied. The large disk *C* has three rings, marked, respectively, 100, 200, and 300. These represent the revolutions per minute which the eccentric will make when the disk revolves at 100 revolutions per minute. When driving by power, the pinion *E* is removed so that the wheel and crank may remain at rest. The jig which Mr. Vezin had made for the writer was provided with three screen boxes, as follows: $4\frac{1}{2}$ inches deep, 20-mesh cloth, openings 0.039 inch; $3\frac{1}{2}$ inches deep, 30-mesh cloth, openings 0.024 inch; 3 inches deep, 60-mesh cloth, openings 0.010 inch. If it is desirable to increase the depth of the bed, it can be done by fitting a small tail-board at the discharge end.

When jigging screen-sized material, the separation takes place in the upward stream, in still water or in a slow downward stream; hence, water must be supplied under the plunger. This is accomplished by carrying a stream to the plunger compartment and maintaining the water in this compartment at a higher level than that in the jig compartment. When water-sorted material is jigged, the separation takes place in the downward stream; hence, no water is admitted in the plunger side, but it is allowed to flow in with the ore on the feed-hopper. The feed-hopper has a groove in which a bit of rubber packing can be slipped under the inclined bottom, so as to contract the opening, and prevent the water from stirring up the ore as it falls upon the water and ore in the screen. When greater suction is desired, the ½-inch bib cock in the rear can be partially opened. The finer screens are provided with a stay box, so as to jig under water, if desired. Place a plug from above in the discharge of the stay-box, and open intermittently, or provide the plug with a side opening, to allow a continuous discharge.

The number of revolutions and the length of stroke are largely a matter of experiment. Each different size can be experimented with until these points are determined, when the

Sizes.		Stroke in Inches.	Revolutions per Minute.	Depth of Bed in Inches.
Mesh per Linear Inch.	Diameter in Inches.			
¼″–4 mesh	0.250–0.157	1	160	3
4″–6 mesh	0.157–0.110	¾	160	3
6″–10 mesh	0.110–0.079	¾	160	3
10″–14 mesh	0.079–0.055	⅝	180	3
14″–20 mesh	0.055–0.039	5/16	200	2
20″–30 mesh	0.039–0.024	3/16	230	2
1st water size		3/16	290	2
2d water size		3/16–⅛	290–310	2

ore, concentrates, and tailings can be mixed together and the test can then be made under the proper conditions. As a general rule the total throw should be two and a half to three times the diameter of the grains of ore, so as to separate the particles sufficiently to enable them to arrange themselves according to their specific gravities. The speed must be sufficient to raise them. The greater the throw the less the speed, and vice versa. The above table is recommended when treating an ore containing iron pyrites and gangue, the gangue being essentially quartz and feldspar.

The concentrates are removed from the sieve by skimming with a straight piece of tin about 8 inches in length, slightly narrower than the sieve box and bent at a right angle at one end. The straight piece is used for skimming, and the right-angled piece for removing the concentrates from the screen.

The Richards sorting tube* illustrated in Fig. 5, was designed by Prof. Robert H. Richards, of the Massachusetts Institute of Technology, to obtain experimental data on water sorting in upward currents. It is a convenient laboratory substitute for the spitz-lutte, or hydraulic classifier, of the mill. Hydraulic water is fed at *e*, at a constant rate, admitted by a dial cock at constant pressure, guaranteed by an overflow column pipe to give a constant head. This passes up and overflows at *i* at any desired speed. The fine ore is fed at *a*, in small quantities at a time. The grains become subject to the action of the current at *b*. If they are light enough to rise in the current flowing at any given time, they are discharged at *i*. If heavy enough to fall, they pass down to the bulb *g*. A rotary motion is given to the water in *d*, to prevent a downward current on one side and an excess of upward current on the other. Two products are obtained at each operation: overflow grains at *i* and settled grains in *g*. The overflow from *i* is retained for subsequent treatment, that is, further water sorting with a different upward current. By varying the velocity of the upward current at each operation, a number of water-sorted products are obtained. The various minerals contained in each of these products may then be separated by jigging (for the coarser sizes) and vanning (for the finer sizes).

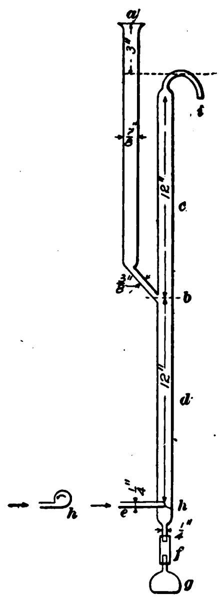


FIG. 5.
THE RICHARDS SORTING TUBE.

The method of calculating and tabulating results is illustrated in the table on page 280, the ore being iron pyrites with a quartz and feldspar gangue.

