Plate 5

Fig. 1

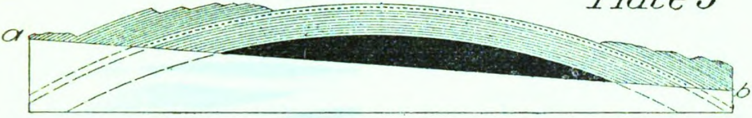


Fig. 2

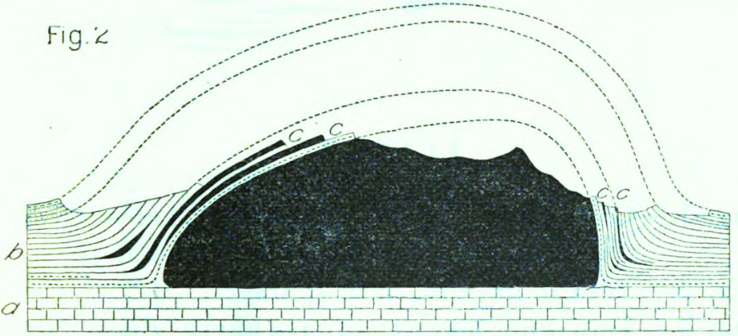


Fig. 3

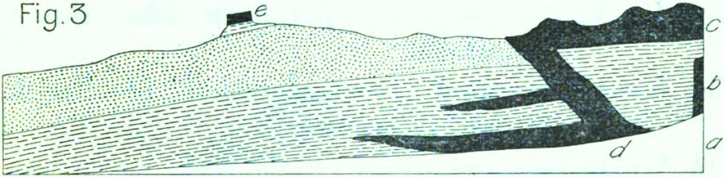
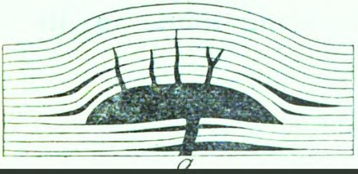


Fig. 4



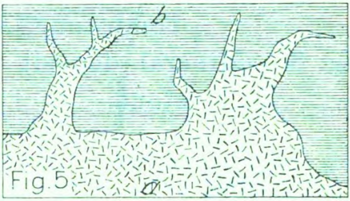


Fig. 5

Prospecting locating and valuing mines

Richard Henry Stretch

R. H. S. DELT.

PROSPECTING, LOCATING

AND

VALUING MINES.

A Practical Treatise for the use of Prospectors, Investors and Mining Men
generally; with an account of the Principal Minerals and Country Rocks;
Ore Deposits; Locations and Patents; the Early Development
of Mines; Earthy Mineral Products; Coal; Gold Gravels
and Gravel Mining; Measurement of Water;
and Artesian Wells.

WITH FIFTEEN PLATES.

BY

R. H. STRETCH, E.M.

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CONTENTS.

PROSPECTING, LOCATING
..AND..
VALUING MINES.

CHAPTER I.

INTRODUCTORY—MISTAKES IN MINING.

THE following pages are not intended for those who have devoted a lifetime to mining and are educated in the many branches of knowledge which go to make the successful mining man, but for those who would like to invest a portion of their capital in the business if they felt safe in so doing, and who hold back because of their complete ignorance of the subject; and to restrain the over-sanguine temperaments of others, by pointing out the elements which may militate against success. At the same time it is believed that the prospector will also find hints which will assist him in his wearisome labors, enable him to make his locations to better advantage than is now the case in a very large proportion of those on record, and furnish him with the language in which he can intelligently describe to others what he has found, so that they shall see it just as he does, and be able to verify his statements upon inspection.

It is hoped that the explanations and suggestions will, to some extent at least, prevent him from spending time and money on valueless prospects or worthless minerals; furnish him with the means to determine approximately the value of what he has found, and show him the way to develop it at the least expenditure of time and labor; and enable him to see clearly what nature has done to his advantage, or the obstacles which have been thrown in his way.

It is not pretended that new geological facts have been presented. Nearly all of them can be found in the books, but they are scattered through many and often expensive works, and in but few cases is there any allusion to the practical bearing of these facts on the interests of the miner, except in the case of coal mining, which has a complete and extensive literature of its own. In all these works, geology, in its relation to coal mining, receives full attention, but it has been otherwise with vein mining for the precious metals. Where it would be impossible to put the subject matter into better language, the writer has quoted freely from recognized authorities, and has used some illustrations which may almost be called common property from the frequency with which they have been copied by one writer after another; but a large proportion of the illustrations are drawn from the writer's own notebooks.

The object of the book may be best illustrated by a few words on the causes of failure of mining enterprises which it is sought to avoid by calling special attention thereto. In mercantile business, failures arise from undue competition, depression in trade, wrong selection of location, want of capital, lack of business tact, want of knowledge of the trade, etc. In gold mining, and to a certain extent in silver mining, we get rid of the element of competition; and in gold mining, at least, depression in trade does not affect otherwise than as a stimulus, but all other causes operate in very much the same manner both in mining and trade.

It should be kept in mind that every pound of ore taken from a mine leaves just that much less in it, and that the end must inevitably come at some time. In this respect a mine differs essentially from a mercantile business which can enlarge its field of operations year after year as population increases or facilities of communication are improved. If the mine only yields, above working expenses, a sum sufficient to repay the cost of the ground, development and plant, the investor might just as well have buried his dollars for the same period of time, and saved labor and mental strain. This state of affairs may easily occur even when the mine has rich ore in sight.

It takes just as deep a shaft to open a piece of ground 500 ft. long as if it were 2,000, but the cost of sinking and pumping, and all expenses of corporate management will be four times as great per square foot of area developed in one case as in the other, and this difference may do away with the possibility of dividends or even the recovery of the invested capital.

Numerous cases of this kind have been seen in Colorado and elsewhere, where small properties which could not stand the burdens thus imposed upon them have proved successful when consolidated, one shaft answering for a much larger property, thus saving the cost of constant sinking, the expense of numerous engines and surface hands, as well as superintendence and office expenses.

On the other hand an enterprise may have so much ground that the energies of the company are scattered over too large an area, one unproductive section eating up the profits of the better ground, thus leading to constant embarrassment; and a failure under these circumstances may do as much to blast the reputation of a district as if the property had been absolutely barren throughout.

This condition of the mine as regards its capital renders it undesirable, if not dangerous, to experiment with new processes of reduction. So many of these, while eminently successful in the laboratory, when worked on a small scale and by enthusiasts thoroughly posted on all the minute details, have proved so inapplicable on a large scale, when operated by less careful men, that a mine cannot afford to employ them until they have proved entirely satisfactory under all similar working conditions. The cost of the experiments should be borne by the projectors of the innovations; all that a mine dare do is to pay a royalty or purchase the machinery when it is no longer an experiment. It is true that the improved machinery, so called, might be a real improvement and a desirable acquisition, but on the other hand, if a failure, it would be only another tax on a treasury which has already its full share of burdens.

Again, the price given for a mine may be so exorbitant, or out of proportion to its development, that while it may pay dividends for a time and apparently be a success, the ore body may "peter out" before the purchase price has been returned in the shape of dividends; and failure will ensue, unless a reserve fund has been set aside, with which to search for other ore bodies. The disproportionate profits of the middlemen or promoters emphasize this proposition, as in the case of the Richmond Consolidated mine in Nevada, which is said to have cost the stockholders $1,375,000 while the vendors received about $280,000, leaving the promoters a clean profit of over a million dollars. Luckily the mine repaid this enormous purchase price, but had it not, it would have been condemned as a failure, when it was not legitimately entitled to be saddled with so great a burden. This was strictly gambling, not mining. The same thing has happened in floating the mines of many other districts, and notably so in the case of the Transvaal—usually with a less fortunate outcome.

A common cause of failure is in not keeping the development of the mine ahead of its current necessities. Such work will naturally reduce the dividends for a time, but it is far preferable to pay for these developments out of the profits of the mine, while it is prosperous, than to have to raise an asessment for the purpose when it is looking poor. Those who have tried the latter plan know the attendant difficulties, which are especially conspicuous in the case of mines represented by unassessable stock. To such mines an empty treasury means almost inevitable death, although a little medicine in the shape of coin might give them a long lease of life. It always happens that there are some stockholders who will not advance any more capital, and the rest do not feel inclined to do so and allow the non-payees to come in and reap the benefits; while there is no way in which undesirable partners like the non-paying stockholders can be got rid of, except by foreclosure of a judgment for an indebtedness of the property.

Another frequent source of lost money is the erection of mills or other reduction works before they are required. Nevada is full of illustrations of this kind of folly, which is more apt to be committed by companies than by individuals. In many cases magnificent mills were erected before the mine had been opened even sufficiently to know if there was a mine at all, and never dropped a stamp. Some of these enterprises were unmitigated swindles and seriously hurt our mining interests abroad, so that the recovery of confidence took years to complete. Not a few of these mills were also utterly unsuited to the ore of the district and were consequently valueless even for custom use on the ore of other mines. In other cases the mills have been too large for the property for which they were erected, and it has been impossible to keep them running steadily—to their injury, as machinery deteriorates rapidly from idleness. It would seem that few miners have any idea of the amount of ore which even a 10-stamp mill will consume in a year. We often hear that a mine is ready for a mill, when it has only a shaft from 50 to 100 ft. deep, or a tunnel of the same length. The absurdity of this proposition is apparent. There may of course be instances where the outcrop is so continuously in ore that there can be no doubt of our ability to put the mine in shape for extraction during the time consumed in the erection of a mill, but this is quite exceptional.

Serious troubles have also arisen from false expectations based on small quantities of rich ore, or rather of narrow seams. If these could be taken out by themselves they would often pay handsomely, even when the quantities would not warrant the erection of a mill, but as they cannot be extracted without removing a large quantity of waste, the cost of doing this has to be taken into consideration, as well as the difficulty of preventing the loss of ore by mixture with the waste, even when carefully hand-sorted. It is not intended to intimate that these very small veins or seams may not be worth working, for seams of very diminutive thickness are worked at the mines at Nagyag in Transylvania; and in some cases, as the native silver mines of Batopilas in Mexico, the sheet of ore is so tough that when less than an inch in thickness it may be left standing while the drift is run alongside, and stripped down once a week or oftener, as may be desirable. The object is to call attention to the frequent excessive cost of working very narrow ore seams, that due allowance may be made and failure avoided.

Want of knowledge of the structure of the deposit is often a source of costly errors. It is not many years ago that the writer saw a summer's work thrown away by a superintendent losing the vein and not knowing how to find it again. Starting on the vein he apparently mistook the bedding of the rock for the wall, as shown in pl. 6., fig. 2, and on reaching the point *B*, where the ore apparently pinched out, went off into the country rock along a small seam in the hanging wall *S*. Not finding the large ore body which was known by its outcrop to exist ahead of the tunnel, he crosscut in the wrong direction at *A* toward *C*, when finding another small seam he turned back on that toward the main vein again. Had he continued on the line *A C* he would have come out to daylight in a direction exactly opposite to that in which he should have sought the ore body. The tunnel was run in hard granite under very adverse circumstances, entailing a serious outlay of money, which must be charged against any future profits, because whatever is spent on a mine ought to come out of it, and at the end of the season's work the property was in a less satisfactory condition than before the tunnel was run; as many observers would naturally come to the conclusion that the mine was practically worthless, if the ore seen on the surface was lost so promptly in depth. (It has since been satisfactorily opened in the right direction.) The same amount of money properly expended under judicious management would have taken the tunnel through a body of ore which crops continuously for several hundred feet, and would have been extracting ore for its entire length, thus making a profit instead of a loss, and putting the mine in shape for stoping.

A most astonishing want of common sense in reading the lesson of the outcrop has caused the loss of much time and money. In the case of the mine shown in pl. 12, fig. 5, the outcrop of the vein occupied the flat slope of a valley with a steep hill to the north, and was scattered over a width of 100 ft. for a considerable distance, but was not continuous, being broken up into little patches of varying size. The ore was rich, and being stained with the blue and green carbonates of copper, was very conspicuous by contrast with the underlying yellowish limestones. Evidently this was mistaken for the outcrop of an immense vein or bed, but a very casual examination showed that the vein was only a thin film between the slates *S* and limestones *L*, for the little gulches running north to the main ravine had cut through the ore in numerous places, in all cases revealing the underlying limestone, and showing the true character of the deposit. That it was not understood was proved by the company running the tunnel *T* to cut the vein. This was started in the foot wall and beneath the seam, and naturally never encountered ore. Had any further proof been wanting, nature had furnished it, for at the eastern end of the location, the bluffs (overlooking Death Valley, Cal.) broke down perpendicularly for several hundred feet, and had the vein been other than it was it must have shown conspicuously on the face of these precipices, which it did not. It would seem that this idea had never occurred to the purchasers, who were out of pocket on the transaction from $100,000 to $150,000 in purchase money and working expenses, while another mining failure was talked about and nothing said of the folly of the investors and managers, who would not believe the facts of the case even when they had paid to find them out.

Again, it is only recently that a man professing to be a mining engineer recommended the exploitation of a bed of bog iron ore, when a casual investigation showed that it was a deposit now forming, only a few inches thick, limited to a few acres of marshy ground, and did not show a few hundred feet to the westward, where the ground breaks down abruptly in a bluff to the seashore, consisting entirely of unconsolidated sand and gravel. Investors in such a scheme would have faced certain failure from the start, and would unanimously have condemned mining as a business.

Another method of losing money is to sink or bore for metals, coal or oil, or any other substance occurring in beds or bedded veins, when nature has told the whole story on the upturned edges of the rocks, as shown in pl. 4, fig. 4, and pl. 3, fig. 5. In pl. 4, fig. 4, a shaft sunk at *D* would disclose no more information than could be gained by walking over the country toward *B*, when the observer will pass over all the rock strata which would be cut in the shaft, with an immensely better opportunity of examining them in detail and without cost. If there is anything of value shown, as a coal seam at *B*, its merits can be discussed before the expenditure of a dollar for underground workings, and an incline could be sunk on it to greater advantage than the vertical shaft *D*, at least until a full knowledge of its character had been obtained. This mistake has been repeated so often that every person connected with mining must be able to recall instances. The same might be said of a shaft at *B*, pl. 3, fig. 5, but at *A*, in the same figure, a shaft would be excusable. In the neighborhood of Leadville, Colo., the writer has seen a prospector sinking in the granite to find carbonate of lead ore, which was an absolutely hopeless undertaking, as can be seen by reference to the cross section of the Leadville district, pl. 1, fig. 2, where the granite and gneiss underlie everything and the ore is associated with the porphyry and limestone beds above it. The utter improbability of success would have been apparent to the prospector had he possessed even a smattering of knowledge of rocks and the occurrence of ore, but his shaft was another member of the army of failures for want of that knowledge. To him the proposition was plain that because others had sunk shafts and found ore at varying depths, without any surface showing, he had just as good a chance as they. On the other hand the want of the necessary preliminary exploration by boring, in the case of coal fields especially (after the presence of coal is known), may entail loss and failure owing to the breaking up of the beds by faults, the presence of which would have been made evident by a proper series of borings in each direction. The beds might not be "faulted" or broken so regularly as in the idealized cross section on pl. 1, fig. 1, which shows a series of "step faults," but the figure will illustrate the general idea. Let *B*, *E*, *F* and *H* represent borings. If only *B* and *H* have been made, the coal seam, represented by the heavy black line, would have been found in each, and its dip fairly ascertained, but no indication of the faults *A* and *B* would have been detected, unless the bore hole *H* had been carried down some distance below the coal, and the works for the extraction of coal, based on these borings alone, might be valueless for working the bed between the faults *B* and *C*. But if the borings had been extended over a larger area and included others at *E* and *F*, the broken nature of the formation would have been disclosed and led to a thorough investigation as to whether the locality could be profitably worked, and if not the cost of permanent works would have been avoided. What has been said of coal applies to many of the gold gravel mines in California as well.

Even if the quantity and quality of the material, such as coal, iron ore, clay and other minerals, which come into severe competition with each other, and require every facility in the way of cheap labor, cheap transportation, and an extended market for successful production, be all that can be asked, the deposits may be so situated with regard to the latter requirements that commercial failure must result from their exploration. André, in his treatise on coal mining, p. 80, puts the case very clearly:

"But if certain clearly apparent circumstances exist which are sufficient of themselves to show that the undertaking cannot be commercially successful, even if all the other circumstances should prove favorable, it is plain to ordinary common sense that it would be sheer folly to prosecute a search which must necessarily be an expensive one, and which must as necessarily end in disappointment. Enormous sums of money have been expended in this way to the great and manifest injury of all legitimate enterprise."

Every mining man can undoubtedly recall numerous cases where labor has been expended on worthless minerals which a very slight knowledge of mineralogy would have saved. The writer has seen a shaft sunk on a body of black obsidian (volcanic glass), under the belief that it was anthracite coal. In another case the men were prospecting for coal in a narrow cañon between basaltic walls, on the strength of a few pieces of carbonized wood in the gravel beds filling the gorge. In another instance several shafts were sunk on a deposit of red jaspery clay, carrying specks of iron pyrite, the prospector mistaking it for cinnabar on account of its bright red color, having probably heard that cinnabar was red, without knowing that usually it assumed that brilliant tint only when scratched or pulverized. For years a prospector in Washington spent money on and clung to the idea that he could develop an iron mine out of a body of clay slate, mixed with quartz and large quantities of iron pyrite, not knowing that the sulphur of the pyrite was a most undesirable constituent in iron, and that there was no probability of the deposit changing its character. Then again tin is an ever-recurring *ignis fatuus*. Recently the writer was assured in perfect good faith by a person willing to prove his faith by his works (if he could get some one to join him), that he had pounded pure tin out of the ore in a common mortar; and another could not be convinced that the polishing of the mortar while grinding so-called tin ore was not a coating of that metal, the iron as he called it being "galvanized!" Such stories lie at the bottom of many a newspaper item, and hundreds of such wild-goose propositions come before the mining engineer and mining men generally every year. But many a prospector will spend the best years of his life on such schemes, and not infrequently drag his equally uninformed friends into them, for want of a little knowledge so easily obtained.

Yet another common source of loss is the failure to ascertain the true value of the ore and the probable character and quantity before erecting expensive hoisting and reduction works. Both of these subjects are more fully treated of in Chapter II., and mention of them is here made only to emphasize the importance of extreme care in all these points. Just as an ounce of quicksilver if thoroughly mixed with a ton of sand will show its presence in every pound of the latter on washing, so a very small amount of free gold will make a big showing in a ton of broken white quartz. The writer has seen a dump on which free gold could be easily found but which gave a return of less than $5 per ton when milled. Coarse gold ores, though the prettiest of specimens, are exceedingly deceptive, and extreme caution is absolutely essential to safety. Gold is so easily extracted from the ore when native (free) that to ask for capital to develop prospects reported to assay $50, $100 and upward per ton is sure to excite suspicion in the minds of those acquainted with the subject, as with a donkey, a little water, a few pounds of quicksilver, and a fair share of patience and physical strength the owner of such a prospect can create his own capital, provided always that the assay represents the whole mass and not some individual specimen.

Costly mistakes are also made through want of knowledge of the way in which ore is distributed through the vein. Experience has taught the writer that not a small proportion of those who might be supposed to be somewhat familiar with the subject imagine that a vein has a uniform thickness like a plank, and like the latter is made up of the same material throughout, so that there ought to be only two kinds of veins, those which never carry ore and those which are continually in ore. Excessive anticipations and undue depression result from such views, a diminution in thickness being never looked for on the one hand or an increased quantity on the other. Probably no vein carries ore from wall to wall throughout its entire length. The probabilties are altogether against such a condition. The spotted character of most ore bodies is well shown in pl. 8, which is a copy of a longitudinal section of the Dolcoath mine (sometimes called Wheal Dolcoath) in Cornwall, England. The length on the vein covered by the section is about 3,300 ft. and the depth about 2,300 ft. The longitudinal elevation of the Comstock lode prepared by the writer for the U. S. Geological Survey shows vastly greater blank spaces. A want of knowledge of how ore occurs in veins has ruined many a mine. Intimately connected with this subject, which is treated at length when speaking of the structure of veins, is the change in the character of ore in depth from various causes, frequently resulting in the abandonment of the mine on reaching the water level. Free gold ores may change into iron pyrites of a much lower grade, yet more costly to work, and rich copper ores may give out entirely, being replaced by low-grade iron pyrite carrying a small percentage of copper too lean to pay the cost of working.

Failure may also occur from want of care in protecting the interior workings, resulting in extensive caves which may involve the loss of a shaft or an entire ore body by mixing it with waste from the walls and reducing its value below the limit of profitable extraction. Even outside of coal mining such accidents are far from infrequent. Only those who have seen the evidence of the immense power developed by the pressure of large masses of earth, or even by its expansion under some circumstances, can realize its amount or extent. Both in coal and gold gravel mining the floor of a drift is apt to rise up or "creep," from the pressure of the surrounding mass squeezing the bottom upward into the space made vacant by the drift or tunnel. This occurs especially when the floor is soft (or as the gravel miners say, "cheesy"). In one instance in California the writer has seen a tunnel driven through the rim, or bed rock of a gravel channel, as might be the lower tunnel in pl. 11, fig. 2, which, when it broke through into the channel, encountered a body of clay and gravel, so soft that it was squeezed by the weight above into the tunnel like a huge sausage, nearly as fast as it could be removed. In another case of a tunnel being driven to reach some old workings, the miners were furnished with a grade-gauge by which to lay the track, so that with one end laid upon the older portion, the new sills could be put in as the tunnel progressed, on the correct slope to connect with the old workings. Owing to the creeping of the bottom during the progress of the work, each set of track timbers as it was laid was squeezed upward before the time came to lay the following section, and the tunnel came out much too high, and was a failure in consequence of thus having acquired too steep a grade.

Finally, litigation resulting from defective locations is a fruitful source of trouble, involving a heavy tax on the resources of the mine. Through a forgetfulness of the importance of determining the direction of lode before making the location it sometimes happens that the lode passes out of the side lines into the property of adjacent owners, instead of extending the full length of the claim, and the mine not only loses a considerable length of the lode, but becomes involved in vexatious questions of boundary lines, the litigation over which may absorb all the revenues or even leave the mine in debt.

Such are some of the causes which lead to failure of mining enterprises. They will be seen to be generally due to want of knowledge on the part of the prospector, investor and managers of the enterprises of some special point in their respective capacities. It must not, however, be understood that all failures result from this cause. There are cases where circumstances arise which could not possibly be foreseen and guarded against, and the judgment of the very best men may err, for we are none of us infallible; but it is desired to show that at least very great losses might be avoided if there were a more general understanding and appreciation of the fact that to be a successful mining man requires a combination of mental and physical qualities such as few other callings demand; and that mining is a business calling for special training just as certainly as technical knowledge is essential to the watchmaker or shipbuilder.

The present chapter has been practically a presentation of failure after failure, and these would be often laughable if the incidents were not so pathetic. The good faith of the men who made the mistakes quoted as samples was unquestionable, and only intensifies the pity felt for their misdirected energies. Fortunately there is a brighter side. The presentation has only been made out of abundant precaution. There is no more fascinating occupation in the world than mining; none that keeps all the faculties so fully alive, and no sensation so pleasant as the handling of the bullion after a successful run!—while it is not unlikely that the percentages of successes would prove as great as in most of the other great industries.

CHAPTER II.

WHAT CONSTITUTES A MINE.

A MERE bunch of ore will not make a mine; and it may be well to examine the factors which really go to constitute a mine. A "mine," then, is any deposit of mineral which can be worked at a profit; that is to say, before the deposit is exhausted it must have returned to the "adventurers" (as the owners or operators are frequently called in England) the original purchase money, the entire cost of the improvements of every nature, and the entire cost of working the ore, whether it be mining, milling, smelting, transportation, supplies, superintendence, or office expenses, together with a fair interest on the money invested. If we charge against the salable product all the expenses except purchase money and plant, we arrive at the running cost of production per ton, and if the selling price per ton be greater than this, the difference per ton will go to the account of purchase money, development and plant; and there must be in the deposit at least a sufficient number of tons of ore, which, multiplied by the profit per ton, will extinguish the original cost of mine and improvements, it being supposed that repairs to reduction or hoisting works, etc., are charged to the cost of producing and milling or smelting the ore.

For instance, if the purchase money and original plant cost $200,000, and the profit per ton over expenses of production and reduction is $10 per ton, the mine must produce 20,000 tons, at least, before it can be called self-sustaining, and a surplus over that amount to cover reasonable interest. If the ore be free gold quartz, or free-milling silver, about 13 cu. ft. in place will weigh 1 ton of 2,000 lb., so that the cubic contents of the 20,000 tons would be 260,000 cu. ft., equal to a block of ground—

260 ft. deep by 1000 ft. long, if the vein be 1 ft. thick.
130 ft. deep by 1000 ft. long if the vein be 2 ft. thick.
65 ft. deep by 1000 ft. long, if the vein be 4 ft. thick.

or, if the ore deposit be only 500 ft. in length—

520 ft. deep by 500 ft. long, if the vein be 1 ft. thick.
260 ft. deep by 500 ft. long, if the vein be 2 ft. thick.
130 ft. deep by 500 ft. long, if the vein be 4 ft. thick.

but if the ore shoot be only 100 ft. in length—

2,600 ft. deep by 100 ft. long, if the vein be 1 ft. thick.
1,300 ft. deep by 100 ft. long, if the vein be 2 ft. thick.
650 ft. deep by 100 ft. long, if the vein be 4 ft. thick.