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*Transactions of The American Institute of Mining Engineers, Vol. XXVII.

AMALGAMATION TESTS

As stamp milling and amalgamation is the cheapest of all processes for the extraction of gold from ores, it is the method most universally adopted. Unfortunately, amalgamation only saves such gold as is metallic and bright. After the upper oxidized part of our gold deposits is passed, the character of the ore changes to sulphides, and sometimes tellurides; in which case only a portion, or none, of the gold is in a state so that it can be saved by amalgamation. Hence, stamp milling is frequently followed by concentration to save the gold contained in the sulphides and other minerals. In certain cases the concentration process is first adopted and the tailings from concentration are re-crushed and treated by amalgamation for the extraction of the free gold which has not been caught by concentration.*

Assay Samples.	Weight. Pounds Avoir.	Assay. Per Ton 2,000 Pounds.		Percentage Saved.	
		Gold. Ounces.	Silver. Ounces.	Gold.	Silver.
Total ore taken from test	50.00	0.70	3.0		
Through 4- and over 8-mesh jig concentrates	1.91	5.50	15.0	30.01	19.1
Through 8- and over 10-mesh jig concentrates	1.52	5.90	18.0	25.62	18.2
Through 10- and over 12-mesh jig concentrates	0.85	6.10	24.0	14.81	13.6
Through 20- and over 30-mesh jig concentrates	0.45	6.50	35.0	8.36	10.5
1st water size concentrates	0.24	8.00	41.0	5.50	6.5
2d water size concentrates from vanning. . .	0.13	9.80	50.0	3.64	4.3
3d water size concentrates from vanning. . .	0.10	11.00	68.0	3.14	4.5
Total concentrates	5.20			91.08	76.7

The most satisfactory method of testing an ore to determine whether its gold contents can be saved by amalgamation, is to

*See "The Metallurgy of Gold," by the writer, in "Mines and Minerals," September, 1896, to August, 1897.

ship several tons, the larger the quantity the better, to some mill and have an actual working test made. However, this is not always feasible, and laboratory tests frequently have to be made. These laboratory tests on small quantities of ore are also sometimes of considerable value in connection with the concentrating tests previously described.

For testing samples of several hundred pounds by amalgamation, the laboratory pan or the "clean-up" pan of the mill is extremely useful, and the results of tests, made by this apparatus, should be closely duplicated by the commercial results obtained in a mill. However, such apparatus is not always obtainable, and tests on small quantities, with the aid of simple apparatus, may be required.

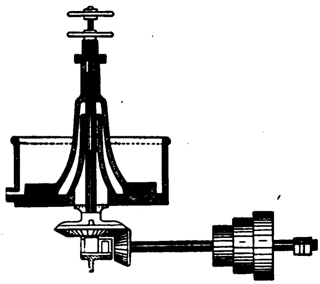

FIG. 6.
CLEAN-UP PAN.

For testing small quantities of ore, the writer has found the following simple method not only useful, but results, so obtained, have frequently agreed closely with actual working results obtained in the stamp mill.

The apparatus necessary is a gold pan similar to that illustrated in Fig. 6, but made of sheet copper. Before using, the bottom of the pan is annealed, and thoroughly coated with quicksilver and silver amalgam, in the same way as the copper plates of a stamp battery are "dressed." The amalgamated surface should extend up the sides of the pan for a distance of $1\frac{1}{2}$ inches. It is best to use considerable silver amalgam in dressing the pan, as the copper surface does not readily save the gold until it is pretty well coated with amalgam. A sample of the ore is pulverized to pass a 30-mesh screen. From this lot the small assay sample is carefully taken and pulverized on the bucking plate to pass a 100-mesh screen. A sample of the pulverized material, three or more pounds in weight, is weighed out and mixed with water in a large tin milk pan, or other suitable vessel. Portions of the mixed pulp are transferred to the amalgamating pan, from time to time, thinned with water, and stirred for half an hour with a round wooden stick, about one inch in diameter. The stirring end of the stick should be rounded and smoothed with sandpaper. The stirring is interrupted, from time to time, and the pan is given a rotary motion, to settle the particles of gold, and allow them to come in contact with the amalgamated surface. The tailings are washed off, from time to time, into a large pan, where they are allowed to settle, and fresh portions of the pulp are added to the amalgamating pan. When the whole of the pulp has been treated in this manner, the tailings are settled, dried, and sampled. The sample of tailing is pulverized to pass a 100-mesh screen, and assayed. The difference between the assay of the ore and the assay of the tailings represents the gold caught by the amalgamated surface of the pan, or, approximately, the gold which can be saved by amalgamation. Results obtained in this way are an excellent guide as to what may be expected from amalgamation in the mill.

INDEX

TESTING GOLD ORES FOR TREATMENT BY CONCENTRATION AND AMALGAMATION