From the foregoing it is evident that the length of the ore body is of immense importance, as the cost of working a mine increases with depth at a constantly increasing rate; and the longer the ore shoot, the shallower will be the workings to accomplish the same results. If the shoot be only 100 ft. long it will be necessary to sink ten times as deep, at a heavy expense, as if it were 1,000 ft. Of course this is assuming a theoretical regularity of deposit.

In order that similar calculations may be made on other classes of ore, the following table gives the specific gravity of the principal metals and their principal ores; the weight of 1 cu. ft. of each, and the number of cubic feet which will equal a ton of 2,000 lb. As the specific gravities of the ores are taken from pure specimens, generally crystallized, they will give, as a rule, quantities too small in the column of cubic feet per ton, as the ores in run-of-mine are seldom free from impurities; so that a somewhat greater number of feet should be assumed in making the calculation, to be on the safe side:

SPECIFIC GRAVITIES OF METALS AND MINERALS.

Metals and Minerals.	Specific Gravity.		Weight of cubic ft. Pounds.	Number of cubic feet to ton.
	Range.	Average.		
Gold	15.60-19.33	19.30	1206.25	1.66
Silver	10.10-11.10	10.50	656.25	3.05
Silver, free ores	5.22-7.36	6.08	380.00	5.26
Copper	...	8.84	552.50	3.62
Copper pyrite	4.10-4.30	4.20	262.50	7.62
Copper, purple	4.40-5.50	5.00	312.50	6.40
Copper, gray	4.50-5.10	4.80	300.00	6.66
Copper silicate	2.00-2.40	2.20	137.50	14.62
Quicksilver	...	13.58	846.00	2.36
Cinnabar	9.00	9.00	562.50	3.55
Lead	...	11.44	715.00	2.80
Lead, galena	7.25-7.70	7.50	468.75	4.27
Lead, carbonate	5.40-6.47	6.00	375.00	5.33
Zinc	...	7.00	437.50	4.57
Zincblende	3.90-4.20	4.10	256.25	7.84
Zinc, carbonate	4.00-4.45	4.20	252.00	7.95
Zinc silicate	3.43-3.49	3.46	216.25	9.25
Iron, cast	...	7.21	450.00	4.44
Iron, wrought	...	7.69	480.00	4.17
Iron, magnetite	...	5.00	312.50	6.40
Iron, hematite	...	4.90	306.25	6.53
Iron, limonite	...	3.80	237.50	8.42
Iron pyrite	4.83-5.20	5.00	312.50	6.40
Iron, arsenical pyrite	6.00-6.40	6.20	387.50	5.16
Iron, chrome	4.32-4.49	4.41	275.62	7.25
Tin	...	7.35	459.00	4.35
Tin oxide	6.40-7.10	6.75	421.87	4.74
Antimony	...	6.70	418.00	4.78
Antimony sulphide	4.52-4.62	4.57	285.62	7.00
Quartz	...	2.65	165.62	12.08
Fluorspar	3 .01-3.25	3.18	198.75	10.06
Sulphate of baryta	4.30-4.72	4.51	281.87	7.01
Water	...	1.00	62.50	32.90

But as we may frequently want the weight and bulk of ores made up of several minerals, the following examples will show how the weight per cubic foot of such ores may be obtained:

Calculation by Bulk.—Take an ore containing say 50% of its bulk in galena, 25% in arsenical pyrite, 8% in zincblende, and 17% in quartz. By reference to the foregoing table we have:

0.50 of 1 cu. ft. of galena	= 234.37 lb.
0.25 of 1 cu. ft. of arsenical pyrite	= 96.88 lb.
0.08 of 1 cu. ft. of zinc blende	= 20.50 lb.
0.17 of 1 cu. ft. of quartz	= 28.15 lb.
1.00	379.80 lb.

Calculation by Weight.—But if it be desired to ascertain the weight of 1 cu. ft. of ore containing the same minerals estimated by weight instead of bulk, we can calculate the bulk of a known definite weight, say 1,000 lb., and instantly determine the weight of 1 cu. ft. by simple proportion. Out of the 1,000 lb. we shall have:

500 lb. galena	÷ 468.75	= 1.068 cu. ft.
250 lb. arsenical pyrite	÷ 387.50	= 0.645 cu. ft.
80 lb. zincblende	÷ 256.25	= 0.312 cu. ft.
170 lb. quartz	÷ 165.62	= 1.026 cu. ft.
1000		3.051 cu. ft.

or 6.102 cu. ft. per ton. By proportion the

Galena	= 0.350 of 1 cu. ft.	× 468.75	= 164.06 lb.
Arsenical pyrite	= 0.212 of 1 cu. ft.	× 387.50	= 82.15 lb.
Zincblende	= 0.103 of 1 cu. ft.	× 256.25	= 26.14 lb.
Quartz	= 0.336 of 1 cu. ft.	× 165.62	= 55.65 lb.
	1.000	328.00	

All other combinations may be worked out by these examples. Assuming the profit on this class of ore to be the same as that of the free gold ore given previously ($10 per ton), it is clear that the ore body would only have to be about half the dimensions before quoted to secure the same results, as 1 ton only occupies about half the space of the first illustration.

Favorable Conditions.—If the mine is so located that its product can be sold to independent reduction works, it is plain that smaller ore bodies may be profitably extracted; and yet smaller ones if the mine be worked by the original discoverers, and the ore is of a grade high enough to yield a margin of profit over the cost of extraction and transportation to market, as in the first case there are no reduction works to be paid for out of the profits of the mine, and in the latter case, neither reduction works nor purchase money. Any ore body fulfilling these conditions may properly be called a mine, and it is such that the prospector is looking for.

Mining Compared with other Business.—Only an exceedingly small proportion of the locations made ever develop into mines, probably not more than one in a hundred. On the Comstock lode, out of several thousand locations on record, less than fifty had any large amount of development, and still fewer ever paid dividends; yet the gross product of bullion from the comparatively few active mines was enormous. Similar conditions hold good in most other mining camps; but it is likely that the percentage of success in mining enterprises is fully as great as in almost any other line of business--certainly as great if the same amount of care has been exercised in selecting the property as is usual in opening a new store or hotel. But the miner must always remember that while the business of the store may expand indefinitely, he is from the very start living on his capital (the total amount of ore in the mine), and that this diminishes daily the more rapidly as the output is enlarged; while after reaching its extreme productiveness the later stages of a mine are merely like realizing on the assets of a failing business.

VALUATION OF MINING PROPERTY.—The value of mining property is therefore not to be estimated by the amount of the dividends it may be paying at any particular time, but by the number and value of the dividends it will be able to pay in the future.

Relation of Profits to Price.—Thus, because a mine has just paid an annual dividend of $1,000,000, it does not follow that the mine is to be valued at $10,000,000 (which would make the dividend equal to 10%), because it can only be worth that figure to purchasers for investment if it is able to disburse that amount or over in dividends in the future with a fair interest on the investment in addition. If the dividends were distributed over ten years at the rate of $1,000,000 per annum, the investors would just receive the original amount paid without interest, so that if the investors are to receive interest at the rate of 10% on the money invested, the mine must pay another $5,500,000 in dividends, making $15,500,000 in all, to be worth $10,000,000 as an investment.

But it might be that the mine had reached its maximum productiveness when it paid the million-dollar dividend, and the ore bodies in sight began to show signs of exhaustion. In such a case the extreme value to an investor would only be the actual profit on the exposed reserves, which might be small.

The chance of finding new ore bodies cannot be expressed in figures. One of the great sources of disappointment in mining enterprises is the over-estimation of mining values, mistaking capital for profit. Another is the payment of unjustifiable prices, not only for properties with considerable development, but for holes in the ground or mere naked locations. It is true that very often the purchaser expects to sell again at a profit and not to work the property, but then he has removed his dealings from mining to the realms of speculation, and has no reason to grumble if failure follows the change.

Ore "in Sight."—Practically the value of a mining location is the net profit on the ore exposed. If there is any promise in the surroundings of a future to the location, this definition might possibly be enlarged to the gross value, the purchaser looking to developments made with his own capital for reimbursement of the original investment and profit. The value then of the majority of original locations is very small. Many of them are absolutely valueless, being made upon a mere stain or a slight difference in the color of a certain streak or layer of rock, or the presence of a little iron pyrite in a particular seam, which only means that there has been decomposition of some of the hornblende or allied mineral contained therein. If, however, there is actually valuable ore in sight, this must be carefully measured for length and breadth, and if these measurements show a continuous workable body the price of the location might possibly be the value of this ore to a depth of a few feet, according to the width of the ore exposed.

The situation is improved by the sinking of a shaft or the running of a tunnel, but a single shaft does not prove the existence of much ore. It simply shows its presence at that particular point to a certain depth and the quantity in sight will be the two triangles *a* and *b* in pl. 13, fig. 1, multiplied by the average thickness. If two shafts have been sunk, as in pl. 13, fig. 2, we can call the shaded portion "in sight." If the development be a shaft with drift from the bottom, as in pl. 13, fig. 3, we can still only consider in sight the portion shaded, with a probability of more because of the ore in the bottom of the drift *c*. The same will be the case if a tunnel is run on the vein as *B* in pl. 13, fig. 4, but if the bottom of the shaft *A* is in ore and the face of the tunnel *B* also, part of the block *D* may be added to the probable reserves (unless the ore is growing smaller in width), though it cannot be considered actually in sight, by which we understand a block of ground exposed on all sides, as in pl. 13, fig. 5, where the blocks *E E* are actually in sight and *DDD* can be added as probabilities, along with an unknown quantity below the lower drift at *F*. In all the foregoing examples it is supposed that the outcrop is the extreme workable length of the ore, and that none of the underground workings have been run out of ore, so that we have no means of judging whether the ore body is holding its own in size, or increasing or diminishing; but if the explorations have developed the facts shown in pl. 13, fig. 6, we can afford to be liberal in the estimate of the probable reserves, as distinguished from ore in sight (shaded), because it is evident that the ore body is not at present diminishing in horizontal length, and may therefore be extensive in depth. If, on the contrary, the result has been as shown in pl. 13, fig. 7, we must be exceedingly conservative, as the ore body is evidently pinching out downward as well as laterally.

It would be easy to extend these illustrations, but enough has been said to show the basis on which estimates of quantity of ore in sight in a mine are arrived at, and also to show that work is the only thing which can give value to a location. Because a prospector has been able to make two or three locations or more, in a season's work, it does not follow that they are actually worth the time spent in securing them. The value of an article is not the price paid for it, or its actual cost to the owner. The price paid may have been out of all proportion to the value, or the actual cost of the article may have been so reduced by improved machinery that it can be bought for a mere fraction of the sum paid for the original production. So the value of a mining property is not to be estimated by what it has cost the parties offering it for sale, but by the profit it will realize to the purchaser.

Grade of Ore.—But even a large body of ore may be valueless if the cost of extraction and reduction equal or exceed the value of the metal extracted from the ore; nor does it follow that, because ore of a certain grade has been profitably worked in one mining camp, this will hold good for all others, as the conditions vary so widely. If everything in the shape of surroundings is favorable, a very low-grade ore may probably yield a profit, while in another camp a much richer ore may bring the miners into debt.

Sampling.—Where no work has been done on a location which shows enough of an outcrop to justify a more extended examination, we can simply sample the croppings thoroughly to ascertain which portions of them carry mineral enough to be valuable, and the character of this mineral, because it is seldom that the outcrop is of uniform value throughout its length. This is not done by taking small hand samples here and there, for the most honest man is not honest enough to be able to select a fair average in such a way. A clean cut across the entire width of the pay streak should be taken at stated intervals, to avoid the interference of the judgment, or the deception of the eye, and each of these samples should be thoroughly broken on a clean floor, mixed, spread out in a thin sheet and quartered. One of these quarters should be broken still finer, remixed and again quartered. This will probably bring the sample down to such a size that its entire mass can be ground to coarse "pulp."

Assaying.—From this pulp samples should be furnished to two independent assayers, retaining the balance for further tests should there be much difference between the results obtained from the assayers (between whom there can be no collusion, as the look of the pulp will not betray any peculiar external characters of the ore by which its identity might have been suspected). To furnish both assayers with the same pulp is also fairer to the assayers, because they are both placed on the same footing, which is not the case when a piece of ore is broken into two pieces and one-half given to each (except in a few exceptional cases), as there may be sufficient difference in the composition of the two pieces, especially in a complex ore, to warrant considerable discrepancies in the results obtained, which would naturally throw a shadow of doubt upon the entire investigation. In gold ores this is very liable to be the case. A small sprinkling of telluride of gold (looking like lead) might run one specimen up into the thousands per ton and the other give only tens. Care should be taken to distinguish between mere specimens and true average samples.

In this way only can reliable results be obtained, but if the ore prove to carry much gold, even then they will not be entirely satisfactory, nor will they indicate the true commercial value of the ore unless determination of the nature and quantity of undesirable mineral constituents be made, if such are suspected from examination of the ore as taken from the vein.

When gold is found only in combination with other minerals it is usually disseminated through them in such fine particles that the distribution is comparatively uniform and an assay will be satisfactory, in so far as the amount of gold in the ore is concerned; but when a portion of the gold has become free, or liberated from the associated minerals (as the various forms of pyrites) by the decomposition of the latter, or still more so when a portion of it has never been in combination, but is scattered through the mass in particles of varying dimensions, the assays will be in all probability valueless, because they may accidentally include quite a large piece of gold (comparatively speaking), and this multiplied by the thousands of times which an assay sample is contained in a ton would give very high results, while the next sample, not containing such a piece, may only show very small or insignificant returns. This may easily occur, as the gold cannot readily be ground fine enough to pass through the sieve with the other pulp, but must be mixed with the pulp after it is ground, and thus the chance of getting a fair average sample is exceedingly small.

Horn Spoon.—Every prospector should carry a horn spoon, made by cutting off the belly of a large cow's horn and polishing the inside with sandpaper, as in pl. 13, fig. 8; or he can obtain an iron one of the same shape, but having one-half galvanized to better show black ore minerals. Such a spoon can be carried in the pocket, and if the presence of free gold in the ore be suspected a few minutes will suffice to grind up a sample on a smooth flat rock with a small hand stone, and wash it out in the nearest water hole, which can be very much smaller than is required for the gold pan, a bucket or even a wash basin being amply large enough. The very finest colors may be detected by this method. If any are found, a sample large enough to secure a fair average should be taken, and the entire mass reduced to pulp. All screenings which will not pass through the sieve should be saved until the process is complete, and then returned to the pulp, the weight of which while dry should be carefully ascertained. The pulp should then be mixed with water, adding sufficient quicksilver to amalgamate the free gold, and thoroughly worked over to insure complete contact of all the gold with the mercury. The amalgam thus obtained may be reduced to a button with the blowpipe, care being taken not to inhale the mercury fumes, and then by simple proportion the amount of free gold per ton may be ascertained with reasonable accuracy, if the average of several tests be taken. Thus, if 5 lb. of ore contain 25c., 2,000 lb. will contain $100.

Segregating Ore Minerals.—An assay of the pulp which is left will give the amount of gold in combination with the "sulphurets" per ton, and the sum of the two the total value of the ore. Also, by washing out the sand the percentage of sulphides per ton of ore may be ascertained, and an assay of these concentrated sulphides will give the value of the concentrates per ton, and enable us to formulate a plan for their reduction. But if the ore contains a number of minerals, such as iron pyrite, arsenical pyrite, zincblende and galena, we cannot decide on the best method until we have ascertained, by assay of pure samples of each of these minerals separately, which it is that contains the gold, or whether it occurs in all of them indiscriminately.

In the case of smelting ores, such as galena combined with zincblende, for instance, the presence of the latter being detrimental to the process, it is especially desirable to know whether the blende carries any appreciable amount of the precious metals contained in the ore, as the difference in the specific gravity of the galena and blende is so great (7.5 to 4.1) that the latter can be easily separated from the former during the process of concentration, and if valueless except as zinc, might be thrown away as a waste product, or reserved for separate treatment if in sufficient quantity to warrant such a course.

If the gold is largely in combination with iron pyrite or other minerals which are easily decomposed by exposure to the action of air and water, the outcrop may yield a good showing of free gold in rusty quartz, stained by the oxide of iron derived from the pyrite, which may suddenly diminish in quantity when the permanent water level of the mine is reached, below which a large portion of the gold may be in combination with the unaltered sulphides. Usually such gold is very fine, almost if not quite like flour, but occasionally, as in iron pyrite from the slates near Fiddletown, Cal., the threads and crystals of gold may be readily seen, and felt projecting from the polished faces of the large cubes.

Special Cases.—In the case of ores containing native copper, the plan of taking a number of pounds and working it in the same manner as free gold is the only practicable way of getting fair results, and the same remark applies to those carrying native or horn silver, in fact to all ores containing minerals which will not pulverize and pass through the sieve; but ordinary assays are applicable to all other ores, provided care has been taken in preparing the samples by having them large enough and thoroughly mixed, so as to secure average results.

Working Tests, Mill Runs, etc.—As work progresses, the accuracy of the results first obtained may be tested to some extent by actual working methods. The facility and cheapness with which this may be done depend upon the nearness of reduction works of a suitable character. High-grade ores can be shipped over trails on mule-back, to works at long distances from the mines, and even if the expenses consume all the returns the experiment will be worth the cost; but low-grade silver ores cannot be handled in this manner.

Arastra.—In the case of low-grade gold ores, in which the gold is free, which will not bear transportation for long distances, good working results may be obtained from an arastra built on the ground, as it occupies only a small space and consumes but a small amount of water. The arastra consists simply of a circular floor made of large flat rocks carefully laid so as not to leave crevices of too large a size between them, inclosed by a low stone wall of suitable height, say 2 to 3 ft. In the center is erected a vertical spindle supported by a cross frame, to which spindle is fastened a long horizontal shaft, and beneath the latter cross arms to which large flat stones ("drags") are fastened by means of short ropes or chains. When a horse or mule is attached to the long shaft, and driven round in a circle, the cross arms drag the rocks attached to them around, and crush any ore which may be fed into the machine between themselves and the floor. Of course the amount worked daily will depend on the size of the arastra, and the softness or hardness of the ore, but it will do its work well and give a fair working test.

Utility of Tests.—By keeping the ore extracted from each 10, 20, or 30 ft. of the shaft or tunnel by itself, and working or shipping the batches separately, the miner will soon learn which portion of the ore body is the richest, and also whether it is fairly uniform in value, or changes frequently within short distances. A few such tests will soon determine the question whether it will pay to build a road to the mine, for the cost of such a road will ultimately have to come out of the mine.

Roads.—Without roads no heavy machinery can be gotten to the mine at anything like reasonable cost. Mining roads are often very costly enterprises owing to the rough and broken nature of the country which they must traverse, and the want of them not infrequently greatly retards the development of otherwise promising mining districts. As all the locations in a new district must share equally in the benefits derived from a main road placing them in ready communication with the outside world, the cost of the trunk road should be raised by an assessment on each location, made, by action of the mining laws of the district, a requisite to a legal title to the location. The lateral branches to the individual mines would naturally be built by the mines at their own cost. A mine opened by tunnels only will of course not feel the necessity of roads so promptly and keenly as one which is compelled by the nature of the ground to resort at once to shaft-sinking, as the former will be able to get along with packages which need not exceed a mule-load in weight, except in the article of timber, but all require the roads sooner or later as a matter of economy even in provisions and supplies.

PLANNING REDUCTION WORKS.—Having then become satisfied that the ore body is large enough and rich enough to pay for its extraction, the character and size of the reduction works remain to be determined.

Smelting.—Should it be decided that the ore will be best reduced by smelting, it is doubtful whether the mine would be justified in erecting its own works, unless it is situated where purchases of various other ores can be readily made in considerable quantities, as few mines produce ore which may not be worked to greater advantage by admixture with other ores which can supply its deficiencies without adding barren material to the charge in the furnace. Ores rich in gold and silver, but poor in lead (usually called "dry" ores), may require rich lead ores to flux properly; or ores with an excess of silica (quartz) may require the addition of lime or iron-bearing ores to accomplish the same result. It is from this circumstance that the great smelting centers, such as Denver, Swansea, etc., have arisen, which purchase everything which may be offered, and mix and work the ores to the best advantage; each class of ore being kept separate in the yard. A furnace charge may thus be made up from four or five different kinds of ore, from widely separated localities, the more refractory ores being added in small quantities to those which work more readily.

Concentration.—It often happens in a vein that on one of the walls there may be a streak of solid mineral suitable for shipment as it comes from the mine, with no—or only slight—sorting, while the balance of the vein is filled with material in which there is so much waste as to render this impracticable; or the entire vein may be of this character.

If the distance from the mine to the smelting works is great, and especially if any considerable portion of it be only trail or wagon road, it may not pay to send these poorer ores, as the whole expense including transportation might very likely more than equal the product. Such ores must be dressed to better grade by some method of concentration (usually by washing, more rarely by air or magnetic separators) if the resulting concentrates are rich enough to bear the cost of transportation; otherwise they may be valueless until the conditions of transportation are modified. Concentrates consisting largely of galena or heavy sulphuretted silver ores may go to the smelter, but those made up almost entirely of iron pyrites, such as are obtained from many gold ores, may be retained at the mine, and worked by chlorination, if the daily product be large enough to keep a small reverberatory furnace for roasting in steady operation. These pyritous ores may also be made into a commercial product by matte smelting.

The capacity of the concentrator should be proportioned to the output of the mine, just as the size of a stamp mill is determined by the same factor, and this output will depend on the size of the ore body and the condition of the development.

Ore Supply Needed.—We frequently hear of a mine being ready for a mill when it has nothing more than a shaft 50 to 100 ft. deep, or a short tunnel on the vein. As an approximation we may say that a mine should produce 1 ton of ore daily for each of the men employed around it, including blacksmiths, carpenters, carmen and outside help. There are of course mines where better than this is done, but these are exceptional. We must therefore have room enough in the mine for a considerable number of men to be engaged in "stoping" ore and this involves a number of drifts or stopes, even for a small mill. If very active development is going on and the ground is easily worked, there might possibly be sufficient ore extracted from the face of the various headings, sinkings or upraises to keep a small mill going; but to depend on these would be bad policy, for the ore in several of them might "pinch" at the same time, and shut the mill down. Indeed, a mill should not be built until the ore body has been so thoroughly explored that it may be perfectly adapted to the requirements, both as regards size and character of equipment, as although it may be possible to find the money for experiments or mistakes, they must all ultimately be paid for by the mine and diminish the profits.

Calculation of Tonnage Mined.—To enable the prospector or miner to form a quick estimate of the amount of ore which he may be extracting daily from a drift, the following table will be found useful. Three kinds of ore are given as types. First, practically clean galena; second, a concentrating ore; and third, ordinary gold quartz ore or free-milling silver ore, neither of which carry much heavy mineral. The yield in pounds is for 1 running foot of a drift 7 ft. high, and this figure multiplied by the number of feet run daily will give the daily yield in pounds, providing there be no waste in saving the ore, as is usually the case in small seams, which are difficult to take out clean, especially if the ore is brittle or friable.

DAILY ORE EXTRACTION PER RUNNING FOOT; DRIFT 7 FT. HIGH; VEIN VERTICAL.

Class.	Weight per cubic foot.	Thickness of Ore.						
		3 in.	6 in.	9 in.	1 ft.	2 ft.	3 ft.	4 ft.
1.............	469	820	1641	2461	3283	6566	9849	13132 lbs.
1.............	....	0.41	0.82	1.23	1.64	3.28	4.92	6.56 tons
2.............	328	574	1148	1722	2296	4592	9888	9184 lbs.
2.............	....	0.29	0.57	0.86	1.15	2.30	3.44	4.59 tons
3.............	166	290	581.	871	11.62	2424	3486	4648 lbs.
3.............	....	0.15	0.29	0 43	0.58	1.16	1.74	2.32 tons

The principle used in this table may be applied also to sinking shafts, thus: multiply the area of the working face (if all ore, otherwise the area of ore seam only) by the number of feet sunk daily, and this by the weight per cubic foot in the table. For instance if we sink 3 ft. daily on a 2-ft. vein and the shaft is 10 ft. long, then 10 × 2 × 3 × 328 = 60 cu. ft. × 328 = 9.84 tons, for ore of the second class; or if a drift be 6 ft. high on a 2-ft. vein and we run 2 ft. daily, we have 6 × 2 × 2 × 328 = 24 cu. ft. × 328 = 3.93 tons. To assist also in forming an estimate of the most desirable size for a mill, the next table will be found useful, being applicable also to the required capacity of a concentrator.

The duty of a stamp varies greatly according to its weight, the height of the drop and the number of drops per minute, the hardness of the ore to be crushed, the fineness of the screen through which the pulp must pass to escape from the battery, and the height of the discharge. In the case of many gold ores, in which the metal is very fine and the rock hard, 1½ tons per stamp may be a fair day's work (24 hrs.), but when the rock is softer, or the gold coarser, it is not necessary to use so fine a mesh, and the duty may run up to 2 tons daily; while if the working of the ore is to be finished by grinding in pans, or the ore is exceedingly soft, a mill may crush still coarser and pass 2½ tons or over under each stamp in 24 hrs. The table is therefore arranged for each of those three capacities, and shows the amount of ore crushed annually, its contents in cubic feet and the area of the vein which would be extracted at various thickness. It is based on the ordinary gold quartz or free-milling silver ores (such as the ores of the Comstock), and 13 cu. ft. in the mine are considered to be a ton, as the result of determinations made on that lode; and 300 days actual running time in the year. If the mill runs more steadily the quantities must be proportionately increased.

CAPACITY OF A 10-STAMP MILL.

Class Ore	Lbs. per cub. ft.	Cubic ft. per ton.	Equal blk. Tons.	Consumption per diem,			Consump. per annum (300 days.)		
				1½ tons.	2 tons.	2½ tons.	1½ tons.	2 tons.	2½ tons.
1..........	165	13.0	1	15	20	25	4,500	6,000	7,500 Tons.
1..........	......	......	......	195	260	325	58,500	78,000	97,500 cu.ft.
2..........	328	6.5	2	30	40	50	9,000	12,000	15,000 Tons.
2.	......	......	......	195	260	325	58,500	78,000	97,500 cu.ft.

AREA OF VEIN EXTRACTED ANNUALLY.

Duty of Stamp.	Vein, 1 ft.	Vein, 2 ft.	Vein, 3 ft.	Vein, 4 ft.
Tons.	Ft.	Ft.	Ft.	Ft.
1½..................	585x100	292x100	195x100	146x100
2....................	780x100	390x100	260x100	195x100
2½..................	975x100	488x100	325x100	244x100

The mixed ore is merely given as an illustration. In fact, as a concentrating ore, it would more likely be treated with rolls or other crushers than with stamps, the object in concentration being to keep the crushed ore in as large grains as possible, as the difficulties of concentration and percentage of loss increase with the fineness of the pulp.

The table itself requires but little comment. While made up for only 10-stamps it can be modified to apply to any desired number—but it emphasizes very strongly the desirability of long ore bodies, as it is evident that to get a year's supply from a tunnel on a vein 1 ft. wide, with a rise of the surface on the hill of 1 ft. in 2, we should have to follow the ore 484 ft. into the hill, and upwards 242 ft. to the surface at the end of the tunnel, as in pl. 13, fig. 9. If the ore shoot were only 200 ft. long we should have to sink on it or run another tunnel, either course involving an extra amount of dead work. If 100 ft. long only, we should have to sink 585 ft., attaining a depth of nearly 2,400 ft. in four years. If 200 ft. long, we should sink 1,200 ft. in the same time. As the cost of sinking and working main shafts is the heaviest item in mining, the length of the shoot, as before stated, is all important.

Backs.—In no case should the outcrop be considered immediately available ore. About 50 ft. in depth, or at any rate a sufficient thickness to avoid caving, which will depend on the width of the vein and the condition of the walls, should be left as a protection to the mine from surface water, for if the ore be extracted it is sure to leave a depression into which the snow and rainfall will drain, and find their way to the lower workings, to be subsequently pumped out at a heavy cost. These croppings will always remain an available asset, and should be the last thing taken out of the mine.

DEFINITION OF A "MINE."—To sum up then, a mine is a body of ore of sufficient size and richness to repay all costs of purchase money, erection of all necessary plant, dead work, extraction, transportation and reduction, with good interest on the capital. Success will depend largely on a thorough knowledge of the size of the ore body as regards length, depth and thickness; the true character and composition of the ore; the adaptability of the hoisting and reduction works to the requirements of the property; careful management by thoroughly competent men well up in the business; avoidance of mistakes and experiments, severe pruning of all unnecessary expenses, and the treatment of the mine as a business undertaking, and not as a gambling proposition.

CHAPTER III.

ROCK-FORMING MINERALS AND ROCKS.

It is not proposed to go further into this subject than to furnish a condensed outline of the composition and structure of the principal kinds of rocks, those most commonly met with in connection with mineral deposits, so that the prospector may be able to recognize the most important of them. To describe all the different varieties would require a volume, and would be of no special benefit in this connection, as the distinctions are frequently founded on the presence of some minerals of difficult recognition and quite secondary importance, and the descriptions would necessitate a much more extensive knowledge of mineralogy to make them intelligible than it is necessary for a miner to possess.

ROCK-FORMING MINERALS.

The principal minerals which make up the bulk of the rock formations are very few, and we shall find that when able to recognize quartz (or silica), feldspar, mica, hornblende and augite, there will not be much difficulty in giving a rock a name. Some of these names may really apply to groups of rocks, but in such cases the name of the group will be close enough. It is the different ways in which these five minerals are combined that distinguish the igneous rocks from each other; and it is the predominance of one or the other in the secondary rocks (or those which have been made out of the wear and tear of the igneous series) which imparts to these secondary (or sedimentary) rocks their peculiar characters.

Granite consists of quartz, feldspar and mica; syenite, of crystallized fedspar and hornblende; and basalt of feldspar and augite, with chrysolite or olivine, so that with specimens of these three rocks before us, or even in some cases with granite and basalt only, we are ready to study the characters by which the minerals are to be recognized. The basalt used for reference should not be so fine-grained that its constituent minerals are indistinguishable to the unassisted eye.

Quartz is the glassy portion of granite which cannot be scratched with a knife. It crystallizes in the well-known form, the separate crystals being always six-sided prisms, terminating in a rather blunt pyramid with six sides or faces; so that the description will be: crystallizes in six-sided prisms (hexagonal) with six-sided pyramid for a termination; color, sometimes tinged with pale smoky or rose color, sometimes violet as in the amethyst, usually colorless and transparent or milky white; luster, vitreous (glassy); hardness, cannot be scratched with a knife, and itself scratches feldspar, glass, etc.; not acted on by sulphuric, nitric or hydrochloric (muriatic) acids.

Feldspar is the white portion of granite which can be scratched with a knife. There are numerous varieties of feldspar, distinguished by their having either soda, potash or lime as one of their constituents in addition to the silica and alumina which are the essential ingredients, but it is not easy to give differences which would be easily recognizable by the beginner in the study. The crystallized forms are usually white, more or less inclined to be transparent or translucent in new fractures, but often weathering to a milky white. The feldspars in granites vary in color from white through pink to dull red, and often occur as seams of varying width running through the body of the rock. These seams are inclined to break into squarish fragments, showing the tendency of the crystals of this variety to have only four sides. In many of the porphyries almost the entire mass is feldspar, the body of the rock being a kind of paste of uncrystallized feldspar, colored various shades of brown, green, pink, red, and purple, with scattered crystals of white feldspar, or transparent quartz, imbedded in the paste, giving to it a spotted look. On decomposition of rocks largely composed of feldspar we have a series of clay formations, just as granites yield sand and sandstones.

Mica is the mineral which in thin plates is often wrongly called isinglass (which is fish glue). In color it varies from colorless or white to black, through various shades of gray, brown, yellow, green and violet, the commonest colors being white, yellow, dark brown, dark green and black. While sometimes found in crystals of large size, they usually are quite small. The crystals are flat, six-sided, and invariably split into extremely thin plates parallel to the base of the crystal. When broken across the crystal, as is often the case in a rock fracture, the characteristic six-sided form may not be visible, but the thin plates separate easily into a brushy edge. These plates are elastic and can be bent considerably without breaking, by which character the white varieties of the mineral can be distinguished from the crystallized varieties of gypsum, which are also white and transparent and split into thin plates or laminæ, but are brittle and break easily on bending. They are also destroyed by the action of heat, whereas mica is practically infusible at ordinary temperatures, and is therefore used for stove fronts, etc. When a rock is broken the crystals may show with the flat side up, when they will appear as in *a*, pl. 13, fig. 14, but if the fracture cuts through the crystal the shape may be like *b* in the same figure, the edges of the thin plates showing distinctly. The colorless or white mica is called muscovite; the brown or black variety, biotite.

Hornblende occurs usually in small crystals, generally black or greenish black. It is harder than mica and does not split into thin layers, which fact can be determined by the use of the knife. It very frequently crystallizes in little square columns like *a* in pl. 13, fig. 15, and sometimes in six-sided crystals, which may, however, be easily distinguished from mica by having two of the opposite sides much wider than the others, as in *b*, pl. 13, fig. 15. Hornblende is not always crystallized. It often occurs in greenish or blackish masses with a fibrous or radiated structure, sometimes forming a rock almost by itself (hornblende rock) and grades down into asbestos, which has practically the same composition, and is only one of the uncrystallized forms of hornblende, of which there are many minor varieties, just as there are of mica.

Augite is similar in appearance to hornblende, except that the crystals in cross section show eight sides, as in pl. 13, fig. 16, and is much less important than hornblende to the student of rock composition, until he has made some progress. We have thus two usually pale or white minerals, and three dark brown, greenish or black minerals to deal with, and a very small amount of practice will enable anybody to pick them out easily. The knife will tell the difference between quartz and feldspar, but mica, hornblende and augite are easily scratched with the knife, giving a colorless streak, and the difference between the three minerals must be determined by the shape of the crystals.

Many other minerals are associated with these, as small grains of magnetic or titanic iron in granites, forming the "black sand" of the miner; but they are not essential constituents, except in a few cases. Garnets, tourmaline, olivine, chlorite, chrysolite and apatite, the last four all green minerals, may occur in small grains or crystals, or may sometimes be so abundant

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as to give a distinct character to the rock, which may then be called a "garnet rock," "chloritic slate," etc., as we shall notice later on.

ROCK STRUCTURE.

All rocks present lines of fracture, even though they were deposited as a solid mass, but some present a series of parallel planes along which they split with great facility, sometimes along the lines of original deposit, and sometimes nearly at right angles to the former. These fissure lines are known as stratification or lamination, cleavage and bedding planes, and it is highly important that they should not be confounded.

Stratification is the result of earthy matter being deposited in water as layer after layer, with intervals of time between the deposition of the layers, during which the first layer deposited had time to harden or form a sort of crust which prevented it mixing freely with the succeeding layer and so on; so that the mass has become like a series of sheets of paper laid one upon the other, and when converted into rock by the lapse of time, and raised out of the water, the rocks split easily along these lines of deposit. The layers may vary greatly in thickness, depending on the amount of sediment brought down by the stream and the length of the flood periods. It is easy to understand that a stream during flood will carry immense quantities of matter into a lake or the ocean, becoming clear during periods of drought, thus fulfilling the conditions called for; and that such streams as the Mississippi, Amazon and Ganges may form beds of vast extent, while others may be limited to the area of a small lake. Rocks formed in this manner are known as sedimentary or stratified rocks.

Cleavage.—Certain rocks, such as roofing slates, while belonging to the stratified series, have become so altered by pressure that they no longer split along the lines of stratification or deposit, sometimes known as "lamination lines" (a term applied to the thinner strata), but on a series of joints which have been subsequently formed by this pressure, generally more or less at right angles to the lines of the original deposit. The old lines of lamination are obliterated, and this new series of joints is much more numerous than the original horizontal planes, and the splitting character much more perfect, dividing the rock into very thin sheets. This structure is known as "cleavage." It is more or less developed in coal beds and is there known as the "cleat," and is the cause of the coal breaking into small pieces when mined. In crystals of minerals the cleavage is the line on which the mineral splits most readily, and is usually parallel to one of the smooth faces (facets) of the crystals. This is well illustrated in mica and gypsum.

Bedding Planes and Strike Joints.—In addition to these splitting planes, all rocks (even limestone and eruptive rocks) have acquired two or three sets of joints, more or less at right angles to each other, which divide the mass into large blocks and greatly facilitate the labor of the quarryman, who takes advantage of them in his mining operations. These may be altogether independent of stratification, being the result of the upheaval and compression of the earth's crust, though in some cases they may follow some of the more or less horizontal lines. Upon their character frequently depends the shape of mineral veins and deposits. The joints which are roughly horizontal, or parallel to the original stratification, are called "bedding planes" or "dip joints," and the series running with the general trend of the rocks through the country, the "strike joints." These joints may be very numerous or wide apart, and are the cleanest cut in close fine-grained rocks such as limestones, where they are not obscured by the stratification planes, and also in some granites, furnishing fragments of all sorts of angles. These joints may be only a few yards long, or may extend for a mile, the latter feature being most prominent in close-grained rocks which have suffered comparatively little disturbance. A little thought will show why building stones should be put into the structure in the same position that they had in the quarry, that is, laid according to their "bedding," being stronger in this way than any other and less liable to scale off, on exposure to frosts and the acids in the rain water of cities.

Metamorphism.—All rocks are constantly changing their character. The mud banks of to-day will be the shales and slates of the far future, and our sand banks. the sandstones of a coming era. In the same way and by the same agencies of time, moisture, pressure and heat, many of the older sedimentary rocks have lost much of their original character. The sandstones have become massive quartzites, in which the small grains of quartz which compose the sandstone are no longer visible; and the slates and shales have lost many of their lines of stratification, besides suffering other changes which have imparted to them a new common character, known as "schistose." Such rocks are called schists. It is sometimes a very hard matter in a hand specimen of these rocks to determine by the eye whether it belongs to the metamorphic or eruptive series, so extensive have been the changes, and only the microscope, or a distant view, when the main features of the mass alone strike the eye, can settle the question. (When the microscope is used in the determination of the rocks, a flake of rock is ground down so fine that print can be read through it, and it is this film that under the microscope tells the story of its origin and composition). By reference to pl. 2, fig. 3, the difference between the structure of slates and schists will be better understood. The upper part of the figure represents a slate rock (let us say one in which there are numerous fragments of hornblende by way of illustration, otherwise a hornblende slate) and the lower part a schist having the same composition, called a hornblende schist. In the latter there has been such a rearrangement of the particles that though the mass retains some traces of stratification, in the parallelism of its bedding planes, it has lost the smooth lamination planes, and consists of a series of plates, thickest in the middle and thinning out all round like a flat lens, the result being a very characteristic appearance (known as "foliated"), in which only a few of the lines of stratification have been preserved, although the process has not been such as to produce clean-cut cleavage. The result has in most cases been to toughen the rock, felting the constituents together, and few are more difficult to handle than this same hornblende schist, as it will not split and is much less brittle than most eruptive rocks. In these metamorphic groups the changes have usually been so great that all traces of fossils have been destroyed, and their geologic age can only be inferred from their associations. They are abundant in volcanic regions and largely associated with mineral deposits. Their ultimate condition when metamorphism is complete, appears to be a return to a rock in which all trace of its sedimentary origin has disappeared and which cannot be distinguished from those which we know to have had an eruptive origin. The term metamorphism is not applied to the simple hardening of muds into slates, or similar processes, but only to those changes in which a rearrangement of the particles has produced a rock with a decidedly differing appearance.

CLASSIFICATION OF ROCKS.

Rocks may be divided into simple and compound, the first class including those which consist essentially of one mineral, such as some limestones, gypsum, rock salt, and serpentine; the second including those which are made up of a combination of several dissimilar minerals.

The simple rocks resolve themselves into two groups, the first of which consists of chemical precipitates, and the second of organic structures.

The compound rocks resolve themselves into what may be called the "original" group, consisting of those of eruptive or volcanic origin, which are again divided into the "plutonic" and "igneous" series, the former term being applied to those rocks which have been intruded from below without reaching the surface, and the latter to those which have been ejected as lava from volcanic vents; and the "secondary" group, which is made up of rocks derived from the wear and tear of all other rocks previously formed, whether original or already secondary. This group may be divided into the "stratified" rocks which have been deposited in layers by the action of water, and those which are the result of volcanic outbursts other than lava, and which may be termed "fragmentary."

The stratified rocks are again devisible into the simple and metamorphic sections.

The boundary lines between all these groups are very poorly defined, and they can only be taken as generalizations. Thus many limestones may contain so much sand and clay, along with their fragments of coral and sea shells, as to be almost a compound rock, but they largely lack the stratified character, while in the compound rocks many which have been ejected from volcanoes also occur in situations where they have obviously never been exposed to the atmosphere at the time of their formation, as the basalts in the coal beds. The following tabular presentation will show the general arrangement in a compact form:

ROCKS CLASSED ACCORDING TO ORIGIN.

A. SIMPLE ROCKS.
  I. *Chemical Deposits*—such as some limestones, rock-salt, gypsum, serpentine.
  II. *Organic Deposits*—such as some limestones, chalk, infusorial-earth, coal, etc.

B. COMPOUND ROCKS.
  I. *Original group:*
    1. Plutonic series—such as granite, syenite, etc.
    2. Igneous series—such as basalt, trachyte, etc.
  II. *Secondary group:*
    1. Stratified Rocks:
      a. Simple—such as shales, sandstones and conglomerates.
      b. Metamorphic—such as quartzite, soapstone, schists, etc.
    2. Fragmentary Rocks—such as breccias, volcanic tufas, and glacial deposits.

SIMPLE ROCKS.—As the limestones fall within the limits of both the divisions of this class no attempt will be made to treat the sections separately. Rock salt and coal are very important commercially, but the lime rocks from the great bulk of this series, either as sulphates (gypsum) or, more commonly, as carbonates (limestone, calcite). The great mass of limestone has been segregated from sea water, into which it has been carried by the streams which have dissolved it from the rocks through which their waters have percolated.

Limestones proper vary in hardness from very soft to quite hard rocks, compact and usually close-grained in structure, ranging in color from white through shades of yellow and drab, to blue and even black, and consist essentially of carbonate of lime, which effervesces on the application of acids; and they may contain so many impurities, such as clay, sand, etc., that they become unsuitable for the manufacture of quicklime for building purposes. This arises from the varying conditions under which they have been formed, and which determine their character. A large portion of them consist of the rocky skeletons of corals or the shells of minute animalcules.

Chalk consists of the minute shells of a vast group of small animals called Foraminifera, which live in sea water in countless millions. These extract the carbonate of lime, which forms their shells, from the sea water, and when dead they fall to the bottom forming a soft ooze, which if exposed to view in future ages would be the same as chalk as we know it. These shells are so minute that only a powerful microscope can show their forms, and it takes millions of them to form a cubic inch of rock. The purer forms of chalk are soft, white and earthy, but time has wrought such changes that some of its varieties become more and more compact, until they grade into limestones, and the organic formations have had their constituents so modified that nearly all trace of their organic origin has disappeared, and they can scarcely be distinguished from the granular crystalline chemical deposits.

Flint, which is a form of silica, occurs in the chalk beds, and has probably been formed by the separation of small quantities of silica from some of the organic remains, by percolating waters, and its concentration into rough nodules of very compact structure, usually dark or blackish in color, and resembling horn or glass in thin fragments.

Coralline Limestones.—Immense deposits of limestone have been built up by coral insects, like the reefs so common in the warmer seas of the world at present, and these usually contain numerous fossils which stand out more or less prominently on the surfaces of the rock which have been weathered by the action of air and water, though they may be indistinguishable on a freshly broken surface. This probably arises fom the greater solubility of the uncrystallized portions of the rock.

Other deposits have been made up of broken fragments of coral detached from the main reef, and washed upon the adjacent beach, where they have been mixed with sand and broken sea shells,forming beds with many impurities.

Besides these, there are compact beds which appear to have been chemically deposited. To this section also belong those deposits made by hot springs which deposit the excess of lime held in solution on cooling as "sinter," a term applied to all such formations, whether formed of lime or silica. If made of the former, they are known as "calcareous sinter," if of the latter as "silicious sinter."

Limestones for making quicklime should be free from silica. When this is present in considerable quantities, it not infrequently makes itself visible on the weathered surfaces, imparting to them a peculiar dry harsh feel, the lime wearing away more rapidly than the silicious portion, which is thus left in relief on the exposed surfaces. These silicious limestones and those carrying clay or alumina, which are not suitable for the production of ordinary lime, are utilized in the manufacture of hydraulic cements.

Marble is a variety of limestone in which the entire mass has become highly crystalline. The finest varieties are as clear and even in grain as lump sugar. In colors there is an infinite variety, many kinds being often found in the same belt. Freedom from iron minerals (which will rust and stain the dressed slabs), purity of color and closeness of grain are the chief elements in determining the value of marble, but cheap transportation to market is essential to the successful opening of a quarry, however good the stone may be.

Dolomite is a magnesian limestone, consisting of the carbonates of lime and magnesia, usually of a crystalline texture and yellowish tints; and while some bodies appear to be original chemical precipitates, others are undoubtedly ordinary limestones which have been changed by the percolation of magnesian waters. Both the ordinary carbonate of lime and the magnesian variety are used as fluxes in the smelting of iron and lead, but all limestones are not of equal value for this purpose, any more than they are for quicklime. A chemical analysis or practical test must determine their value for both purposes.

Magnesite in composed of carbonate of magnesia, and is much less common than limestone or dolomite.

Limestone crystals (calcite, calcspar) are often mistaken for quartz, and as it is a frequent accompaniment of metallic ores, the chief differences are worth noting. In crystallized limestone the characteristic shape is rhomboidal; that is, the crystals are four-sided, but none of the angles are right angles, while each pair of sides is parallel. When crystallized in pointed forms with six sides, the crystals are like pyramids, without the straight portion seen in quartz, and the apex is more pointed. This sharp-pointed character has given it the name of "dogtooth spar." In addition to these differences it is much softer than quartz, being easily scratched by the knife, and splits easily along the line of cleavage. Carbonate of lime (calcite) is not likely to be mistaken for any other mineral than quartz except feldspar and gypsum, and from these it may be distinguished by the action of acids, or by the fire test to ascertain if it will form quicklime. This will set slowly, whereas burnt gypsum forms plaster of paris and sets promptly when mixed with water, but does not become as hard as the cements made by calcining silicious limestones.

Gypsum (sulphate of lime) differs from the carbonate in that it does not effervesce with acids. It is valuable chiefly as the source of plaster of paris and as a manure, the latter consisting simply of the raw pulverized rock. Gypsum crystallizes in white translucent masses which scratch very easily and split into thin non-elastic flakes, which may sometimes be obtained of great size; this form is known as

Selinite.—Fibrous, very silky varieties of gypsum are known as "satin spar;" and the close-grained forms, when of even texture and finely crystalline, are distinguished as "alabaster."

Infusorial earth resembles chalk in appearance and general constitution, being made up of the skeletons or shells of minute organisms, but the term is generally applied to those which consist of the scales of little vegetable organisms called "diatoms." These are made of silica instead of lime, and consequently the rock is not acted on by acids. The excessive fineness of the powder derived from crushing these earths, and the hardness of the individual particles, make them very useful for polishing powders, which are known commercially as "tripoli," "electro silicon," etc.

Serpentine is essentially a hydrated silicate of magnesia, and is a dark blackish-green rock, with very smooth slippery joints, genérally highly polished and variegated with greenish or yellowish films, like soapstone or French chalk such as is used by tailors. The more brilliantly colored varieties are used for ornamental stonework, under the French name of "*verde antique.*" While some serpentines have been original deposits on the sea floor, others have been in all probability intruded masses of eruptive rock, containing olivine, which have undergone extensive metamorphism and assumed their present aspect.

Compound Rocks, Original Group.—Instead of describing these rocks under the two series named in the table, which is based on their origin, and often calls for extended investigation to determine to which series any particular rock should be referred, it will be sufficient to here classify them by some striking physical peculiarity which is easily recognizable by everybody.

Three distinct forms may be recognized: (1) Those which are entirely crystalline, or made up of a mass of crystals each of which is distinct; (2) those in which a certain portion of the crystals are scattered through a "paste" of feldspar, which is very compact and does not show any distinct structure; and (3) those which do not show any signs of crystallization, but are of the same character throughout.

It must be understood that this arrangement is purely arbitrary, as it separates closely allied forms; but it possesses the great advantage of being applicable without the use of the microscope, which is essential to any scientific classification. In this place the object is simply to enable the miner to find out the approximate name of any particular rock with the smallest amount of trouble, and not to educate him for an expert petrologist. Only the most characteristic of these rocks will be described.

In the crystalline rocks the size of the crystals does not change the name of the rock. The size of the crystals may be said to merely indicate the rate at which the mass of rock cooled, and the amount of pressure under which the cooling took place. If an ejected lava cools very rapidly there is no time for the particles to arrange themselves in any particular manner, and the product is a rock which has all the appearance of the slag from a smelting furnace. If the rate of cooling has been slower we have a crystalline rock in which the separate crystals are small; and if the cooling has been excessively slow we may have large and well-defined crystals, there having been ample time for a complete arrangement of all the contents of the rock into their respective kinds, according to the proportions of the various constituents and their relative affinities. While this may be stated as a general proposition, it must not be taken as an absolute rule, as it may be varied by the more or less easy fusibility of the different minerals varying the process. These rocks vary greatly in their mode of formation, though they all agree in their comparatively deep-seated origin. As they are intimately connected with the great changes in the earth's crust, and probably owe their fusion to the heat developed by the immense pressure and friction incident to these changes (and perhaps by chemical action), it is not surprising that we find them chiefly in those localities where these changes are most actively at work, namely in the great mountain ranges. They may be found as great bosses or as dikes which have been squeezed into the rocks from below while in a plastic or semi-fluid condition, as in the case of some granites (pl. 5, fig. 5) or of the trachytes shown in pl. 5, figs. 1, 2 and 4. In the latter case the force exerted was not sufficient to break through the crust of overlying rock, but was sufficient to lift a portion of the surface into the form of a dome, the space thus formed being filled with the molten rock, a portion of which through smaller vents found its way in the horizontal layers of the sedimentary rock, forming beds between them, just as the basalt lava has found its way into coal seams, as shown in pl. 5, fig. 6, and between the shales as in pl. 5, fig. 3. In these figures No. 4 shows the theoretical structure of such a lava mass, showing the pipe *a* through which the lava (black) was seeking an outlet, and the lava forming a solid mass with branches penetrating the overlying strata, and forming thin beds between them. In fig. 1 we have the top of such a mass exposed in the side of a cañon, of which *a b* is the bed, with the strata (partially worn away) curving over the solid lava; while in fig. 2 we have an actual cross section through a mountain formed out of such a block, the solid lines showing what remains in place, and the dotted lines the original shape of the portion which has been removed, *a* being the bed on which the lava (black) spreads out, and *b* the shales, between the layers of which thin sheets of lava found a lodgment, as shown by the alternating outcrop of *c*, *c*. In fig. 3 we have similar horizontal beds of lava *c*, penetrating the strata as offshoots from the dike *d*, but the lava at *c* is evidently only the remains of a similar sheet from which the superincumbent strata have been worn away, and not an outflow in the open air, because remains of other lava sheets are found above other strata at higher levels, as at *e*. In fig. 6, *a*, *a*, are shales, *b* coal, and *c* basalt, the latter intruded into the coal bed through the dikes *d*, *d*. In this case the coal is destroyed and the lava, originally black, has been altered to a whitish rock by the action of the coal on the cooling lava.

In other cases the lava has forced its way to the surface, through the fissured rocks, and overflowed from the dike in immense sheets, or has been ejected from volcanic cones in huge streams, which have traveled many miles, filling up valleys and even continuing their course under the sea. Similar eruptions take place on the sea floor. Volcanic eruptions are also frequently accompanied by the formation of vast fissures on the flanks of the mountain which become filled with lava, and all these exhibitions of deep-seated heat produce profound changes in the rocks which they traverse, the heat of lava streams being preserved for many years after all volcanic activity has ceased, so slowly do they cool when once crusted over.

It is thus evident that the same body of lava may cool under very different conditions, and these have more or less effect on the appearance of the rock, so that the determination of the different kinds is often a matter of difficulty even to experts.

ORIGINAL COMPOUND ROCKS, FIRST GROUP (wholly crystalline).—Adopting the simplest though arbitrary classification for the sake of convenience, and disregarding for the present purpose differences of origin, the compound "original" rocks (including both plutonic and eruptive rocks) of the first group embrace such species as granite, syenite, felsite, elvanite, trachyte, basalt, etc.

Granite is a mixture of quartz, feldspar and mica. It may be either fine-grained or coarse, and vary in color according to the color of some one of its constituents. If the mica is white, we have a nearly white or light-colored granite; pink and red granites take their color and names from the tint of the feldspar, just as very dark or even black granite results from the abundance of black mica. When the feldspar is white and mica black in moderate quantities we have various tints of gray. It is often traversed by dikes of younger age, usually paler in color and more compact than the rock which they cut; and though called the oldest rock, it is frequently found as veins (connected with the main mass) which penetrate both the stratified and unstratified rocks above it (as shown in pl. 5, fig. 5), which are usually much altered thereby. Granite belongs to the group of rocks called "plutonic," which have not broken through the surface of the earth's crust, but have consolidated at some depth beneath it. Sometimes hornblende is present in small quantities along with the mica, when it may be termed hornblendic granite, on the principle of using as a descriptive adjective the name of any peculiar mineral present in a rock but not essential to its composition.

Granite seems to be the underlying rock of the entire series, and if this be the case it is not strange that all the rocks which have been derived from it should show a tendency to return to it, in appearance and composition, during the lapse of time, through the agencies of heat and pressure.

Felsite, felsite-porphyry and elvanite are crystalline mixtures of quartz and feldspar, usually so intimately mixed that in felsite the crystallization is scarcely visible, while elvanite is more distinctly granular. The latter rock is of frequent occurrence in the mining districts of Cornwall, and the dikes of it are known by the miners as "elvans," from which term the scientific name of the rock has been derived.

Trachyte and Rhyolite.—In many respects trachyte resembles granite, but may be easily separated by the feel of a fresh fracture, which is exceedingly sharp and rough, suggesting the surface of a cat's tongue. It occurs as dikes and large eruptive overflows, belonging to the series of modern lavas. In color the rock has a wide range of variation from gray to pink and brown. In composition the feldspar predominates over the quartz and is usually accompanied by hornblende, mica or augite. It may be considered the modern equivalent of the older granite, but differing from the latter in being a volcanic product. Rhyolite is another rock so closely related to trachyte that the beginner will find it hard to separate them. As the mode of occurrence and general associations are entirely similar to trachytes, the distinction is not of essential consequence.

Syenite.—The foregoing rocks have quartz as an essential constituent, while in syenite and basalt it is absent as free or visible quartz, or nearly so. Formerly syenite was considered a crystalline mixture of quartz, feldspar and hornblende, but the term is now used for a rock made up of crystalline feldspar and hornblende, with mica as an accessory or accidental mineral. In appearance it strongly resembles granite (but the knife will show the absence of quartz), and occurs in much the same way. The feldspar has a different composition from that found in granite.

Basalt is the last of the wholly crystalline series which need be noticed here. It is usually a very dark, blackish, fine-grained rock, consisting of feldspar and augite, with a variety of associated minerals, such as olivine, occurring as small olive-green grains, of which the oxides of iron and manganese form about 15% of the mass, making the rock unusually heavy (sp. gr., 2.95). It has been ejected from modern volcanoes in immense quantities, covering hundreds of square miles in the States of Washington and Oregon, the successive eruptions or overflows from dikes forming a series of layers, resembling strata, and having in the aggregate an immense thickness. It is also the rock now being ejected by the volcanoes in the Hawaiian Islands, and, from its fluid character when molten, forms perfect rivers. It was such lava streams which filled the mountain-valleys of California and covered the gold-bearing gravels during the second outbreak, as the trachytes had previously done at a much earlier period. When cooled rapidly, as on the surface of a new outbreak, it becomes full of bubbles formed by the expansion of the steam contained in the lava (to which it owes its fluidity), and it is in these cavities that opals, calcite and similar minerals have been formed by percolating waters. The porous lavas, with the bubbles so filled, are known as amygdaloids (from a word meaning almond). Below the surface the pressure has prevented the expansion of the steam so perfectly, so that the bubbles get smaller and smaller till the mass becomes perfectly crystalline. Very fluid lavas may be so filled with these air, gas, or steam cavities that they look spongy and will float on water as "pumice stone," or they may be drawn out by the violent winds eddying round the crater into fine threads like spun glass, in which form they are known as "Pele's hair," Pele being a goddess associated with the Hawaiian volcanoes. Basalt frequently crystallizes into a columnar structure, the pillars being five or six-sided, with ball-and-socket joints. This columnar structure is always at right angles to the sheet of lava, so that in dikes they form more or less horizontally from wall to wall, and in overflows more perpendicularly.

SECOND GROUP (porphyritic).—In this group we have quartz-porphyry and a whole series of other porphyries in which visible quartz is absent and which for the purposes of the miner we may designate simply as "porphyry," using the term as a general one.

Quartz-porphyry or dacite consists of a paste of feldspar which shows no sign of crystalline structure, the color of which may range from dirty white to pink, purple, brown or slate-gray. In this paste are scattered small grains of transparent quartz, making a very characteristic rock which occurs in large masses, the rock belonging to the series of old lavas. It is largely developed in the Comstock mining region.

Porphyry.—Under this head may be classed all the rocks in which the paste just described contains distinct crystals of feldspar, giving them a spotted appearance. They may contain mica, hornblende or augite as an additional mineral, and it is the presence of these, along with differences in the composition of the feldspars, which constitutes the basis for a new name.

They occur as dikes, veins, intruded sheets, or as surface deposits, and include such species as porphyrite, diorite or greenstone, andesite, phonolite or clinkstone, etc.

THIRD GROUP (non-crystalline).—In this group we have pumice stone, already described, and as the principal rock—

Obsidian, which is a lava cooled very rapidly, looking like coarse bottle glass, and hence frequently called "volcanic glass." It is of various shades in greenish black, black or red, and the red varieties are sometimes marbled with black streaks which are drawn out in the direction of the flow of the lava stream while yet in a pasty condition.

It is not pretended that the foregoing descriptions are absolutely scientific. To lead the miner into the mysteries of orthoclase, plagioclase and triclinic feldspar would be to hopelessly bewilder him; yet many of the distinctions between the various eruptive and intrusive rocks are based on the one or other of these feldspars being the predominant component. The use of a powerful microscope is often necessary to settle disputed questions, and all rock-students know how many of these there are. If the descriptions will enable a person to distinguish a granite from a porphyry, a felsite from a basalt, or a trachyte from a quartz-porphyry, they will serve their purpose; indeed, they would almost do so if they will separate an eruptive or volcanic rock from a schist, and a schist from a shale. The student who once begins to take an interest in rocks will soon discover that their varieties are almost infinite, but that they resolve themselves into a few tolerably well defined groups, and will inevitably be led to examine into their differences and perpetually to ask himself the reason why. When the eye is thus trained it is time enough to name these slighter differences, which are puzzling enough to expert observers.

A general term for many of these eruptive rocks is "trap," from a Scandinavian word meaning steps or stairs, in allusion to the forms in which they often "weather." This weathering, a term applied also to the changes which take place on the surface of rocks exposed to the destructive action of the elements, is sometimes of great assistance in determining the true character of the rock, especially in those with a fine grain and dark color, as the feldspar on exposure, instead of retaining the glassy look which it may have in the mass (making it hard to recognize), becomes milky white and shows distinctly on the surface of the bowlders, even though in a clean new fracture the latter may be nearly uniform dark bluish-gray or almost black. In other cases the outer surface may be pitted with little angular holes from which the crystals have been dissolved, thus readily separating the rock from the stratified series to which it may otherwise have much resemblance. If depending on the pitted surface, however, care must be taken to ascertain that the pits are not "casts" of crystals of iron pyrite, as this mineral is abundant in all rocks whether eruptive or stratified, especially so in the former when decomposition of the mica or hornblende has set in.

SECONDARY COMPOUND ROCKS, STRATIFIED SERIES.—The character of the rocks which are in process of decay and are being swept into the smaller streams and thence through the rivers to the ocean, plays an important part in the formation of soils and the sediments carried away by water and deposited to form rocks. If granite were the only rock being worn away by a stream, and the disintegration were complete, we should have clean deposits of sand and clay full of mica and hornblende. But when the stream began to cut into other rocks there would ensue a change in the character of the deposits, which would become yet more strongly marked if the destruction of the rocks had extended into groups already stratified. It is, therefore, easy to see that the conditions surrounding the formation of stratified rocks are very complex, and we must look for great local differences even in rocks made at the same geologic period. So great is this difference at times that it would be impossible to place many rocks in their right chronological order if it were not for the fossil remains with which they abound, so that the prospector should religiously preserve all such fossils as he may find, or take such a note of the locality that he may direct others to it.

The ultimate analysis of the foregoing compound original rocks gives approximately the percentages shown in the following table, compiled from Geikie, from which it will be seen that they resolve themselves into three groups chemically. The large percentage of iron and manganese in the porphyries and basalt is largely due to the presence of grains of magnetic iron in the porphyries, and the oxides of iron and manganese in the basalt.

CHEMICAL COMPOSITION OF ORIGINAL COMPOUND ROCKS.

	Silica.	Alumina.	Lime.	Iron, Manganese, etc.	Potash.	Soda.	Magnesia
	%	%	%	%	%	%	%
Granite.......	72	15	1.6	2.2	5.1	2.8	0.3
Quartzite.....	77	13	0.7	1.1	4.3	0.7	1.0
Syenite.......	60	17	4.4	7.0	6.6	2.4	2.6
Trachyte.....	60	17	3.5	8.0	5.0	4.0	1.0
Porphyries...	53	16	6.3	14.0	1.3	2.2	6.0
Basalt........	45	15	10.5	15.0	1.5	3.5	6.5

The potash, soda and magnesia, being soluble, are carried away on decomposition, and form the alkaline matter which accumulates in lakes without outlets, such as Walker, Mono, Pyramid, and other lakes in the Great Basin between the Sierra Nevada and Rocky Mountain ranges in the United States, giving them their intensely saline character if the rocks furnishing the material contain but little magnesia, and a bitter taste if there be much of the latter present. Thus the drainage of a basalt region should furnish magnesian, and of a trachyte country saline waters.

The silica, alumina, lime and iron are thus left to form the sedimentary rocks. The iron plays its part chiefly as a component of the clays and a cementing material for the sandstones, to be afterward leached out and accumulated in local deposits as bog iron, which by the changes of time becomes the source of other iron deposits of various kinds. The lime, being less soluble than the alkalies, is slowly leached out of some of the rocks, especially by water containing carbonic acid, and redeposited on exposure to the air as a sediment by the springs which have dissolved it, or is carried to the ocean to furnish material for the coralline structures or the shells of its multitudinous life.

The quartz and clay, the chief constituents left, furnish the bulk of the sedimentary material, which, with the addition of waterworn fragments of undecomposed rock naturally resolves the deposits into two series, to the first of which belong the conglomerates, gravels and sands, and to the second the muds and clays (derived chiefly from the alumina), shales and slates.

All material washed into a stream by the rainfall on the adjacent hills, and falling therein by the undermining action of the current on the banks, becomes a source of sedimentary deposits. If the fragments are too large to be moved by the current, they remain in the stream bed until gradually worn away by the attrition of smaller rocks and sand over them; if smaller and movable, they are only carried along to the first dead water, whether it be a lake or the ocean, and there deposited, and this deposition involves a sorting of the material. The larger and heavier pieces will be deposited first as coarse gravel, then finer gravel, then sand, and the finest sediment being carried the furthest will be laid down as mud or silt, unless the lake be so small and the current of the stream so swift that it is swept into the outlet beyond, leaving only a deposit of sand and gravel. It will thus be seen that the same material may appear as gravel at one place, sand at another, and mud at another. But large streams usually carry only the finer sediments when they reach comparatively level country, having left the larger particles at the foot of the mountain slopes, and as in the case of the Amazon they may spread this over a sea bottom hundreds of square miles in extent. A similar process is carried on at the sea beaches where the reflux of the tide may carry the finer material seaward, leaving the coarser at the foot of the bluffs.

While stratification usually occurs horizontally, it is not necessarily so, as in the case of mountain streams the coarse gravel would accumulate the most rapidly, forming a sloping bank, on which the layers deposited in successive flood times would take the same inclination. So, in like manner, the ashes ejected from volcanic cones, falling on the sloping sides of the same, would accumulate in layer after layer, presenting all the appearance of deposits made in water, but retaining the slopes of the flanks of the cone.

Conglomerates are largely formed on sea beaches by the rolling of the rocks washed out of the shore bluffs into rounded fragments, which will naturally be of various kinds of rock, according to the material of the hills which are being worn away. Deposits formed by river action are apt, from the circumstances under which they are formed, to be much more limited in extent than those made along shore lines. They consist of rounded pieces of rock of various kinds cemented together either with hardened clay or silica, and sometimes with iron oxides derived from percolating waters or the black sand. They may be fairly fine if made of gravel, or excessively coarse, and, if made up chiefly of one rock, may be known by the name of that if it is specially desired to distinguish and separate them, as quartz-conglomerate, or trachyte-conglomerate such as is found in connection with the lavas of the California gold-gravel channels. Some of the schists contain bowlders, leading to the conclusion that they are, in this case, merely altered or metamorphic conglomerates; and in other cases the cementing process is so perfect and the consolidation of the mass so complete that the pebbles will break in two on a general line of fracture, without becoming removed from the mass. Cuttings through conglomerate beds stand with nearly vertical walls.

Sandstones consist essentially of sand cemented together with iron, each grain being coated with a thin film of iron oxide, which imparts the general color to the mass, as in the red sandstones. The grains of sand when cleaned of the coating may be either tinted or colorless. Mica forms a common addition to many sandstones, as well as lime and clay, when they may be distinguished as mica-sandstone, etc. The lime and clay are not readily discernible to the unaided eye. Flagstones are only sandstones which split easily into thin slabs, suitable for sidewalks. Buhrstones are sandstones so thoroughly cemented that they are very hard and rough enough to furnish the grinding surface required in millstones. "Freestone" is sometimes a sandstone which cuts freely in any direction, either with the stratification or across it, but hardens on exposure to the air. The term is however sometimes applied to limestones and other rocks which present the same characteristics.

Quartzite is a sandstone which has been subjected to the action of heated waters, which have aggregated the grains of sand together with a silicious cement, probably derived from a partial solution of the grains of sand themselves, until the rock has lost its granular structure, and to a large extent resembles massive quartz. It is a common rock in mining regions, and occurs with other metamorphic rocks, but also in situations where the associated strata have undergone no change.

Clays are formed out of the alumina in the feldspar and other minerals, silica excepted, of the eruptive or volcanic rocks, and are the finest of the sediment carried in suspension by water, varying in color and composition according to the rock to which they owe their origin, and the particular stage in the journey of the stream at which they were deposited. They may be exceedingly pure, in which case they are called "fat" in the language of the brickmaker and potter, and from this range downward to a clay loam, in which there may be a very large excess of impurities, of which iron forms a large part. The richer clays require the addition of sand to make good brick, but possess the advantage of a more uniform composition, which enables the manufacturer to regulate the addition of sand to a nicety and thus produce an article of uniform quality; the poorer kinds make only the most inferior grades.

Fireclay.—A good fireclay has a composition of silica 73.82%, alumina 15.88%, oxide of iron 2.95%, water 6.45, with traces only of lime, sulphur, magnesia, soda and potash, which is very nearly the chemical composition of granite, with the lime, potash, soda, and magnesia eliminated, so that such clays could easily be formed by the decomposition of that rock. Fireclay is largely associated with coal seams, the clay floor retaining the waters which made the tangled swamps in which many coal beds were probably formed.

Kaolin or porcelain clay is derived from the decomposition of the feldspars of the granitic rocks and porphyries, and is essentially a compound of the oxides of silicon and aluminum mixed with water, the composition when pure being silica 46.3%, alumina 39.8%, water 13.9%. Impurities are frequently present, the principal one being iron derived from the other minerals present in the rock from which it was formed. When pure it is white, ranging through yellowish to brownish red, when much iron is present, say 5% or upward. The preparation of the clay by grinding, washing and settling is a slow and tedious process.

Shales are only hardened clays which have been deposited from time to time in thin sheets, so that the resulting mass splits readily into thin layers along the lines of deposit; but while they all retain this common character, they vary greatly in composition, and may be distinguished from each other by the names of the minerals which may give a special appearance to the rock, as mica-shale, hornblende-shale, silicious shale (when sandy) or simply clay-shale. In color they vary as much as in composition, from pale gray to black; in the latter case they are usually colored by small scales of graphite—black-lead or plumbago—derived from the carbon of the organic matter washed down with the clay sediment and buried with it. This organic matter may be so abundant that the shales may be called bituminous or oil-shales.

Slates.—For all this series of rocks the term slate is also very generally used, as clay-slate, mica-slate, etc.; but, strictly speaking, the term slate is applied only to those rocks which have lost their shaly character by end pressure on the strata, and now split on the lines of cleavage, as previously defined, such as roofing slate (pl. 12, fig. 4). In these latter rocks the particles have rearranged themselves at right angles to the line of pressure. This effect has been repeatedly produced exprimentally, and the student must early relinquish the common idea of the absolute rigidity of rocks. As a matter of fact, they are plastic or may be molded to an extraordinary degree, many of the shales and slates having been folded and wrinkled like sheets of paper, and this not only on a grand scale, but down to the most minute plications. Samples of this folding are shown in pl. 12, fig. 8, where the folding element has been the intrusion of the dike *d;* and in pl. 4, fig. 6, where the cause has been general lateral pressure, crowding the rocks into a smaller amount of space horizontally. Not only can cold lead under a sufficient pressure be squeezed as a jet through an aperture suitably provided, but cold iron can also be pressed so as to penetrate into the angles of suitable molds. This facility with which rocks can be modified in their structure, and bent and folded, has an important influence on the filling of veins, as intense heat is developed in the process, and this, in the presence of water, will decompose and rearrange all the components of the rock, dissolving some which are replaced by new combinations and producing metamorphism.

SECONDARY GROUP, METAMORPHIC SERIES.—All the shales and slates may be thus converted into schists, previously described. As in the case of the shales, each variety may be distinguished by the predominating or characteristic mineral, as *mica-schist,* which gradually shades off into *gneiss,* which is a rock having a composition exactly like granite, but without the uniform crystalline character of the latter, or the foliated structure of the schists. In gneiss there is a tendency for all the mica to be laid in horizontal or more strictly speaking parallel lines, while the quartz may occur in pure bands, and there is a tendency of the mass when viewed on the large scale to look like a coarsely stratified rock. From this characteristic appearance there may be a gradual change until it is hard to say whether the rock should be called gneiss or granite, leading us to the conclusion that many so-called granites are only the last stage of the metamorphism of an original sandy bed of clay containing mica, such as are common everywhere.

When hornblende is the chief mineral, we have *hornblende-schist,* a tough, dark greenish rock, which shales off into a rock so essentially composed of hornblende that it loses the schistose character and becomes what is called *hornblende rock.* When the shading off is in the direction of a more crystalline structure, the gradations may be toward a *hornblende-gneiss,* and from that to syenite, just as the mica schists grade into granites. It will, of course, be understood that these changes are not to be seen in small specimens, but only in the large area of a mountain range.

When the metamorphism has proceeded so far that the micas have been decomposed, so as to liberate the magnesia by the absorption of water, we have a series of rocks all of which are characterized by a smooth, slippery, greasy feel to the touch, commencing with *talcose schists,* of a greenish or yellowish tint; inclining to reddish from the decomposition of the minerals containing iron. On further change we may have *asbestos,* forming in the seams and joints of the rock, or the whole mass may be converted into *soapstone,* which is a compact whitish or greenish rock, without pronounced crystalline structure, easily cut by the knife or turned in a lathe. From its infusibility and the facility with which it can be cut into suitable blocks, soapstone forms an excellent lining for furnaces which are subjected to intense heat.

Chlorite-schists are similar in composition to talcose schists, but the talc is replaced by an apple-green mineral called chlorite, which not infrequently occurs along with quartz in mineral veins, as on the mother lode in California and elsewhere.

This series of rocks may be thus summed up, on two lines of progressive alteration, according to the starting point:

(1) Sands, sandstones, quartzite; (2) muds, clays, shales, schists, gneiss, syenite or granite.

SECONDARY GROUP, FRAGMENTAL SERIES.—Besides the rocks previously described, all of which show evidence of deposition in water and something like a regular order, there are still a few which cannot strictly be classed with them. These are either volcanic or glacial.

Volcanic Products.—Volcanic outbursts are often accompanied by the discharge of enormous quantities of dry dust and stones, some of which are rounded and others angular, or the dust may be an impalpable powder. Some of these may have been deposited under water, when they naturally have a distinct stratification; while in those laid down in the open air this structure may not be so well defined, though the alternating character of the material ejected may have formed apparently stratified layers on the sides of quite steep mountain cones. The discharges may consist entirely of lava fragments, or may include pieces of all the rocks traversed by the volcanic vent, and in many cases they have been cemented together by a lava paste. The various conditions in which they are found suggest appropriate names, as *volcanic conglomerate,* where the pebbles and bowlders are rounded; *volcanic breccia,* where these are angular; *volcanic agglomerate,* where there is a mixture of the two foregoing, usually without any distinct stratification. The finer materials are called *tufas* or *tuffs* and as a rule are distinctly stratified; and while of volcanic origin may contain organic remains or fossils, equally with ordinary water-formed sediments. The term *lapilli* is applied to the coarser portion of the volcanic dust, so largely ejected prior to the appearance of lava at many volcanic vents, to distinguish it from the finer volcanic ash, which may be a powder so fine that it can be carried hundreds of miles by the wind before finding a final resting place. This finest ash forms a large part of the sediment brought up from the floor of the deep sea, where it gathers as slowly and silently as dust in a deserted room.

Glacial Products.—While all the material discharged by glaciers into running streams is undistinguishable from other sedimentary deposits, those dropped by melting ice present only faint traces of sedimentation or none at all. Where floating ice is dropping its load of earth, sand, gravel, rounded bowlders and angular fragments, on the top of strata which are forming under the surface of lakes or shallow seas, we may find immense bowlders or bunches of gravel irregularly mixed with such deposits, which, while they betray the condition of the climate at the period of their formation, do not justify any special name to such accumulations of sediment. But where the glacial deposits are laid down by ice in deep waters, where the deposit of river or ocean sediment is forming very slowly, we shall have an irregular accumulation of material, without the regular stratification of river deposits, showing only what may result from the more rapid descent of the largest pieces, which, if they fell on a surface already smoothed by the more slowly descending finer sediment, would present faint traces of sedimentation, but the lines would not be traceable for more than comparatively short distances, the successive deposits fading out laterally and overlapping each other. Such also are the deposits of *bowlder clay* which have also been formed by the grinding action of an ice sheet. There is nothing to prevent such deposits carrying ore, except the irregularity in their composition on account of the wide area from which they may be drawn, and the uncertain distribution of the valuable metals in the earlier rocks.

GEOLOGIC SUCCESSION OF EVENTS.—It is scarcely within the scope of the present volume to enter into a description of the geological succession of the rocks, as it would require a volume by itself and be of little practical value to the miner, except as regards coal and iron, the character of which is largely influenced by their geologic age, owing to the changes which have taken place in their composition with the lapse of time under the influence of heat and pressure.

The accompanying table gives the outline scheme adopted by the U. S. Geological Survey. The progression is from the bottom upward, the order being as shown in the stratified rocks now accessible, though the whole series does not appear in any single locality. Below the Archæan is the granite foundation. "Era" and "period" relate to time; "system" and "group," to the rocks. Subdivisions of periods and groups are called "epochs" and "formations" (according to time and rocks respectively). The names for these smaller divisions vary in different localities, and authors differ in classifying and naming them, so that a more complete presentation here would only be confusing.

ORDER OF SUCCESSION OF GEOLOGIC TIME AND ROCK FORMATION.

Era or System,	*Period or Group.*
Era of Man	Quaternary.
Cenozoic or Tertiary	Pliocene. Miocene. Eocene.
Mesozoic	Cretaceous. Jurassic. Triassic.
Palæozoic	Permian. Carboniferous. Devonian. Silurian. Cambrian.
Archæan	Huronian. Laurentian.

[See also the arrangement proposed by LeConte and Dana, pp. 322, 323.]

CHAPTER IV.

PHYSICAL CHARACTER OF MINERAL DEPOSITS.

MINERAL deposits may be roughly classed under three heads: Beds, veins and masses. These divisions correspond to differences in form, and, in part, to differences in origin.

BEDS.—A large proportion of the rocks met with consists of substances arranged in distinct stratified layers. If any of these layers consists of a useful mineral, or contains enough to make it valuable, it is said to be a deposit in the form of a "bed," "seam," or "stratum," sometimes spoken of as a "bedded vein" or "blanket vein." The most important of all bedded or stratified deposits is coal; but in addition there are beds of iron ore, copper-bearing shales or slates, lead-bearing sandstones, silver-bearing sandstones, gold, tin and platinum-bearing gravels, as well as beds of rock salt, clays, slates, limestones, gypsum, oil shales, etc. The characteristic feature of a bed is that it is a member of a series of stratified rocks, and as such was laid down or formed after the rocks on which it rests, and before those which lie on its top. This peculiarity at once distinguishes a bed from a true vein.

Roof and Floor.—The layer above it is called the "roof" of the deposit and the one below it the "floor," when it remains horizontal or nearly so, but when highly inclined the terms "hanging wall" and "foot-wall," applied to true veins, are equally applicable to beds, but less expressive.

Thickness.—This is the distance from the roof to the floor at right angles to the inclination of the floor, being the shortest distance between the roof and floor, and this may be very much less than the length of a crosscut run through the deposit on a horizontal line, the two becoming nearer in length as the bed approaches more and more to the vertical; in the latter case they would be equal.

Dip is the inclination of the floor from a horizontal plane, and may be spoken of either in degrees of a circle, as for example ten degrees (10°); or expressed in feet, as 1 in 10, 1 in 20, etc. Other equivalent terms are "slope," "pitch" "underlie" and "inclination." Dip, of course, is due to the disturbance of the deposit by elevation or depression, causing tilting or bending, since its formation (a horizontal layer having no dip); but as such disturbance has been almost universal, nearly all bedded deposits have more or less dip, at the present day. Sometimes the beds may be nearly horizontal, as in Staffordshire, England; or raised to an angle of 50° as in the Cumberland coal series in the Skagit Valley, Wash. (pl. 2, fig. 10); sometimes they may be vertical or even folded over as in pl. 4, fig. 6, a structure which is found in the Appalachian mountains, and in some of the Franco-Belgian coal fields, where a vertical shaft passes six times through the same bed, because the folding has been so complicated.

Strike.—The strike or course of the bed is the direction of a horizontal line drawn along the floor of the deposit, such as the bottom of a tunnel following the mineral, without grade. This direction will clearly be at right angles to the dip of the bed, and will consequently vary as the dip varies; so that, if it is desirable to run a tunnel on a deposit in a perfectly straight line, it must have a course or direction as nearly as possible at right angles to the general dip, instead of to the dip at any particular locality. But this is not always possible.

From the above it will be clearly seen, by reference to pl. 13, figs. 10, 11, 12, 13, that while in fig. 10 the strike would be east, in fig. 11 it would vary from northeast to east and thence to southeast; in fig. 12 it would be north, going round by east until it was south; while in fig. 13 it would turn to all points of the compass in succession and indicate a saucer-shaped basin. From what has been previously said it will be obvious that even when the bed may be covered on the surface its position, if it exists beyond the point of discovery, should be traceable by the rocks with which it is associated; but a search in this manner should be governed by the rock which forms the roof, as this must lie comformably above it, while it is possible that the deposit may lie on the upturned edges of a great variety of rocks as at *E*, pl. 2, fig. 1.

The thickness of workable beds varies within very wide limits according to their richness in some special mineral or its scarcity. Some workable beds of coal are only 1 ft. thick and range up to as much as 60 ft. or over in exceptional cases. The copper-bearing shales of Mansfeld are only from 10 to 20 in. thick, while the lead-bearing sandstones at Mechernich are no less than 85 ft., and some beds of slate, limestone and salt greatly exceed these dimensions. But whatever the thickness may be at any particular point, it does not follow that this will be maintained over the entire area of the deposit. Sometimes this may be the case over a very extensive area, but there must necessarily be a boundary to the deposit in all directions, and toward these limits it may dwindle away to a feather edge, with the probability of the greatest thickness being near the central portions of the original deposit (not necessarily that part left to our inspection). Toward these edges, as in the case of coal and iron deposits, the bed may contain many impurities and become valueless; or in the case of slates and limestones a gradual change may take place into another kind of rock, such as clay-shales into sandstones and these into conglomerates. Pl. 2, fig. 1, *D*, shows a bed of coal, as originally laid down, thinning out in all directions. It may consist of a uniform mass, with impure edgings, or it may be divided into several layers by thin sheets of clay or waste matter, called "partings," in which case it often happens that the character of the coal above a parting is different from that below in important particulars, and should be mined separately. Partings are not necessarily a detriment to a deposit, as they frequently facilitate mining.

Outcrop.—It is not always easy at first sight to distinguish the outcrop of a bed from that of a true vein, but it will usually be found more continuous and more uniform in its composition.

VEINS may be described as comparatively thin sheets traversing what are called "country rocks," which were formed earlier than the veins themselves; and occupy crevices formed by fracture of the inclosing rocks, or have been formed along the lines of junction of such rocks by changes in those adjacent. It is this origin at a later date than that of the rock formation which constitutes the essential difference between a vein and a bed.

Dikes.—The above description includes all veins of porphyry or other intruded rocks, such as granite or basalt, as well as those containing the useful or precious minerals. Veins filled with porphyry or similar rocks of whatever kind are usually called "dikes."

True Veins.—The term "vein" is more properly restricted to those which are more or less filled with useful minerals, whether in workable quantities or otherwise. Building stone should be excluded from this definition, as many valuable varieties (besides those found in beds) are the product of dikes. In the United States the terms "vein," "lode," "lead" or "ledge" are used indiscriminately in different localities, but all have the same meaning, while in Australia and South Africa the term "reef" is often applied to mineral veins as well as to bedded deposits like gold-bearing conglomerates. For the purposes of the U. S. land offices the description of a lode as given by Justice Field in the celebrated case of the Eureka Cons. *vs.* the Richmond Co. is accepted, viz.: "We are of opinion, therefore, that the term [lode], as used in the acts of Congress, is applicable to any zone or belt of mineralized rock, lying within boundaries clearly separating it from the neighboring rocks." This definition evidently covers both true veins and all bedded deposits.

Miners often speak of coal and iron veins, but this is a misapplication of the term. When a bed lies on the upturned edges of much older rocks, as in pl. 2, fig. 1, *E*, it shows conclusively that before its deposition long periods of time had elapsed, in which the lower strata had been raised above the water, uplifted into new positions, worn down to a new surface and again depressed below the water level; and we can form some comparative idea of the relative ages of bedded veins by the thickness of the strata which have accumulated above them. In the case of true veins we can only judge of their age by knowing that they must be younger than the rocks in which they lie, and the comparative age of these is judged by the fossil remains found in them.

Dip.—Like beds, veins have dip, strike and walls. As a usual thing the dip of true veins is apt to be steeper than that of the majority of beds, though such a distinction is not absolutely necessary. The dip is measured from a horizontal line as in the case of beds, and is expresed in degrees. If the vein is vertical the dip is 90°. In pl. 9, fig. 1, the veins *A*, *B*, *C*, and *D*, have respectively dips of 47°, 68° and 86°, while vein *E* is vertical (90°). In some cases the dip may be so flat that when the vein is exposed by the wearing away of the hanging wall it may appear almost like a bed. Such cases are often termed "blanket-veins," but a very slight examination will show, in most cases, their true origin.

Strike.—Owing to their different origin, the strike of true veins is more likely to have a uniform direction than in beds, as the inclosing rocks have not usually been subjected to so much movement since the formation of the fissure as has been suffered by the strata containing the beds; or, if movement has taken place, the weakness of the fissure has directed the motion into that plane and simply caused a reopening of the fissure, and not infrequently a refilling of it with a different class of mineral deposits. See pl. 6, fig. 6, where the thin slabs of rich gold ore *B* occur on each side of a large central core of poor or barren quartz *A*. The conclusion is frequently irresistible, taking into consideration the great amount of motion of the walls of the lode as shown by their shattered condition, that on a reopening of the fissure the contents of the lode were concentrated in the way shown, to the impoverishment of the main body of quartz.

Outcrop of Veins.—The outcrop of a vein, sometimes called "croppings," is the portion of the vein exposed on the surface. It does not follow that the visible outcrop corresponds with the true strike of the lode. This can only occur when the vein is vertical, or outcrops in a level plain, when it would show a comparatively straight line and the true course, whatever the dip might be. It is not often that such a case occurs. On the contrary we find the bulk of mineral veins in rough and broken mountain regions, and in these cases the tracing of the outcrop becomes a more difficult matter, especially when the vein crosses ravines or valleys filled up with gravel or debris which hide its presence. All veins with a pronounced dip have a crooked or serpentine outcrop, and the flatter the dip the more sinuous this outcrop will appear. By reference to pl. 9, figs. 1, 3 and 5, these peculiarities will be easily understood. Their great importance becomes apparent when making locations on a vein and in the legal aspect of these locations. Fig. 1 is a longitudinal section along the bed of a ravine, showing five veins *A*, *B*, *C*, *D*, *E*, and their outcrops ascending the hill on the side furthest from the observer, as from *g* to *s*, *h* to *r*, *k* to *p*, *l* to *o*, and *m* to *n*. All the veins are supposed to run north and south. It is evident that on the crest of the ridge the outcrop of the vein *A*, dipping east, will be west of its position in the gulch by the distance *sa*, while in the cases of the veins *B*, *C*, *D*, dipping west, the outcrops on the ridge will be east of the position of the veins in the bed of the gulch as shown at *h*, *k* and *l* by the distances *br*, *cp*, and *do*. It can also easily be seen that on descending the opposite side of the hill, the outcrop of *A* would swing back again up the ravine, while all the others would swing down, producing, if the outcrops were continuous, an appearance something like that in figs. 3 and 5. In fig. 3 we have details of the outcrop of two veins, *B*, *B*, and *C*, *C*, running north and south on the two sides of a ridge, and both dipping to the west; and in fig. 5 similar details of two veins *A*, *A*, and *D*, *D*, dipping east. The outcrops in fig. 3 are shown by the black lines *A*, *A*, and *D*, *D*, and in fig. 5 by the similar lines *B*, *B*, and *C*, *C*. A little study of these figures will make the matter clear, without elaborate description. All the peculiarities of the outcrop may be illustrated by taking a large smooth potato, and cutting it into halves lengthwise. Lay the two halves flat side down on the table side by side and we have two miniature hills with a ravine between them. Now if a cut be made across both hills inclining from right to left we shall have a vein in miniature, and if the pieces be drawn slightly apart so as to show the white of the inside in contrast with the brown skin, the pale line thus made visible will indicate the outcrop of the vein, and will be found similar to figs. 3 and 5. By making the first cut flat and subsequent ones steeper the gradual approach of the outcrop to a straight line as the view becomes more and more vertical will be quickly apparent, until the vertical cut will represent the vein *E* in pl. 9, fig. 1.

The outcrop may either be a very conspicuous object standing many feet above the surrounding surface or barely visible on the hillside; it may be merely outlined by a surface depression, or form a deep gorge, according to the relative hardness of the vein matter and the country rock, or the difference in the contents of the vein at different points in its length.

Dikes, which have a nearly uniform composition throughout their length, often traverse a country for miles, standing up like ruined walls, as at the Devil's Slide in Utah, on the Union Pacific railway, and at other places which nearly every traveler can recall, but such uniformity very seldom exists in mineral veins. On the mother lode of California the barren portions are largely made up of threads and stringers, while the valuable portions consist of immense bodies of solid quartz, which have protected the present hills from wear and tear, while the ravines have been cut out alongside the lode (pl. 7, fig. 6) or through the barren portions at right angles, or nearly so, to the vein, as in pl. 9, fig. 7, where *A,A*, represent quartz bodies; *B*, the barren intermediate ground and *c,c*, the visible outcrops. This structure is continuous for many miles. In Mariposa county especially the heavy white quartz crops out from the crests of one hill after another, crossing their summits like the comb of a helmet, in a most conspicuous manner, with deep intermediate ravines. In these cases the ravines are due to the absence of ore in the outcrop, but in other cases the ravines are due to the presence of soft, friable, easily decomposed ore in the lodes, and form along the veins, in gorges of varying depth according to the degree of difference in hardness between the lode and its wall rocks. A good illustration of this structure is found in the Monte Cristo district on the west slope of the Cascade range in Washington, where the abrupt bluffs, forming the walls of an ancient glacier basin, are furrowed with deep, abrupt gorges, similar to pl. 9, fig. 6. The veins here cut across the slates with a dip of about 60°, and having undergone extensive alteration, besides being mineralized with friable ores, are now softer than the metamorphic slates, so that as the vein wore away the overhanging wedge of rock *B*, broke off from time to time, leaving a steep slope to the footwall side of the ravine, and a nearly vertical bluff above the hanging wall, from which large fragments are annually detached by the action of frost and sunshine, widening the ravine, while at the same time the melting snows deepen its bed along the course of the vein. In such cases the foot of the bluffs is covered with an immense "talus" or broken rock slope, consisting of angular frost-detached fragments broken from the cliff above, which have buried the outcrops in the lower portions of the valley, roughly indicating their position, however, by winrows of immense bowlders which have been detached, for want of support, from the overhanging wedge *B*, and have rolled down the slope without being more than partially broken up in the fall.

In other cases the hardness of the vein matter and that of the inclosing rock may be so nicely balanced that they both wear down at about the same rate, and the croppings may be covered with earth, etc., or as the prospector says, "blind;" that is, hidden or hardly visible; or the vein may become blind because since the time of its formation new strata or volcanic overflows have been laid down upon the containing rocks, as in pl. 15, figs. 13 and 14, which show such a case in longitudinal and cross section. In this case if ravines have cut down through the "cap-rock" the vein may be seen cropping on the side of the ravine as at *A*, fig. 13, being lost under the cap *B*, but reappearing at *C* on the other side of the hill.

This cap may be either sedimentary or eruptive rock, or it may be the consolidated snow (*neré*) of a snowfield, both forms being seen in the Monte Cristo region; so that the importance of determining accurately the strike and dip of the vein, so as to recognize it on both sides of the mountain, becomes very apparent.

But in whatever manner the outcrops may occur the same rule will generally hold good for quite an extensive district or group of veins, and a recognition of this fact may save the prospector many a weary mile of travel and hard climbing.

If the vein has a very flat dip and is located on a more or less conical hill, it may even crop entirely round the summit of such a peak, as shown in pl. 7, figs. 10, 11, in which fig. 10 is a vertical section and fig. 11 a ground plan of the same. We have here a series of trap dikes with bedded quartz veins lying between granite and slate. The drawings represent the Vanderbilt mine near Silver Peak, Nevada, and show a similar structure to that of the Tyndall mine in Colorado.

Spurs.—It not infrequently happens that a vein presents more than one outcrop, the main lode presenting itself at the surface with several minor lateral branches, as shown in the cross section of the Dolcoath mine, pl. 7, fig. 1. These are generally more numerous on the hanging wall side of the lode, and present in the greatest numbers when the dip of the vein is flat, as was the case in the Comstock lode, of which a general idea is presented in pl. 2, fig. 2. These "spurs" may run nearly parallel to the main lode, and standing more vertically unite with it in depth, or they may run out into the general bedding of the rock, as shown in pl. 6, fig. 2, *s,s,s*. In the former case it is easy to understand how the cracks in which they are formed were made by the weight of the overhanging wedge breaking it across from time to time, or the sliding of the hanging wall on the foot-wall pulling it apart, a cause which might also give rise to the spurs which branch out into the bedding.

Horses.—In other cases, especially in very large veins, these spurs after leaving the vein may reunite with it in all directions, resulting in a mass of barren rock entirely surrounded by vein matter, to which the term "horse" is usually applied. These are frequently spoken of as masses of rock which have fallen into the fissure, but they have usually moved but a very slight distance, if at all, from their original position.

Walls.—When the vein is vertical the walls may be distinguished by the points of the compass, as the north, south, east or west wall, but when the vein has a slanting dip the lower wall is designated as the "foot wall" and the upper as the "hanging wall," as in pl. 7, fig. 7, where the granite forms the foot wall, and the slates the hanging wall of the quartz series *B*. In England the term "cheeks" is sometimes applied to the walls.

Gouge.—Not infrequently there occurs between the vein matter and the country rock a seam of clayey matter called "gouge" or "selvage," which may be of extreme thinness or reach a thickness of as much as 30 ft., as in the Potosi mine on the Cromstock lode. This is apparently the result of a grinding or crushing movement of the walls of the vein upon each other, under enormous pressure, and where a portion of the vein has been mixed with material from the walls the gouge is often rich enough in mineral to go to the reduction works. Mine clay may also result from chemical decomposition of the wall rocks.

Slickensides.—Where the motion has been considerable, and the walls or vein are hard enough to resist the grinding action and reduction to clay, both the wall and the vein matter become marked with parallel lines or striœ, called "slickensides," or "slickens," which indicate the direction of the motion, and frequently the quartz or wall has taken a polish equal to anything which can be produced artificially.

"Frozen" Veins.—In other cases it may happen that there is only one well defined wall, the vein matter being firmly attached to the other, and gradually fading out into the barren country rock, as shown in pl. 6, fig. 3, where *C*, *C*, may be slates or any other rock; *A*, a dike cutting the same, and *B* the ore vein with a well defined wall on the right hand but "frozen" to the dike on the left side. The condition of the walls is a matter of much interest to the miner. If the ore is frozen to its alls on both sides it is almost a positive indication of uncertainty of continuance in depth, but heavy clay seams or gouges are taken as favorable indications from the evidence they supply of a deep-seated fissure.

Vein Matter.—The material with which the vein is filled is known as the "gangue" or "matrix," usually by the former term. It is not necessarily quartz. It may be limespar (calcite, calcspar) fluorspar, barytes, or even the decomposed remains of a porphyry dike. The term matrix alludes to the filling being the mother of the ore. It does not follow that all this gangue carries ore, or that it is of uniform thickness through the entire length of the lode. The movement of the walls may have brought two swells opposite each other, as in pl. 6, fig. 2, at *B* and in pl. 2, fig. 9, and the vein is then said to "pinch" or "peter out;" or the ore may be confined to slabs on the walls, as in pl. 6, fig. 6, where *B* may represent ore and *A* the barren quartz gangue. Fig. 5, on the same plate, is an exaggerated representation of a condition frequently seen in the softer kinds of granite, where instead of the vein pinching completely, as in fig. 2, the motion since the vein was filled with quartz (black) has been able to reduce the portions of the wall rock between the swells *B*, *B*, to a condition of gouge or nearly so, and a new wall has been established as *W*, *W*.

Ore Chutes.—It may happen that all the gangue or matrix is charged with ore, but this is seldom the case. In the majority of cases there are wide and long barren spaces in the lode and the ore is concentrated into "chutes" (also spelled "shoots"), as shown in pl. 9, fig. 7, *A*,*A*. These may vary greatly in dimensions, being sometimes so short horizontally in proportion to their length that they are called "pipes." In addition to the dip, which they have in common with the vein, they have an inclination to the right or left of a line drawn on the dip at right angles to the strike, which his called the "rake." For instance, looking down an incline on the vein, the ore may go off to the right or left of this incline, and this feature is usually common to all the veins in a district which have the same strike and dip, and the rake is usually the greatest in the flattest veins. In pl. 9, fig. 2 (a cross section) shows the dip of the vein, and fig. 4 (a longitudinal section) the rake of the ore chute *C*, which is estimated from the true dip line, in this case 37°.

MASSES.—Under this head are included irregular deposits which cannot be classed as either beds or veins. Their forms are various, and sometimes they are merely indefinite impregnations in permeable ground, leached out from finely disseminated mineral in the surrounding country rocks. Some iron and manganese ore bodies, formed in troughs or cup-shaped depressions, are best described as "masses," as also are many segregated deposits of tin, copper, and silver ores. The most pronounced type is perhaps to be found in the large isolated bodies of lead and zinc ores in limestone. Small deposits, of whatever mineral, are called "pockets" or "bunches." The main characteristics of masses are irregularity and isolation; but these do not prevent their being, in many instances, very valuable. If their shape is decided in any direction, they may be said to have strike, dip, rake or pitch, roof and floor, or walls, etc.

CHAPTER V.

ORIGIN OF VEINS.

All veins of whatever kind, whether bearing valuable minerals or not, are the result of movements in the upper portions of the earth's crust, producing cracks or crevices, which have been subsequently enlarged and filled with some material different in its physical and chemical qualities and appearance from the rocks in which the fracture has taken place.

These movements, which may be the result of earthquakes, or the readjustment of the pressure caused by the thinning of one portion of the crust by denudation and the thickening of another portion by the deposition upon it of all the material brought down from the mountains by the action of rivers, are intimately connected with the process of mountain building, and consequently show themselves most strikingly in mountain regions, in which also volcanic agencies have played a most important part.

Fissures and Faults.—Such fractures in the rocks, when they have been accompanied with more or less motion of one side of the mass upon the other, or of both on each other, are known as "faults" or dislocations. They may show themselves only by a mass of broken material, or the break may be comparatively clean cut, and may be very short, or extend for many miles, as in New Zealand, where one earthquake (1845) produced a fissure in the southern island which averaged 18 in. in width and was traceable for a distance of 60 miles parallel to the axes of the mountain chain, while the earthquake of 1855 gave rise to a fracture which could be traced along the base of a line of cliffs for a distance of about 90 miles.

But whatever the cause and however long the fissure may be, it must terminate at each end somewhere, otherwise it would cut the world in two; and it is evident that however great the elevation or depression of the bounding walls at any one point, there can be no such motion at its two extremities; and that the grinding action of the motion, which prepares the fissure for the formation of a mineral vein, must be nothing at either end, and greatest where the displacement of the walls has been most extensive.

It does not, however, follow that all fissures will produce mineral veins, for there must be a combination of circumstances to cause such depositions; but as these faults may have been, and often have been, formed subsequent to the formation of bedded deposits such as those of coal, iron or gold-bearing gravels, it is therefore necessary to know something of the features which these faults present to enable us to again find a broken bed or vein when lost in the course of working.

Throw.—The simplest form of fissure is shown on pl. 3, fig. 4, *A B*, with the greatest motion at *n,o*; *CD* in the same figure (after Geikie) shows a fissure splitting at the ends into minor branches, the amount of "throw" or displacement of the walls being given in figures, which indicate the greatest movement in the middle, as before explained; while *EF* shows one in which the walls have been drawn apart at right angles, or nearly so, to the main fissure, forming "spurs." A similar structure is shown in pl. 6, fig. 2. In *CD*, pl. 3, fig. 4, while the greatest total movement has been say 30 ft. it does not follow that all this movement was on one side of the fissure, for one side may have been raised and the other depressed in varying proportions.

These figures are horizontal plans. Pl. 1, figs. 3, 4, 5 6, 7, show the simplest kind of fault in vertical cross section, if the break were an absolutely straight line, which, however, is not often, if ever, the case. Fig. 3 shows a fracture in a series of bedded rocks without any apparent displacement, although it is possible that there might have been such horizontally. Figs. 4 and 5 show a movement of either or both of the two walls on each other in the direction of the arrowheads; but there would be nothing in such a case, as the fracture is clean cut, to indicate the direction in which the movement had taken place, whether the foot wall had been depressed as in fig. 5 or elevated as in fig. 4, or the reverse in the case of the hanging walls; but in fig. 6, 7, the movement is clearly shown by the bent and broken edges of the strata, to be an ordinary fault or depression of the hanging wall in fig. 6.

Reverse Throw.—Elevation of the hanging wall (or depression of the foot wall) is shown in pl. 1, fig. 7. Such a throw is also seen in pl. 11, fig. 5, from the gravel pit at Laporte, Cal. The direction of the throw is called the "hade."

Pockets Formed by Faulting.—If a fault, instead of being a clean, straight cut, has a sinuous or wavy form, as in pl. 2, fig. 7, the result of motion of the walls in the direction of the arrowheads would be very different, producing the form shown in fig. 8, or a vein of very uniform width throughout, if the movement were a mere separation horizontally; whereas, if the movement had been in the direction of the arrows in fig. 9, the swells of one wall may have been brought against the swells of the other wall, resulting in a series of lens-shaped pockets, especially if the course or strike of the lode be also sinuous and it has suffered more or less longitudinal as well as vertical displacement. On sinking on the outcrop at *a*, fig. 9, the vein would be found widening rapidly, forming what the Mexicans call an "A" vein; while, if the surface had been worn away to the dotted line *bc*, similar sinking would reveal a vein rapidly diminishing in width or a "V" vein.

Very rapid widening of an ore body in this way is liable to be accompanied by an equally rapid contraction, and vice versa. An easy method of getting a thorough understanding of this important phase of fissure structure is to tear a piece of paper in two halves along a wavy line such as is shown on pl. 2, fig. 7; when, by moving them apart in various directions upon a dark background, every phase of the question can be readily studied, particularly if in one instance the waves are made short and deep, and in another long and gentle. Pl. 6, fig. 5, is an exaggerated illustration of such structure, to show that when the ore (black) is lost at *B* the search for the next swell must be continued by following the crosshead or seam which cuts the ore body off (this being the original fissure line), and not by following the false wall *W W*, which has only been formed by the motion and pressure crushing the swells of the country rock *AB* into a shattered mass of vein matter; or, yet worse, by presuming that the course of the ore body is the general course of the vein, and following that direction into the country rock on one of the joints which originally determined the shape and position of the swells on the line of fracture.

Gashes.—When such fissures have been formed by pressure from below bulging the surface upward as in pl. 2, fig. 4, a simple gash may have been formed, which was later on filled with mineral matter from above or laterally; or by the action of surface waters, became, as we so often find, the line of a watercourse following an anticline *e*. A sagging in a syncline might conceivably give rise to the opposite effect, as in fig. 5.

Step Faults.—In other cases, the elevation has been so great, and the strain on the strata so enormous that when they did give way the central mass with the largest base exposed to the elevating force has been thrust furthest upward, while the masses on either side have settled down in gradually lessening steps until the movement fades out into undisturbed country, producing a series of "step faults," of which pl. 1, fig. 1 is an ideal and fig. 2 an actual illustration, the latter being taken from the reports of Prof. Emmons on Leadville, Col., where the drop of 2,000 ft. at the Mosquito fault is reduced going westward to only 750 ft. at the Carbonate.

Trough Faults.—The faults shown in pl. 3, figs. 1, 2, 3, known as "trough faults," are more complicated, and are best explained in the language of Mr. Jukes, who proposed the following satisfactory solution of the problem: "Suppose the beds *AA*, *BB*, etc., fig. 2, to have been formerly in a state of tension, arising from the bulging tendency of an internal force, and one fissure, *FE*, to have been formed below, which on its course to the surface splits into two, *ED* and *EC*. If the elevatory force were then continued, the wedge-like piece of rock between these two fissures, being unsupported, as the rocks on each side separated, would settle down into the gap as in fig. 3. If the elevatory force were greater near the fissure than further from it, the single fissure below would have a tendency to gape upward, and swallow down the wedge, so that eventually this might settle down, and become fixed at a point much below its previous relative position. Considerable friction and destruction of the rocks, so as to cut off the corners *g*, *h*, fig. 3, on either side, would probably take place along the sides of the fissures, and thus widen the gap, and allow the wedge-shaped piece to settle down still further. When the forces of elevation were withdrawn, the rocks would doubtless have a tendency to settle down again, but these newly included wedge-shaped and other masses would no longer fit into the old spaces, so that great compression and great lateral pressure might then take place." Pl. 4, fig. 5, (after Jukes) shows such a fault or wedge cutting into a bed of coal, which from the enormous pressure resulting from the resettlement of the strata "has been reduced to a paste of coal dust and very small coal."

Very frequently the line of fault becomes the bed of a watercourse and in time a ravine. This may result not only from the weaker nature of the rock on this line (as evidenced by the faulting itself), but also from the tilting of strata along the fault plane. Such a fault-formed valley may or may not at present be occupied by a watercourse. Pl. 12, fig. 9, shows a cañon following a fault in Death Valley, Cal.

Every mountain region is full of faults, and they abound especially along the great ranges, where the movements have been so great as to bring to the surface, alongside of each other, rocks which in the order of succession are separated by many thousands of feet; and in these movements we have an explanation of the sudden change in the character of mineral deposits on opposite sides of lofty mountain chains which sometimes seem inexplicable. But almost every vertical exposure of rock in such places as railroad cuttings, and not only of rock but of unsolidified beds of sand or gravel and clay, shows a multitude of minor fissures intersecting and displacing each other, sometimes in the most complicated manner, but presenting evidence of the universality of the process which has opened the way for the circulation of underground waters, without which it would seem that the filling of a portion of the fissures could not have been accomplished.

There does not appear to have been any time in the earth's history since the first solidifying of the surface when such fracturing and movements have not been going on, and consequently we find veins of one age intersected and sometimes dislocated by others formed on fractures of later date, until in some cases there may result a very complicated condition, as shown in pl. 2, fig. 6, which a thorough knowledge of the theories of faulting alone can explain, and for want of which loss and disappointment may ensue from mining operations therein. It does not, however, follow that because one vein may be apparently faulted and thrown by another, such is always the case, as at the crossing of *AA* and *CC*, where the fissure *A* may have jumped along *C* because the line of least resistance may have been different on the two sides of *C*, which would make *A* younger than *C*; but where the dragging of the rocks is present, as at the intersection of *AA* with *BB*, the presumption is strong in the absence of other evidence that *AA* has been faulted and thrown by *BB*.

Stockworks.—The complication arising from these sources may be so intricate that it becomes impossible to say which set of fissures is of most ancient date, and they may become so numerous and minute that individual mining becomes an impossibility, and the mass is extracted as a whole, if extracted at all, under the name of a "stockwork."

Rocks vary so greatly in their hardness, texture, composition, brittleness, and facility of splitting that they break in very different ways, and this peculiarity must inevitably exert an influence on the character of the fissures by which they may be traversed, and a knowledge of what may be expected in each case is essential to a clear understanding of the methods to be employed in opening and working mineral veins to the best advantage.

"*True Fissure Veins.*"—Anyone of the faults shown in pl. 1, which must evidently extend downward to an unknown depth, may under certain conditions form what is known as a "true fissure vein" (an old-time term for what was thought to be the best and most permanent type of a mineral deposit), which is simply a fissure, sometimes miles in length, coursing directly across the country in a more or less straight line, and cutting through the rocks indiscriminately, but varying in width and character according to the rock in which it may occur both in length and depth, and filled with mineral matter other than eruptive rocks.

Strike Faults.—A fault may cut the rock formations at right angles to their strike, or it may run more or less parallel with the strike, but cut the rocks on their dip, by being usually more nearly vertical than the strata penetrated, in which case the vein would be formed on a "strike fault," and at the surface present many resemblances to what is known as a "contact vein."

Effect of Country Rocks on Fissures.—If the fissure is entirely in the same rock it may maintain a tolerably uniform character for its entire length and depth, but if it cut rocks of various kinds it may pinch out almost entirely in those which are tough, expanding in those which fracture more easily, either from splitting readily (as slates) or from extra brittleness (as certain quartzites). If it traverse a limestone formation it may for a time completely lose the character of a fissure vein with definite walls, in a comparatively short time after its formation, on account of the great facility with which lime is removed by the action of water, especially when containing carbonic acid, and the irregular cavernous structure thus caused.

It therefore becomes an important question when ore is found in a certain rock to ascertain to what extent that rock is developed, and whether the associated rocks are of such a character for hardness or softness that a vein, as the miners say, can live in it. The writer has in mind an extensive region where the disregard of these general principles has led to the useless expenditure of large sums on veins which a very slight geological knowledge would have taught the miners could not be of permanent value, because, however rich the surface ores, they were contained in the fragments of a bed of schists overlying a tough solid syenite, in which the vein exposures were very narrow, and into which the veins found in the schists would inevitably pass in their lower portions.

If the vein has been formed on a strike fault, there is a yet greater chance of irregularity from the tendency of the break at times to follow the bedding planes of the rocks, while at others it cuts through them, resulting in shattered masses which form "horses" or barren patches of country rock in the middle of the ore body; or the fracturing may have been so extensive laterally that we have a mass of parallel threads and stringers, instead of a smaller but more compact deposit.

CONTACT VEINS.—From such veins as the latter the passage is easy to those formed on the contact of two bodies of rock of different kinds. Such contacts may be divided into four groups: (1) Contacts between sedimentary rocks such as slate and quartzite, quartzite and limestone, or sandstone and conglomerate; (2) contacts between sedimentary and intrusive or igneous rocks, such as slate and granite, or limestone and porphyry; (3) contacts between two igneous rocks as porphyry and syenite; and (4) contacts on the walls of dikes which may traverse a series of either sedimentary or igneous rocks.

When contact veins of the first two classes stand at a high angle or approach the vertical there is at first sight but little difference in their appearance from fissure veins, but as they always maintain the same relation to the inclosing rocks they are apt to have a more uniform character both in structure and filling. It is plain also that they must partake of all the wavy irregularities of shape which have been imparted to the rocks in their upheaval, and if followed downward to a sufficient depth must eventually flatten out, as no beds of stratified rock can continue to descend toward the center of the earth indefinitely, from the very nature of their origin; still, the contact is usually of great extent, and there is no reason why the vein should not be so also.

This feature becomes especially pronounced when the contact lies nearly horizontal or only slightly inclined, as at Leadville, because we are able to reach it with comparatively shallow shafts over large areas, the extent of which in one direction represents the strike of a vertical lode, while the extent in the other is practically the same as the depth reached on the vertical lode only by deep sinking with all its limitations. In such horizontal contact deposits we do not look for horizontal motion, and have only to encounter the troubles arising from subsequent faulting, as in pl. 1, figs. 1 and 2, but in many cases of steeper contacts there are evidences of vertical motion, in which case we shall usually find the contact to be local and accidental; the fissure being really a strike fault continued to the surface on a contact plane which proved to be the line of greatest weakness, as in the case of the Comstock lode in Nevada, which strikes nearly parallel with the axis of the mountains on whose flanks it is located, and presents varying contacts in Virginia City, Gold Hill, and Silver City, but has been proved to descend into the syenite at Virginia City, below the level of the Sutro tunnel, the character of the lode changing at the same time as well as the composition of the ore. Thus evidence of motion in an apparently contact vein may be taken as *prima facie* proof that the contact is not continuous, and that the vein really belongs to the group of fissure veins, and will partake of all their peculiarities of structure and filling.

When two sedimentary rocks are conformable, but have a more or less wavy surface of junction, a sliding movement of one upon the other will give rise to openings and pinches, just as in the case of secondary faults on warped planes in homogeneous rock, and an opportunity for the formation of a contact vein is presented, as in pl. 1, fig. 8. Such a vein might be regarded as either a contact deposit or a fissure vein, but is more naturally considered in the former class.

As the rocks on the two sides of a contact are seldom of equal hardness the character of the vein will probably be governed by that which is most liable to decay, removal or fracturing. This is especially the case with slates and limestones, the former on account of the facility with which they split and crush; the latter because they are so easily dissolved.

Compression Veins.—No person with any experience in the mountains can have failed to notice the folds and bends in slate rocks, from gentle waves to minute crumplings, which have been produced by forces pressing on the ends of the lines of stratification, until a structure similar to that shown in pl. 6, fig. 1, has been reached, a structure which can be easily imitated by squeezing the leaves of a book together endwise, between the covers, held slightly apart. If such slates are on a line of contact, as at the Keystone mine, Amador County, Cal., and have been subjected to such pressure, many good mines have been the result; but where such action has taken place in the body of a large mass of slate, in the absence of any special controlling element, such as a dike, great uncertainty will exist as to the extent of the movement, which, having full play in all directions, may have simply resulted in a multitude of irregular minor foldings. In all such cases the whole vein does not consist of a continuous sheet of ore, although there may be such at the immediate contact, but of a series of lenticular masses, overlapping each other, which may occupy a belt several hundred feet in width, the broadest portion of one being generally opposite the thin end of another. It is obvious that such mines will require extensive cross-cutting to make certain that no ore body has been overlooked.

Limestone Contacts.—In a limestone contact, whether steep or flat, the actual line of contact which will form one wall of the lode may be comparatively smooth, while that in the limestone may be very irregular, depending somewhat on the solidity of the limestones or their varying degrees of solubility, and the destruction of the limestone by this means may be so complete that the ore body will apparently consist of a cemented conglomerate, the pebbles in which are only the insoluble cherty or flinty residue so abundant in chalk and silicious limestones.

The remaining groups may be considered together, as while there may be cases of contact of two eruptive rocks without the presence of a dike, as on the Comstock, the majority of contact veins in purely eruptive rocks are alongside of or controlled by dikes cutting masses of some other variety, as in many Colorado mines. The essential feature of all lodes formed on the contact of dikes is that the latter have been squeezed from below into the fissures as they were formed, and that consequently their walls must extend downward to the source of the pasty rock with which they were filled, and that this source is, in depth, beyond our ability to explore. While such contact lodes thus present a general similarity to fissure veins in their length and depth, they possess one important feature not present in the latter—that one wall of the fissure is always of the same composition, a fact which will tend to maintain a more uniform character in the filling, at least on one side of the vein. The wall away from the dike will, of course, be liable to changes as the rock of which it is formed varies, but such changes will be rather those incident to the influence of the heat of the injected dike, as the baking of clay shales into jaspery or flinty products, rather than variations in the shattering of the walls, as the forcing apart of the walls of the fissure and simultaneous filling with a plastic substance would prevent grinding of the faces of the fissure against each other, while such fragments of the walls as did fall off would be buried in the intruded mass, and carried by it upward on its course toward the surface if the rent extended that far. In such lodes we may find a sudden change in the principal mineral on passage from one rock to another, but a constant admixture of some other ingredient which owes its presence to that of the adjacent dike; or the ore on one wall may be of a totally different character from that on the other, as at the Keystone mine, where, next to the so-called greenstone hanging wall, the quartz is massive, white and blocky, while that of the slate foot wall is banded with numerous parallel blackish lines of slate, making the "ribbon rock" of the miners; or, as on the Comstock, where the nearly vertical ore bodies in the porphyry, as they approach the much flatter syenite foot wall, carry an appreciably larger proportion of gold; or, as at a mine in northern Washington, the ore on one wall may be distinctly a silver proposition, and on the other, only 15 ft. away, as decidedly a gold one.

In all these cases of dike contacts, the point at which ore will form and the shape of the deposits will be governed by the same influences as in other contacts, whether the lode has been formed by the gradual shrinkage of the mass of the dike in cooling, or by substitution through the circulation of water along its bounding planes.

Gash Veins.—Shrinkage of sheets of lava may also produce veins which will not extend into the underlying granite or other rock, as at the Stonewall Jackson mine, Ariz. Such occurrences may be classed with the "gash veins."

Segregated Veins.—In other cases, like that shown in pl. 7, fig. 5, there may be neither a clean cut fissure nor a line of contact, nor a controlling dike, but a series of ore bodies arranged along a general line of shattering and without definite walls, the change in the rock becoming gradually less marked laterally until it fades out into the unaltered country rock. Such occurrences are known as "segregated veins," by which term it is understood that the mineral has been concentrated by the action of water into the crevices of a shattered or sheeted belt of rocks from the surrounding rocks themselves. This "sheeting" is well seen in many mines in granite, where an apparently solid and smooth wall will scale off in slabs or sheets, after a short exposure to the air, making it almost impossible to say where the true wall may be, and rendering a large opening necessary to secure a relatively small amount of ore. Many miners make the mistake of considering all the sheeted mass as a part of the vein, thus deceiving themselves with the hope that the ore body may ultimately be as wide as the sheeted portion. A little study will show the falsity of such a notion, as it is quite conceivable that the step faults shown in pl. 1, fig. 1, might be so numerous that the spaces between would not exceed the thickness of the slabs just spoken of. Most faults through rocks which do not break too easily into small fragments show this sheeted structure, as the result of the dragging of the sides at the moment of fracture. Where there has been much of this action we may look for more or less numerous veins parallel to the main lode of a district, which may carry more or less ore, but being only incidents accompanying the principal disruption are less likely to afford the conditions which will develop them into lodes of equal value.

General Conclusions.—It may therefore be set down as an axiom in mining that as a prior condition to the formation of mineral veins there must have been such fracturing of the rocks as to facilitate the circulation of underground waters vertically as well as horizontally, and that the nature of the fissures thus produced will be influenced by the varying hardness, brittleness or solubility of the rocks thus fractured, as well as by the direction in which the force may have been applied. The "filling" of the vein will depend on other conditions, but one may reasonably expect that the structure of veins in granite, for instance, will be similar in widely separated mining camps; and so of veins in tough limestone, or easily fissile slates, and other characteristic rocks; and we may take the generalization still further, and expect to find all the veins in any mining district, in the same rock and belonging to the same system, similar to each other in filling as well as structure.

But it does not follow of necessity that all veins in any particular region are of the same age. On the contrary we frequently find several systems, each characterized by a general common strike and dip, showing that such regions have been the seat of several fissure-forming disturbances, which may have been of very widely varying force, and followed by fillings of a totally different character; but usually the most strongly developed system will either show a decided parallelism to the general direction of the mountain range, or else nearly at right angles thereto; and, while one system may be a good ore producer, another may be practically valueless. It thus early becomes necessary to identify their peculiarities and avoid loss.

While absolute dislocation of the strata or rocks may have been necessary to produce the entire series of fissure veins, whether parallel to the strike of the rocks or more or less at right angles to it, simple folding of the strata may have been sufficient to so far displace the lines of contact of two sedimentary rocks as to open the way for the formation of contact veins; or to so far rupture a belt of rocks without actual displacement as to permit the formation of segregated veins or deposits, or to rupture horizontal beds of limestone sufficiently to allow the percolation of water through them, with the consequent excavation of irregular chambers.

These changes are common to all mountain regions, and are not unknown even in comparatively level countries, but they have not resulted in the formation of mineral veins in all localities. There are extensive mountains areas almost entirely destitute of valuable mineral deposits; and therefore, while the preliminary fracturing of a country is absolutely essential to the formation of mineral veins, their subsequent filling with valuable contents must be explained by the operation of agencies which were local in their action, and at the most very indirectly connected with the agencies which formed the original fissures. The fracturing of the rocks simply made the formation of the veins possible. The formation of a crevice did not necessarily involve the formation of a vein, but only governed the physical aspect of such a vein when formed.

CHAPTER VI.

FILLING OF MINERAL VEINS.

Igneous Theory not Tenable.—It is a popular idea that all mineral veins have been filled from below by the material being forced into them while in a molten condition. This would involve intense heat. While there can be no question that the porphyritic and basaltic dikes have been filled in this manner, a multitude of facts compel us to look for some other explanation for the majority of metalliferous veins.

That the intrusion of dikes has been accompanied with heat is abundantly proved by the changes which have been effected in the rocks through which they pass, or into and between which they have been squeezed as sheets. When cutting through coal beds or penetrating them, as in pl. 5, fig. 6 (after Jukes), which covers a length of nearly 1,000 ft., the coal has been deprived of its volatile matter and becomes what is called "blind coal," or is even reduced to a small quantity of black soot. Sandstones become fused into a glassy quartzite; slates are hardened into a flinty substance with change of color, while other rocks have become porphyritic, as alongside the great trachytic dike which cuts across Onion Valley in Plumas County, Cal. This dike has a width of about 30 ft. and stands up as a wall on the hillside to a height of 90 ft. in places, and is apparently connected with surface sheets which overflowed from it. The country rock is a blackish green slate, but close to the dike it has been so altered as to look like a porphyry, being spotted with white feldspar crystals, which gradually become less conspicuous as the vicinity of the dike is left, until they fade out entirely in the plain-colored, unaltered general country rock. The same lava flow contains large fragments of the country rock which have been torn from the sides of the fissure during its formation. and altered in exactly the same way, just as we convert clay into brick by the action of heat. From these well established facts we would be justified in looking for similar changes in the walls of mineral veins, if they have been produced in the same way. We do find changes in the walls, it is true, produced by the action of heat, but they are such as result from the action of hot water and steam, and not of molten matter. The latter when once injected will gradually cool off, and when once cold will produce no further change, while the hot water may continue to circulate for ages, so long as the source of heat remains unchanged, and produce changes much more extensive and more widely disseminated than the action of injected lavas.

A few illustrations may render the discussion of this question more intelligible, and lead naturally to the important influence which rocks have on the nature of the vein material.

It is well known that if we melt copper and silver together we produce an alloy in which the silver is indistinguishable except by assay or analysis, yet in the Lake Superior copper mines we find blotches of white silver in the heart of solid masses of native copper or crystallized on the surface of the copper, showing that in the latter case plainly, and in the former by inference, copper and silver were deposited in the vein alternately, some of the silver at least after the formation of the copper had ceased.

At the Head Center mine, Tombstone, Ariz., crystals of gold are found planted on the surface of horn silver (chloride of silver); yet when melted together gold and silver form an alloy with the greatest facility, and the affinity of the metals for each other is so great that native gold always contains more or less silver.

At the Alston Moor lead mines in England, where galena in a matrix or gangue of fluorspar is worked, lead crystals (galena) are bedded in fluorspar, with lime crystals (calcite) planted on the lead crystals, and crystals of "blackjack" (zincblende) on the lime crystals—four minerals superimposed on each other, one at least of them (zincblende) volatile at a low temperature and another (lime) practically infusible.

In the Sierra Nevada mine, Virginia City, Nev., a seam of broken rock and clay, which has been made since the formation of the vein, is filled with minute crystals of red oxide of copper, formed by the coppery waters which filter through it from the higher levels.

In the upper part of the wash of Furnace creek, on the eastern side of Death Valley, Cal., is a beautifully regular vein of fibrous limestone (satin spar) cutting nearly vertically through beds of coarse conglomerate, which show no signs of alteration (pl. 7, fig. 8). Fig. 9, same plate, shows quartz veins in the same neighborhood and similarly located.

In the mines at Batopilas, Mexico, native silver occurs in veins of calcspar, which have an extraordinary persistence, frequently dwindling down to a mere seam, often less than 1 in. wide for long distances, and then opening out to a width of several feet. In places probably 90% of the ore is crystallized native silver, a large proportion of the remainder being crystallized ruby silver (arsenical) and crystallized black sulphide of silver, the latter often in branching flakes like moss formed in the joints of the rock alongside the veins.

Near Yankee Hill, Butte County, Cal., beautiful specimens of crystallized gold are found in the joints of the porphyries, usually in thin flakes, taking the shape of combs, fern fronds, etc. In this case there is no indication of veins or vein matter.

At West Point, Calaveras County, Cal., gold occurs in the solid granite. At Drytown, Amador County, Cal., gold occurs in limestone; and in Mariposa County, near Coulterville, both in the black clay slates and serpentines. At Fiddletown, in Eldorado County, gold is found in the iron pyrites which abound in the slates. The crystals are often of considerable size, chiefly cubes, and the gold can be seen projecting from the smooth faces of the crystals.

It would be possible to extend the list of similar cases of crystallization indefinitely, but it is not necessary to more than call attention to the fact that in many cases, if not in all, these crystals are formed in cavities, many of them of such size as to be called caves or caverns, which are not characteristic of any of the dikes which we know to be the result of injection from below. Good illustrations of this formation of crystals in closed cavities may be seen in the hollow balls filled with quartz crystals, called "geodes." The miners call the smaller cavities found in veins "vugs."

Metals also occur in gash veins which must have been filled from the surrounding rocks, having no connection with the interior of the earth.

Galena occurs in irregular deposits in limestone, where there is no evidence of vein structure.

Chrome iron occurs in isolated masses in blackish-green hornblende schists; while platinum, iridium, osmium, etc., occur chiefly as grains in sand or gravel deposits, which have probably been derived from the decay of rock strata, and not from veins, as their occurrence in veins is unknown.

In the case of the "compression veins" in slates, as at Amador and Sutter Creek, Cal., pl. 6, fig. 1, the ore bodies, carrying gold, are often completely surrounded with slates identically the same as the black clay slates to the westward of the vein, which show no trace of alteration by heat either as applied by molten lava or hot water, although they have been subjected to immense pressure and have been folded in every direction.

In Cornwall the remarkable case occurs of a vein producing copper for many hundred feet in depth, while encased in slates (called "killas"), but changing to tin when it passes into the underlying granite, as shown in pl. 8 and pl. 7, fig. 1, which represent a longitudinal section and a cross section of the Dolcoath mine.

Again, we have those peculiar veins in which the minerals are arranged in bands parallel to the walls, as in pl. 7, fig. 4. This case is similar to those in which crystals of different minerals have been deposited on the top of each other in succession.

In pl. 7, fig. 5, we have a case in which a band of rock has been altered, and contains more or less parallel ore bodies (shown in black), with numerous threads and stringers connecting them, the whole "stockwork" fading out into the inclosing rock without any positive definition or walls.

Many other cases of interest might be cited, but these are sufficient to show the difficulties which surround the theory of igneous filling of mineral veins from below by injection in the form of molten or pasty matter.

In the case of the limestone deposits there is no connection by well defined fissures with the interior of the earth, through which the filling could have taken place; and in the case of the Batopilas mines it is inconceivable that a mineral so infusible as limespar could have been injected into fissures, frequently less than an inch in width; while if we admit the possibility of the lime being fused, the heat would have been so intense that the adjacent rocks would have been fused into lava, and the minerals found in the injected material would have been volatilized and entirely eliminated, unless retained by condensation in the cooler surface rocks, in which case the ores would be found only near the surface and in the country rock as well as in the lode, and the latter would be barren or unproductive in depth, which from actual exploration we know is not the case. That heat does operate in this way we know from the quicksilver mines of Lake County, Cal., where the surface rocks are filled with minute globules of mercury, which have been brought up from below by the action of hot springs and steam, and condensed near the surface, where the temperature fell below the volatilizing point of the mercury.

Similar difficulties meet us in the case of the lime vein on Furnace Creek, and indeed in all cases where minerals occur intimately associated with limestone, either in the body of the rock itself, or in the crevices, or where it becomes the gangue accompanying the ore.

The occurrence of gold in porphyry, slate, lime, granite and serpentine, outside of veins, is also inexplicable on the theory of upward injection; as also the presence of minerals in gash veins and the slates of the mother lode in California.

The same appears patent of all those cases where minerals are found which readily form alloys and have a similar melting point, in close contact, yet each retaining its individual character; as well as in all cases of superimposed crystals lining cavities or vugs in the vein, especially where the cavities are of such dimensions as to become worthy of the name of caves.

That crystals do form in dikes or veins of igneous (or rather of plutonic) origin is not denied; but they form a compact mass, the various minerals crowding each other to distortion, and mixed in tolerably uniform proportions, as in granite and the porphyries, in which cavities are almost unknown; while such crystals as they do yield outside of the mass are found in crevices formed at a later date than the origin of the rock.

We have still the case of the Cornish veins, which is only a type of many others, where the imagination can hardly realize how a vein can be filled from below, during the same operation, with copper in its upper portion and tin in its lower, and why the change in the character of the injected material should have taken place just at the junction of the two rocks which were traversed by the fissure.

In such cases as the occurrence of flakes of horn silver in the joints of quartzites at the Isabel mine, near Globe, Ariz., which can be scraped off, leaving the quartzite absolutely barren of silver; and the same ore in the joints of limestone west of Tucson, Ariz., where the surface of the joints gives good assays, while the silver penetrates the blocks of limestone in steadily diminishing quantities for only a few inches, leaving their interior entirely innocent of ore, we cannot invoke the igneous theory, because there are no veins to be injected.

The same may be said of the horn silver found in the Leeds mine, near the southeast corner of Nevada, which in many respects is one of the most remarkable occurrences of silver on record. There is no true vein; the matrix or gangue in this case is a nearly horizontal bed of sandstone, in which are found large quantities of vegetable remains, such as wood, twigs and leaves, and it is these which carry chloride of silver in quantity sufficient to make working of the mass not only possible but profitable. In this case there cannot be a suspicion of injection.

More doubt hangs over the silver ores in the trachytes or rhyolites of the Calico district, San Bernardino County, Cal., which occur in the crevices of a truly eruptive rock; but even here the ores may lie in fissures formed subsequently to the eruption of the trachyte.

We are thus compelled to look for some other method by which the fissures, now called veins, have been filled with their mineral constituents. Among those familiar with the subject the igneous theory, which held sway for many years, has been generally abandoned as incapable of explaining the greater portion of the phenomena.

Aqueous Theory.—The distribution of ore in veins is of the most irregular character. In some of the gold veins of California the metal is collected in well-defined pockets, containing all the way from a few pounds up to half a million dollars, surrounded by barren white quartz in immense quantities. In other mines we find the ore in threads and stringers, more or less parallel to the general direction of the walls, fading out into the country rock which evidently forms the general mass of the vein, in fact constituting its gangue. These and other allied facts suggest the modern explanation, which attributes the filling of veins to the circulation of heated waters in the earth's crust.

Distribution of Metals, etc., in Nature.—Of late years researches into the constitution of sea and mineral waters has revealed the presence in them of a long list of elements in the form of salts, establishing the fact of their solubility in nature as well as in the chemist's laboratory. In mineral waters the metals iron, arsenic, lithium, cæsium, rubidium, copper, zinc and manganese have been detected, along with the elements of earthy minerals which form the gangue of veins, such as silica, magnesia, lime, alumina, fluorine and baryta; besides soda, patash, boron, chlorine, iodine, bromine, phosphorus and sulphur, many of which latter form salts which are excessively soluble.

Sea water, according to Prof. Forchhammer, in addition to the chlorides and sulphates of sodium, magnesium, potassium and calcium, contains silica, boric acid, bromine, iodine, fluorine as acid, and the oxides of nickel, cobalt, manganese, aluminum, zinc, silver, lead, copper, barium and strontium; and arsenic, gold, lithium, rubidium, and cæsium have been discovered since Forchhammer wrote. The experiments of Prof. Liversidge on the sea water off the coast of Australia give positive results as to the presence of gold. Other investigators also have detected gold in sea water.

Daintree reports the occurrence of gold in the serpentines and pyritic diorites of Queensland, and the pyritic granites of New South Wales.

The nodules or concretions of manganese dredged from the ocean floor by the Challenger expedition showed the presence of nickel and cobalt.

Prof. F. Sandberger has announced the discovery of small quantities of silver, lead, copper, nickel, cobalt, bismuth, arsenic, antimony and tin, in silicates such as olivine, augite, horneblende and mica, which are constituents of igneous rocks.

Prof. Dana records the occurrence of nickel in the Vesuvian lavas, and also the chlorides of lead, copper, iron and manganese, as forming on the lavas at the craters from the heated vapors; and similar results would probably be obtained at other volcanoes had they been as carefully studied. He also notes the presence in minerals which form a portion of gneiss and granite, of manganese, lithium, cerium, lanthanum, didymium, yttrium, zinc, berylium, titanium, molybdenum and cobalt; the latter metal also in mica schists with arsenic.

J. S. Curtis determined the presence of gold and silver in the silicates of the rocks adjacent to the Comstock lode, the silver chiefly in those of the hanging wall diabase or porphyry and the gold in those of the foot wall syenite; and when writing on the quicksilver deposits of the Pacific coast of the United States, Prof. G. F. Becker reports the presence of antimony, arsenic, lead and copper in the underlying granites at Steamboat Springs, Nev.; and records the fact that these springs are to-day depositing quicksilver, gold, antimony, arsenic, lead and copper.

Daubrée gives the following list of elements, arranged somewhat in the degree of their importance (Maskelyne adds lithium and antimony): iron, magnesium, silicon, oxygen, nickel, cobalt, chromium, manganese, titanium, copper, aluminum, potassium, sodium, calcium, arsenic, phosphorus, nitrogen, sulphur, chlorine, carbon and hydrogen, several of the compounds of which are peculiar to meteorites. The majority of the meteoroids with which the earth comes in contact are exceedingly small, and a weight of 1,000 lb. is probably uncommon, but when the daily number encountered by the earth, estimated at 20,000,000, is multiplied by years and centuries it is evident that the addition of their contained minerals to the earth's surface is worthy of notice. These minerals, forming part of the sedimentary strata, could find their way into veins without even the intervention of volcanic agency. It is more than probable that the cobalt-nickel-manganese nodules of the deep sea are derived from the meteoric dust falling on its surface.

Outside of the eruptive rocks we find ore minerals disseminated in secondary or stratified rocks, such as slates and sandstones, as well as in limestones, and it is from all of these sources combined that the metals have been concentrated into veins.

Underground Circulation.—It is evident that water is the active factor in all these changes. We must remember that a considerable portion of the water which falls upon the surface of the earth does not pass off promptly into the rivers, but is absorbed by the earth and rocks, and by the action of gravity penetrates to depths practically unknown. Of this we have absolute demonstration from its presence in the quartz crystals of deep-origined eruptive rocks, as numerous but exceedingly small bubbles, only visible under a powerful microscope; and from the enormous volumes of steam which are given off by volcanoes in eruption, and which continue to be evolved from the lavas after their ejection. We must not imagine the crust of the earth as a solid mass, through only the crevices of which water may find a passage; there is abundant evidence that every particle of the earth's crust to depths of which we have any knowledge, and presumably far below, is charged with water, and that there is no substance known which is not permeable by it. Under pressure it can be forced through iron, appearing as a perspiration on the outer surface of the confining flask, and with such a practical demonstration we are compelled to admit the fact as stated.

Heat.—While this water at the surface may be cold, we know from the evidence of borings and mining works that the temperature increases with depth from that point near the surface at which it remains stationary through summer and winter alike, so that in the Comstock lode, at the 2,300-ft. level of the C. & C. shaft, the thermometer registered about 150° F., and at the 3,000-ft. level of the Yellow Jacket shaft 170°. There is no difficulty in imagining this temperature increasing to the boiling point of water (212°) and rising greatly higher, until it becomes so intense that the water may be said to be "white hot." This heat is not the product of actual fires. It may be partly caused by chemical action, but is more extensively due, in all probability, to the pressure on the earth's crust caused by its steady and constant contraction as it cools, and to the friction from the wrinkling movements. The rocks become hot during compression and movement and impart their heat to the contained water, which, aided by hydrostatic pressure, brings it to the surface and it is dissipated in hot springs; or, if such a vent is not made, by volcanic eruptions, or the intrusion of lava into upper and colder strata.

Solution, Transportation and Deposition.—We are now prepared to understand the action of water in the subsequent processes. We have the waters penetrating the rocks everywhere, the cooler waters descending, the heated ones tending to rise, or being forced to the surface along the lines of least resistance, such as the fault fissures, by the pressure of other waters or steam.

The ability of water to decompose rocks depends on the presence of carbonic acid and alkaline material such as the carbonates of soda and potash, and its solvent powers are increased with a rise of temperature. Its first carbonic acid is derived by rain water from the atmosphere, and the moment it touches the earth it begins its work of decomposition and rearrangement, picking up and dissolving one mineral and depositing another. Water traversing an open fissure would thus leave a portion of its contents on the walls, both sides alike, as it gradually cooled in its ascent, just as sugar candy will crystallize out of the sugar solution as it is cooled or evaporated, the process of cooling producing the same result as that of evaporation, in both cases the liquid being unable to carry so great a load drops it at the first opportunity. In this manner have veins like those of the Wheal Mary Ann lode in Cornwall been formed (pl. 7, fig. 4), *a*, being chalcedony (silica combined with water), *b*, glassy quartz terminating in crystals; *c*, galena; and the central core *d*, chalytite (carbonate of iron), the deposition on both walls being similar and indicating the origin of the minerals. The change in the deposited mineral may have taken place either because of the exhaustion of the locality from which it had been collected by the water, or from such divergence in the course of the underground flow by disturbances like earthquakes that the material was drawn from a new series of rocks. A similar incrustation of small cavities by waters abounding in silica has formed agates, the banding being due to the changing presence of the coloring material. Compact and close-grained as these agates may seem, they are in reality porous, for it has for centuries been a common practice to boil them in suitable materials to increase the brilliancy of the coloring of the bands, the change being due to the partial absorption of the material with which they have been treated. When the cavity has not been completely filled, it is either left with a smooth surface of chalcedony (which does not crystallize) or lined with crystals of quartz, calcite, etc. In such manner also have opals and other minerals been introduced into the oval cavities of basaltic lavas, and thus we have also an explanation of how minerals can be deposited as crystals on the top of each other by just such changes in the character of the circulating waters.

Source of the Ore.—The source of the minerals thus deposited is to be found in the country rocks of the region, mainly the eruptives, which, as we have seen, contain nearly all, and probably would be shown to contain quite all, of those known; or even from the secondary or stratified rocks derived from older igneous rocks, into which the mineral constituents of the latter must unquestionably have been carried during their deposition as sediment. That lavas have been deprived of their valuable mineral constituents in this way is fairly proved by the experiments of Prof. Becker and Dr. Carl Barus, on the Comstock. The hanging wall of that lode is diabase (in Virginia City), known by the miners as "blue porphyry," a term which well expresses its appearance when freshly broken. The Sutro tunnel has exposed the structure of the east country (that is, on the hanging wall side) for more than three miles, and developed a series of bands showing plainly the results of solfataric action (by heated waters), with alternating bands of hard blue porphyry. Outside of, and next to the lode, the rock is hard and suggestive of no change, except by the presence of iron pyrites, which is nearly always a product of decomposition, but under the microscope it becomes evident that extensive changes have taken place in it. Its crystalline structure has been modified, the hornblende and augite (silicates) have been altered, pyrite having been made out of their iron, and the silver which is present in them further away from the lode has disappeared, the natural conclusion being that it has found its way into the lode through water.

Form of Deposit.—All veins were not formed in the manner described as occurring at the Wheal Mary Ann lode and others similarly constituted. This presupposes an open fissure, and it does not seem possible that all fissures in which veins have been formed remained open during the process. In many it is plain that such was not the case, because they show no true walls, as in the Great Flat lode, Cornwall (pl. 7, fig. 5, and pl. 6, fig. 3), where the ore *B* is frozen to the dike *A*, and there is only one wall; or in pl. 6, fig. 1, where the masses are lenticular and not connected with each other (Keystone mine, Cal.); or in pl. 6, fig. 2, where there is no trace of banding, and the hanging wall shows many feeders or stringers not seen on the foot wall. The maintenance of an open fissure in the case of such a structure, as pl. 2, fig. 2 (a generalized cross section of the Comstock lode in Virginia City), would have been an impossibility for the three or four miles of its length, the foot wall having a dip of only 40°; but it is equally plain that a slight sliding of the hanging wall on the foot would produce just such cracks as *a*, *b*, *c*, *d*, accompanied by an immense amount of broken material. In many such cases there is no true gangue, the ore occurring in the original country rock, decomposed it is true, in bands or stringers more or less parallel to the walls, or strike of the rocks which have undergone decomposition, but fading out into the unaltered country rock on either side as at the Great Flat lode, or only on one side, as in pl. 6, fig. 3; while in fig. 1 there is one true wall at the contact line. In these cases we can only account for the presence of ore on the supposition that as the percolating water dissolved and carried away the particles of the rock it left in their place particles of ore, simply making an exchange, and it can easily be understood how this substitution would go on most rapidly and most extensively in those portions of the fissure which had been most shattered during its formation, as the material would have been more largely ground into powder at such points, not only allowing more water to find its way through those portions, but presenting vastly greater surfaces to the action of the water. Thus a cube with faces 1 in. square has a surface as 6 to 1 of bulk, while a cube with faces 2 in. square has a surface of only 3 to 1 compared with bulk. It is at such places that the largest deposits have taken place, and it is thus that "horses" have usually been formed in the lodes; not by masses falling into an open fissure, but by the water circulating through crevices, completely surrounding a block of country rock. We constantly find pieces of country rock in veins completely inclosed in ore, and these are only horses on a very small scale. The Savage mine, at Virginia City, afforded abundant specimens of mineralized porphyry, suggesting this origin, and those of Monte Cristo, Wash., offer many more illustrations which are totally inexplicable on any theory of large open fissures. Many such veins have acquired slicken sides and gouge by subsequent movements of the rocks, which would naturally follow such lines of weakness, and may even have undergone a partial refilling and reconcentration of their own constituents, some portions having been impoverished to enrich others. That such movements have taken place is shown by the crushing of the quartz in some of the larger bodies on the Comstock lode, so that it was known to the miners as "sugar quartz."

These examples suggest an explanation which will account for nearly all cases of vein structure, and attention in the field will show how beautifully the cycle of changes is constantly in progress, beginning with the earliest fracturing of the rocks and the first rainfall, with no cessation to the present time.

Rationality of Natural Processes. — A moment's thought will show that under any circumstances some such results as have been outlined must have been the outcome of the surface changes of the earth. Even had the original veins been solid masses of gold, silver, copper, etc., their contents would, as they were worn away, have been scattered far and wide through the rocks which were formed out of the earth's first crust, even if that crust itself did not contain them, and the condition of the rocks which we have pictured would have been one of the first results of erosion, and the formation of veins by segregation or substitution must have commenced even in those early days, by the workings of the laws of chemical affinity, which imply the abandonment by one element of its associate in a compound when it meets with another which is more to its liking under suitable conditions for making the exchange.

How easily these changes are effected may be seen in the occasional action of metallic compounds in the cabinet. Just as the iron pyrite crystals, so abundant in some of the gravel mines of California (pl. 11, fig. 3, shows a petrified tree covered with them), drop to pieces and decay with extraordinary rapidity, so specimens of pyrite of the bronze-colored variety from the Glacier mine, Monte Cristo district, Wash., after remaining in the writer's cabinet only two months, were entirely decomposed, the pyrites having absorbed moisture, which combining with the contained sulphur had produced sulphuric acid, which in its turn had combined with the gangue of the specimen (partially altered porphyry), forming glistening salts and rough concretions, not only on the specimen originally attacked, but on the adjacent ones which happened to be in contact with it, however slightly. The amount of moisture absorbed was so great that what remained of the specimens could not be handled without staining the hands black. On seeing the change the writer remembered extracting from the same vein, in a previous year, samples with the same appearance, having undergone the same changes in place. If then the small amount of moisture which is present in a dwelling room can effect such changes, we are at no loss to understand how much greater ones can be effected by nature in her vast underground workshops, with her absolute disregard of the element of time.

Ore Deposits in Limestone.—In a somewhat similar way have the greater portion of the deposits in limestone been formed, percolating waters eating out passages and chambers, which have been subsequently filled with iron, lead or zinc ores by the waters traversing them. The ability of water to excavate caves, such as the Mammoth Cave in Kentucky, and hundreds of others in all extensive limestone regions, is so well known as to require no further comment, except that the most remarkable feature about them is their subsequent filling with large bodies of mineral, usually of only one or two kinds, much less complex in their constitution than the filling of veins; which suggests a different, probably cooler, condition of the percolating water. Such deposits are of the most irregular shape, due to the vagaries of the water which hollowed out the chambers, and when the walls are reached they may generally be scraped clean, as the mineral does not usually penetrate the limestone to any depth. Pl. 6, fig. 8, is a sketch of such a deposit formed in limestone, on the bedding planes and joints, and controlled only by the lines of flow of the water, as indicated by the arrowheads. Such are the deposits of Wisconsin and Illinois. Fig. 4, same plate, shows the limestone traversed by the dike *B*, and the arrowheads the possible direction of the water flow, which if descending, as at *A*, might form ore bodies as shown in black, or if ascending, as at *C*, either as hot or cold water under pressure would present a similar structure. Fig 7 shows the structure of the veins at Tombstone, Ariz., being successive strata of slates *S*, limestone, *L*, quartzite, *Q*, and dolomite (magnesian limestone) *D*, traversed by the quartzose fissure veins *A*,*B*, which are connected in the limestone by the flat bodies of rich lead ore, *C*. In pl. 1, fig. 2, we have at Leadville, Colo., lead ores lying between the limestone flour, the deposits being nearly horizontal, and porphyries for a roof.

On pl. 7, fig. 2, we have hematite *B*, deposited in cavities of the mountain limestone *A*, at Ulverstone, England. Subsequent to the deposition of the ore it is evident that a further portion of the limestone was dissolved by waters free from iron, forming a later cave which was filled with the clay *C*, the whole being probably partially worn away before the covering of dirt *D* was laid down at a much later date. In fig. 3, same plate, we have a similar formation at Altenberg, Germany, only calamine (silicate of zinc) takes the place of the hematite in the former illustration. *B* is a body of limestone, lying between the slates *A*, the zinc ore *D* filling a cavity of erosion, and the clay *C* filling a cavern of later date formed after the deposition of zinc ore had ceased.

In most such cases it is probable that the filling took place by waters percolating through rocks of later formation, lying above the limestone in which the caverns were formed, from which they abstracted the iron and zinc, only to redeposit them when presented with a more tempting morsel in the shape of lime.

Ores Possibly Derived Directly from the Sea.— Most chloride and bromide ores of silver and lead are found near the surface, in the joints of limestones and quartzite; it is very probable that such rocks have derived the ore found in them from sea water, when they were a portion of the ocean bottom. In Arizona there are many occurrences of these ores in localities where such a condition has been possible, there being evidences of the former existences of an ancient inland sea. A similar explanation is advanced to account for some gold-bearing conglomerates, in which the gold is supposed to have been precipitated from the ocean, near shore. By a secondary process the gold sparsely disseminated in mud beds at the bottom of the sea might be concentrated in quartz veins, traversing the shales and slates formed by the consolidation of these beds. The ocean-formed ore bodies would, if derived directly, be beds or impregnations and not true veins.

Electro-chemical Action.—Around many of these phenomena, as around so many of the operations of nature, there hangs a suspicion of the intervention of electricity. The action of electrical currents is forcibly suggested in the case of native copper mixed with native silver, or of gold crystals deposited upon horn silver; but even if such an agency was active in their production there must have been a previous leaching of other rocks to provide the solutions from which the metals were reduced and crystallized.

A Cycle of Perpetual Change.—That operations such as we have been describing are constantly going on in nature, and that no extraordinary processes need be invoked to account for the phenomena we see, is plainly evident from the changes which take place in the outcrops of veins and elsewhere. We constantly find incrustations of various salts, such as alum and those of soda and potash, forming on the sides of caves, and even of other minerals on the walls of deserted mines; we secure copper from the waters discharged by copper mines or mines of coppery iron pyrite by allowing it to run over scrap iron, which is destroyed by the acid in the water and copper released; the pyrite in the outcrop of veins is decomposed under the joint action of air and water, leaving a deposit of rusty iron-stained gangue, while the sulphuric acid percolates downward to produce other changes; we find surface pyrites likewise decomposing, parting with their sulphur and iron, only to combine with oxygen, and form the red and black oxides of copper, which are richer than the original ore, and in fact are merely concentrates of ores which may even be too poor to work when the limits of the changes are reached, which is usually where the presence of permanent water prevents contact with the air. We also find that many carbonates of lead have a core of galena, which is the sulphide, and know that the conversion has taken place since the deposition of the galena; and if we look carefully around us we will meet everywhere with alterations going constantly forward. Brought up from the unknown interior of the earth by lavas, the minerals are collected from them into veins, only to be again scattered as the veins are worn away in the general destruction of the earth's surface, and mingled with the fragments of the lavas in sedimentary deposits, which, as we have seen, ultimately return to granite, only to be intruded into the overlying strata, the wearing away of which uncovers the granite, and the circle is completed. Formation, rearrangement, destruction, reformation and return to the original are the perpetual cycle of the changes in veins, and not only of them but of the rocks in which they are contained.

Local Limitations.—These views afford a natural explanation of the reason why mineral veins are confined to certain regions and are not found in all areas of dislocation. We have no knowledge of the appearance of the original crust of the earth, as it was formed under conditions which we can never hope to see, but it is evident that all minerals, except meteorites, now upon the surface of the globe, in whatever condition, must have been derived either from it or from rocks which have been ejected through it. At the moment these began to decay we have the commencement of the whole stratified series, through which, in some form or other, all the mineral constituents of the original rock must be scattered, according to the size of the particles, except those which were perfectly soluble; but always on lines descending seawards. In the course of time these sediments would be again brought to the surface, to be again worn away into new sediments, mixed with the debris of a new series of eruptive rocks, the process being repeated with ever-increasing complexity, but with a constant increase in the metallic contents of the crust, if such were brought from below by the eruptive rocks from time to time.

But just as soon as fracturing began, and with it the circulation of heated waters, the concentration of the minute particles into veins would begin, which as they in turn were eroded would furnish particles of larger size to the sediments, and in time these might contain sufficient mineral to form large deposits when concentrated by the circulating waters, even at long distances from the seat of the original eruptive rocks from which the mineral was derived. Such sediments, still retaining the mineral fragments, like the lead and copper-bearing shales and sandstones, can be conceived to be still forming.

We can now see why all fractured regions are not metalliferous. There must have been an original area of eruptive or volcanic rocks to start the metal-bearing series, for without this no amount of folding or dislocation could have produced an ore vein.

We can also understand the spotted or pockety character of many veins; and why there should so often be in a district one strong "mother" vein, as the main fissure would offer more unimpeded channels for the circulation of water than the smaller lateral crevices; and why veins of different geologic age in the same district should be filled with different minerals, as the source from which the first series was filled may have been exhausted before the formation of the next.

CHAPTER VII.

INFLUENCE OF ROCKS ON VEIN FILLING.

It is evident that if there is any relationship between ore minerals and rocks, or if, in other words, the useful minerals are more particularly found associated with some particular rock in preference to others, the knowledge of the facts would be of great value to the prospector, for when he had gained an idea of the rocks of any particular district he would have a general idea of the minerals which he was likely to find there, and could familiarize himself with their appearance, from books or otherwise, and not only know what to look for, but how and to recognize them when found.

The following imperfect table, compiled from recognized authorities, while far from being as complete as could be wished for, undeniably shows that there is such an association of minerals with certain rocks, the reasons for which we may not at present thoroughly understand, but which is not only of interest but of practical importance.

The greatest difficulty in preparing such a list is to give equal prominence to all parts of the subject, because while a certain ore may be found at two separate localities in two different rocks, it may be of no especial value in one of them and of vast importance in the other. It is almost impossible to correlate such differences. One might quote 20 mines in a single district, all having practically the same character, and only one in another district of different rock structure but producing the same metal, thus giving undue prominence to the former mode of occurrence; and it is not always possible to estimate the "personal equation" in the various published accounts, which phrase is understood to include the amount of knowledge and accuracy of the writer and preconceived theories unconsciously coloring his views.

To overcome these difficulties, and yet keep the table within reasonable limits, a limited selection of cases where the information was full enough has been made from the literature of the subject. The selections are for districts, not individual mines, and though insufficient for a thorough scientific discussion, will be sufficient for our purpose. It does not include iron ore, as that is chiefly found in bedded deposits, not subject to the same influences; nor the minor minerals, such as nickel, cobalt, antimony, bismuth, etc., as they are usually the accompaniments of other ores, and do not form the prominent or controlling mineral of the deposit which imparts to it its positive character, although these may have a preference for one mineral rather than another, and occur most frequently in combination with it.

ROCKS ASSOCIATED WITH ORE DEPOSITS.

Rocks.	Principal and Associated Minerals.	Locality.	Remarks.
	GOLD.		
Trachyte	Tellurides	Nagyag, Transylvania	Veins very small.
Diorite	Free	Sudbury, Ontario	
Diorite		Allison mine, Amador Co., Cal.	
Andesite		Thames district, New Zealand.	Veins in zone of brecciated andesite.
Porphyry	Tellurides	Telluride belt, Colo	In joints, with silica.
Porphyry	Free	Butte Co., Cal	
Porphyry		Berezovsk, Russia	Dikes cutting schists.
Porphyry—granite contact	Free	Boulder Co., Colo	Dike cuts granite and gneiss.
Granite or gneiss	Iron pyrite and tellurides	Wyom'g mine. Nevada Co., Cal.	
Granite or gneiss		Soaprot mine Calavera Co., Cal.	
Granite or gneiss	Tellurides	Sent'nl mine, Boulder Co., Colo.	
Granite—line contact	Iron pyrite and oxides	Wermouth conces'n, Honduras	Granite hanging, calcspar foot wall.
Slates	Iron pyrite	Keystone mine, Amador Co., Cal.	Black clay slates.
Slates		Siberia	
Schists	Iron pyrite	Mariposa Co., Cal	Talc and serpentine.
Schists	Iron pyrite	Peshaston Creek, Wash	Talc and serpentine.
Schists	Iron pyrite, zincblende, galena	Yavapai Co., Ariz	Quartzose and talcose schists
Schists		Berezovsk, Russia	Chloritic, talcose and clay schists.
Schists	Iron pyrite	Georgia	Mica, talc, hornblende and chlorite schists.
Schists		Tomoh, Siamese Malay'n States	Mica and chlorite schists.
Schists		Maryland	Mica schists and in sheeted walls.
Schists		Otago, New Zealand	Quartzose schists—no eruptive rocks.
Schists		Tolema, South America	Between laminæ.
Schists and eruptive rocks.		Calaveras Co., Cal	Schists broken through by diorite dikes.

ROCKS ASSOCIATED WITH ORE DEPOSITS.—*Continued.*

Rocks.	Principal and Associated Minerals.	Locality.	Remarks.
	GOLD.		
Schists and eruptive rocks.		DeKaap, South Africa	Schists overlying granite; gold in banded bars always near eruptive rocks.
Schists and eruptive rocks.		Haile mine, S. C.	Talcose slates cut by diabase dikes. Slates form gangue.
Schists and eruptive rocks.	Silver	Honduras & Rosario Mg. Co., Honduras.	Greenstone foot and silicious slate hanging wall.
Schists and eruptive rocks.	Free and pyrites	Homestake mine, S. Dak	Schists, overlain by porphyries with parallel intrusions and dikes.
Slate—sandstone contact	Free	Bendigo (or Sandhurst), Australia.	On anticlinal folds, very continuous.
Slate—quartzite contact	Copper,-lead, zinc and pyrite	Nova Scotia	Beds in abruptly folded strata.
Sandstone		Voraspotak, Russia	In gypsum veins.
Sandstone and eruptive rocks.	Copper pyrite, iron pyrite, blende, etc.	Mt. Morgan, Queensland	Altered sandstone with dolerite and rhyolite.
Sandstone and eruptive rocks.		Black Hills, S. Dak	Ore sheets in Potsdam rocks; quartzites connected with dikes and intrusive sheets.
Conglomerates		DeKaap, South Africa	In beds.
	GOLD—SILVER.		
Syenite—diabase contact	Chiefly iron pyrite	Comstock lode, Nev	Most gold in southern portion where sedimentary rocks occur or where lode is altogether in syenite.
Lime shale—trap contact	Galena, etc	Black Hills, S. Dak	Ore sheets in Potsdam rocks, silicious lime shales connected with dikes and intrusive sheets.

ROCKS ASSOCIATED WITH ORE DEPOSITS.—*Continued.*

Rocks.	Principal and Associated Minerals.	Locality.	Remarks.
	SILVER—GOLD.		
Schists	Iron pyrite, galena, blende and copper.	Colombia, South America	In quartzose mica schists.
	SILVER.		
Rhyolite	Iron pyrite, gray copper, oxide of tin, zinc blende and galena.	Potasi, South America	Veins cut Tertiary shales and rhyolites; carry massive iron pyrites.
Rhyolite		Calico, Cal	
Trachyte	Zincblende and barite	Beaver Co., Utah	Fissure in trachyte.
Trachyte		Carbonate and Rattler mines, Utah	Quartz veins.
Porphyry	Silver sulphides	San Marcos, Honduras	
Granite	Galena, zincblende, pyrite, manganese.	Butte, Mont	In fissured zones. Rhyolite near.
Granite		Flint Creek, Mont	
Syenite and eruptive rocks.	Copper, zinc, lead and pyrite.	Yuscarau, Honduras	Syenite, traversed by dikes of greenstone, porphyry and basalt.
Syenite and eruptive rocks.	Antimonial silver	Cucaren, Honduras	Syenite and porphyry.
Limestone	Sulphides and native silver	Opoteca, Honduras	Ore mills freely.
Lime shale and granite contact.	Manganese	Flint Creek, Mont	Ore in granite, cutting lime shale quartzite contact.
Lime shale and andesite contact.		Cerro Pasco, South America	Silicious ores in shales between lime and andesite.
Shales		Port Arthur, Canada	Black shales, capped by trap beds. Veins cross intrusive dikes.
Shale—rhyolite	Silver sulphides	Rosario mine, Honduras	Veins in rhyolite or shales, sometimes on contact.
Schists—andesite	Antimonial silver	Bocaneme, South America	Interbedded veins near andesite, dike.
Sandstones	Silver chloride	Silver Reef, Utah	In sandstone beds.

ROCKS ASSOCIATED WITH ORE DEPOSITS.—*Continued.*

Rocks.	Principal and Associated Minerals.	Locality.	Remarks.
	SILVER—GOLD.		
Sandstones	Silver chloride	Leeds, Utah	In sandstone beds with fossil plants.
Quartzite	Sulphides	Ontario mine, Utah	Very continuous.
	LEAD-SILVER.		
Granite	Zincblende, arsenical pyrite	Maine	
Granite	Zincblende, arsenical pyrite and gold.	Monte Cristo, Wash.	
Granite and gneiss		Spain and Saxony	
Limestones and dolomites.	Silver	Eureka, Nev	
Limestones and dolomites.	Silver	Juab Co., Utah	In stratified lime.
Limestones and dolomites.	Silver	Emma mine, Salt Lake Co., Utah.	
Limestones and dolomites.		Sweden and England	Veins in limestone.
Limestones and eruptive rocks.	Silver	Beaver Co., Utah	Ore on contact of trachyte and lime.
Limestones and eruptive rocks.	Silver	Black Hills, S. Dak	Ore deposits in Potsdam rocks, in connection with dikes and sheets of igneous rocks.
Limestones and eruptive rocks.	Silver	Lake Valley, N. M	Ore underlies porphyrite in limestones; andesite and rhyolite eruptions.
Limestones and eruptive rocks.	Silver and iron	Leadville, Colo.	Contact of limestone and porphyry.
Limestones and eruptive rocks.	Silver	Aspen, Colo	Ore in limestones associated with eruptive rocks.
Lime—quartzite contact	Silver, gold, copper and iron pyrite.	Aspen, Colo	Ore beds between lime and quartzite; andesite cap.
Lime—quartzite contact	Silver	Stockton, Utah	Concentrating ore.
Lime—quartzite contact	Silver, gold	Old Telegraph mine, Utah	Tone veins, with quartzite foot, lime shale hang'g wall.

ROCKS ASSOCIATED WITH ORE DEPOSITS.—*Continued.*

Rocks.	Principal and Associated Minerals.	Locality.	Remarks.
	LEAD-SILVER.		
Lime-shale contact	Silver, gold	Tombstone, Ariz	
Quartzite—porphyry contact.	Silver	Salt Lake, Utah	Ore on contact.
Slates	Zincblende and copper	Maine	
Slates		Connecticut	Mica slates.
Slates		Bohemia	Clay slates.
Slates		Cornwall	
Schists	Silver, zincblende, iron pyrite.	Monte Cristo, Wash	Associated eruptive rocks.
Schists	Silver	Pontgiband, France	Mica schists and gneiss, traversed by granulite dikes and capped with basalt. Lodes cut the dikes.
Conglomerates	Zincblende and silver	Suyape, Honduras	Conglomerates and marl beds.
Conglomerates	Silver, zincblende and iron pyrite.	Los Angelos Mg. & Smelting Co., Honduras.	Conglomerate foot wall.
	COPPER.		
Eruptive rocks	Native	Lake Superior	In ash beds of amygdalordal diabase.
Eruptive rocks		Maine	In "trap."
Eruptive rocks	Sulphide ores	Connecticut	In "trap."
Eruptive rocks		Sudbury, Ontario	Lenticular beds in diorite.
Granite and gneiss	Silver	Butte, Mont	In fissured zones rhyolite near.
Granite and gneiss	Copper pyrite	Fahlun, Sweden	In beds.
Granite and gneiss	Sulphide ores	Maine	Veins in gneiss and quartzite.
Eruptive rocks and schists.	Nickel	Sudbury, Ontario	Near contact of graywacke and diorite, or in the diorite.
Eruptive rocks and schists.		Capelton, Quebec	Various schists associated with diorite.

ROCKS ASSOCIATED WITH ORE DEPOSITS.—*Continued.*

Rocks.	Principal and Associated Minerals.	Locality.	Remarks.
	COPPER.		
Granite—lime contact	Oxidized ores	Globe, Ariz.	
Limestones	Oxidized ores	Clifton, Ariz.	In or near to the Carboniferous limestone. Another writer says "felsite porphyry."
Limestones		Bisbee, Ariz.	Confined to the limestone. No regular stratification.
Lime—sandstone contact	Oxidized ores	Globe, Ariz.	
Sandstones		Mansfield, Saxony	Disseminated.
Sandstones	Gray copper	Nova Scotia	Beds and layers in sandstones and shales, with fossil plants.
Sandstones		Texas	With fossil plants.
Sandstones		Russia	In grits, sandstones and shales. Carbonates around carbonized plant remains.
Sandstones	Vitreous copper	Connecticut	
Conglomerates	Native silver	Lake Superior	Beds of conglomerate.
Conglomerates	Carbonate ores	Copper Basin, Ariz.	Sandstone conglomerate, cemented by copper; lies on granite charged with copper pyrite.
Slates		Cornwall, England	
	ZINC.		
Gneiss		Maryland	Small veins.
Gneiss		Ammerberg, Sweden	In granitic gneiss.
Porphyry—lime contact.		Southwest N. Mex	In lime at contact of dikes cutting lime and granite.
Limestones	Galena	England and Belgium	Including dolomites.
Limestones	Galena	Connecticut	Including dolomites.
Limestones	Galena	Wis., Mo., Iowa and Ills.	Including dolomites.

ROCKS ASSOCIATED WITH ORE DEPOSITS.—*Continued.*

Rocks.	Principal and Associated Minerals.	Locality.	Remarks.
	ZINC.		
Limestones	Galena	Arkansas	In Rush Creek, beds of silicious lime.
Limestones		New Jersey	In beds in limestone, crossed by trap dikes.
	TIN.		
Granite		California	
Granite		Maine	
Granite		Cornwall, England	
Granite		Banca, East Indies	
Granite		Malay peninsula	
Schists		Cornwall, England	Metamorphosed clay slates.
Schists	White micas	Black Hills, S. Dak.	Lenticular masses of granitic structure in schists, parallel to bedding. Tin takes place of ore constituent.
Rhyolite	Silver ores	Potasi, South America	
	ANTIMONY.		
Gneiss		Dauphiny, France	
Limestone	Common associate of galena ores.	Sweden	Concretionary masses.
Sandstone		Arkansas	In veins.
	NICKEL.		
Serpentines	Usually an associate of other ores as pyrite and magnetic pyrite.	New Caledonia	
	CHROME.		
Serpentines		France	
Serpentines		Norway	
Serpentines		Shetland Islands	
Serpentines		Bohemia	

ROCKS ASSOCIATED WITH ORE DEPOSITS.—*Continued.*

Rocks.	Principal and Associated Minerals.	Locality.	Remarks.
	Chrome.		
Serpentines		Ural mountains	
Serpentines		Maryland	
Serpentines	Nickel traces	California	
	Manganese.		
Gneiss		North Carolina	Vein 4 ft. wide.
Limestones	Gold	Tombstone, Ariz.	Chambers in lime.
Limestones		Arkansas	
Clay beds		Crimora mine, Va.	Beds resting on sandstones.
	Mercury.		
Metamorphic rocks		Almaden, Spain	Veins in mica schists.
Metamorphic rocks		New Idria, Cal.	
Metamorphic rocks		Illyria, Europe	Bituminous schists and lime.
Metamorphic rocks		Reddington mine, Cal.	Bituminous schists
Metamorphic rocks and rhyolite.		New Almaden, Cal.	Serpentines and sandstones shattered parallel to rhyolite dikes.
Metamorphic rocks and basalt.		Sulphur Bank, Cal.	Ore in basalt area above and in sandstones.
Metamorphic rocks and basalt.		Knoxville, Cal.	Near basalt area.
Metamorphic rocks and basalt.		Steamboat Springs, Nev.	Near basalt area.
Metamorphic rocks and basalt.		Great Eastern mine, Cal.	Contact veins in basalt.
Metamorphic rocks and basalt.		Geysers, Cal.	In surface rocks at hot springs.

In the following table the eruptive rocks have been necessarily placed together, because while trachyte has 4 mentions, diorite 6, andesite 5, rhyolite 7 and basalt 5, there are 25 notices of simply igneous rocks —prophyry, trap, or other indefinite names, which cannot be classified.

CONDENSED TABLE OF ROCKS AND ASSOCIATED METALS.

Metals,	Eruptive and Intrusive.							Sedimentary.								
	Alone.		Associated with					Alone.						Contacts.		
	Granite, Gneiss, Syenite.	Eruptive.	Gneiss, Granite, Syenite.	Sandstone, Quartzite.	Schists.	Shales.	Limestone.	Sandstone, Quartzite	Schists.	Shales.	Conglomerates.	Limestones.	Serpentines.	Lime and Shales.	Lime and Quartzite.	Slates and Sandstones.
Gold	3	7	1	2	5	..	1	1	9	2	1	..	..	....	....	2
Gold and silver	....	....	1	....	..	1	..	....	1	..	..	..	..	....	....	....
Silver	2	5	2	....	1	1	2	3	..	1	..	1	..	....	....	....
Lead	3	....	....	1	..	..	5	....	2	4	*2	4	..	1	3	....
Copper	3	4	....	....	3	..	..	5	..	1	2	2	..	....	1	....
Zinc	2	....	....	....	..	..	1	....	..	..	..	5	..	....	....	....
Tin	5	1	....	....	..	..	..	....	2	..	..	..	..	....	....	....
Chrome	....	....	....	....	..	..	..	....	..	..	..	..	7	....	....	....
Manganese	1	....	....	....	..	..	..	....	..	..	..	2	..	....	....	....
Mercury	....	....	....	....	6	..	..	....	†4	..	.	..	..	....	....	....

By further condensation we have the following table:

COUNTRY ROCKS BROADLY GROUPED.

Metals.	Granite, Gneiss, and Syenite.	Sedimentary Rocks.	Associated with Eruptive Rocks.	Totals.
Gold	3	15	16	34
Gold and silver	....	1	2	3
Silver	2	5	11	18
Lead	3	16	6	25
Copper	3	11	7	21
Zinc	2	5	1	8
Tin	5	2	1	8
Chrome	....	7	....	7
Manganese	1	2	....	2
Mercury	....	4	6	10
	19	68	50	137

* Probably remains of beds of lime. † All in belts of hot springs.

The rocks in the foregoing tables may be further classified according to the amount of silica or quartz which they contain, into three groups:

1. *Highly silicious:* Granite, gneiss, mica schists, sandstones, conglomerates, quartzites, eruptive rocks, and some limestones.

2. *Moderately silicious:* Chlorite, talc and clay schists and shales, conglomerates in part, and some limestones.

3. *Scarcely silicious:* Limestones and dolomites.

Examining the metals in the foregoing list we find in the case of—

Gold.—Twenty-six occurrences in rocks abounding in quartz (silica) out of the 34 localities, and in some of the remainder the same conditions probably exist, as many shales and conglomerates are highly silicious. Only one occurrence is noted with limestone and in this case the foot wall of the deposit is granite.

Gold and Silver.—All three occurrences are in rocks abounding in silica.

Silver (aside from silver-lead ores which are classed as lead) occurs in 13 very quartzose rocks out of 18 instances, and the remaining 5 are probably silicious, as many limestones are highly silicious.

Copper also occurs with 18 very quartzose rocks, and probably with 19 out of the 21 localities, if not more, as the Clifton deposits are differently described by two writers, and the other limestone locality may carry much quartz.

Lead, however, occurs in the quartzose series in only 10 out of 25 localities, the remaining 15 being in association with limestones, while some of the former may have lime to some extent as a minor constituent.

Zinc shows 6 out of 8 times as an associate of limestone and only twice in the quartzose group.

Tin.—All 8 of the occurrences are in quartzose rocks.

Chrome.—All 7 localities are in serpentines, usually associated with gneissic or hornblendic rocks.

Manganese is associated with both extremes of rock.

Mercury.—All 10 localities are in highly metamorphosed rocks of various kinds, but nearly all are associated with recent eruptive rocks and hot springs.

The relative importance of these occurrences is best tested by the output commercially of the different metals. Tested in this way, the highly silicious rocks produce the bulk of the gold, silver, copper and tin; the non-silicious or true limestone rocks, the bulk of the lead and zinc, and rocks which on decomposition yield both silica and lime, give complex ores of gold, silver, lead, copper, zinc, tin and manganese, with many other less prominent metals.

Metals Associated With Each Other.—Gold and silver are so intimately associated in nature that all gold may be said to contain some silver; and most silver ores carry gold, from mere traces up to important values. Gold containing a large proportion of silver is pale in color and is sometimes called "electrum;" while some native gold-silver alloys are almost white.

Lead and silver are also so related that lead ores as a rule carry some silver, if only a trace, and from that up to large amounts in value, though not in bulk, without any special change in their outward appearance.

Lead and zinc are also intimate associates, as are also lead and antimony.

Copper and silver, or copper, silver and gold, often go together.

Iron and manganese, or iron and chrome, are frequently associated.

Nickel and cobalt are closely related, both chemically and in occurrence.

Arsenides and antimonides of other metals are often found together, and either or both with sulphides.

Country Rock and Gangue.—The ore minerals proper usually compose only a fraction of the whole vein filling, the gangue minerals being present in larger, often very much larger quantity. The rocks through which the underground waters pass must contain material suitable to form this gangue—silica for the quartz, lime for the calcite, fluorine for fluorspar, sulphur for the sulphate minerals, etc. The gangue minerals are closely related to the metals and true ore minerals (as quartz to gold, calcite to galena, etc.); hence the connection is really threefold—country rock, gangue, ore.

Relation of Eruptives.—While eruptive rocks are frequent accompaniments of ore, they are not absolutely essential to its presence either in the silicious rocks of Otago, New Zealand; or the sandstone reefs of Bendigo, Australia, or the non-silicious limestones of the Central States in America. In only 50 out of 137 cases are eruptive rocks mentioned in connection with the ore deposits as being of possibly prior origin, or about 36%, while in 68 cases, or about 50%, there is no apparent connection of either eruptive rocks or granite. Possibly eruptives existing in the neighborhood of ore deposits, but not actually contiguous, are sometimes overlooked or not reported.

There are cases in which the metal in the deposits undoubtedly appears to have been derived from them. But outside of these instances there are others where the outbursts of eruptive rocks have simply produced the necessary conditions of heat and fractured rocks, furnishing waters of the requisite temperature and providing ample facilities for their percolation through materials so crushed as to be easily soluble.

Similar results have been obtained in other places, without the aid of eruptive rocks, by the enormous pressure involved in the complicated folding which we see in such cases as the sandstone reef at Bendigo, Australia, or the abruptly folded strata in Nova Scotia, so that it would appear that any cause which will produce heated water and fractured rocks is sufficient to furnish the conditions for vein filling, the material for forming the deposit being drawn from any one or all of the rocks indiscriminately through which the water has been circulating, whether above, below, or alongside, near to or at considerable distances from the point of final deposit; and that this place of final deposit is largely determined by the character of the rock through which the water may be circulating at the time it is compelled to part with some portion of its mineral burden, and not by the character of the cause which produced the fissures, or the nature of the associated eruptive rock, unless the ore is deposited in that rock itself. The following extracts strike the keynote and indicate a line of examination which will explain nearly all, if not quite all, the phenomena of the association of minerals with each other, and the rocks in which they occur. Speaking of the ore deposits in the Potsdam series of rocks in South Dakota, Dr. F. B. Carpenter says: "These ores are in some sections almost exclusively gold-bearing; in others, they carry partly gold and partly silver, and again in other places the silver predominates." "It seems as though the porphyry at Bald mountain brought mainly gold; at Ruby basin, only a few miles distant, gold and silver in nearly equal quantities (in value); while at Galena, 12 miles distant, silver-lead predominated. That is, broadly speaking, gold predominates in the quartzites, but gives place to silver as we approach the more calcareous portions forming the upper parts of the Potsdam; while in the massive limestones such ore bodies as are found, like the Iron Hill, carry exclusively lead and silver, yet the porphyry is in all instances the same."

Variations in the Mineral Solutions.—But in following up this line of argument we must remember that all waters will not be charged with the same mineral, or the same water always with the same mineral, as their contents must vary with the nature of the rocks from which they draw their supply, and consequently they can only deposit what they have in solution for the time being, and may carry that for long distances for want of a suitable precipitating agent. They may have only one or many minerals in solution, but at any rate we are prepared to understand the occurrence of gold in the joints of porphyry, of silver in the joints of quartzite, of lead and silver in the seams of limestone, and why the character of the ore should change so suddenly when a vein passes from one series of rocks to another, as for instance from a silver-bearing galena with zincblende and iron pyrite in decaying porphyries with lime feldspars, or a gold-bearing arsenical pyrite in the underlying granite; from copper in silicious slates to tin in a still more silicious granite, where also the character of the mica (white mica being common in tin-bearing rocks) appears to have an influence, or to be, like tin, a result of the same influence; or from deposits of galena in limestone to barren material in the intercalated beds of "toadstone" (an ancient eruptive rock), as in the lead deposits of Derbyshire, England.

Influence of the Country Rocks.—The practical miner, however, is not so much interested in the scientific explanation of such sudden changes, but he is very materially interested in the fact that they do occur, as they may involve serious and costly changes in the character of the reduction plant, or a loss of the vein altogether, as at the Stonewall Jackson mine, Arizona, where the native silver found in the surface porphyry disappeared altogether when the underlying granite was reached; or, as on the Comstock lode, when the fissure left the syenite-porphyry contact and passed into the underlying syenite, where it presented only occasional bunches of gold ore, instead of the silver deposits of the eruptive contact levels.

The lesson inculcated is the desirability, to say the least, of a thorough examination of the line of outcrop of the deposit under consideration, before erecting reduction works, not only to avoid the necessity of change, but to determine the probable extent of the ore-bearing ground; for if the ore be confined to a certain class of rocks in any particular district, the extent to which such rocks are developed is an important element in the future of a mining camp, and must largely govern the amount of money which it will be wise to invest in means of transportation, etc.

The views here set forth also explain why long belts of country produce similar ores, while parallel belts at no great distance—often only a few miles—may produce a totally different series over a like extent of country; or why the ores on one side of a mountain range should present a totally different appearance from those on the other, where both series have been subjected to the action of the same eruptive rocks, or to no such action on either side. It is simply because they occur in parallel belts of rock of differing composition, the outcrops of which are presented to us on the flanks of the mountain ranges in which they lie, more or less parallel to the general summit of the range or axis of elevation. Thus below the free gold belt of the mother lode in California—which, however, is not a lode in the true sense of the word, but a belt of gold-bearing rocks, in which many deposits occur roughly parallel to the general strike—there lies in the foot hills a band of copper-bearing rocks of equal extent north and south, while higher up in the range there is a belt of limestone country with which are associated ores of a more complex character, galena as might have been expected making its appearance.

Again, just as the ancient schists of the Carolinas and Georgia furnish ores of the same character, over a distance of many miles, so do the ancient metamorphosed rocks of the Cascade range, in Washington, furnish for miles on the western slope complex ores of very uniform character in each member of the rock series, but differing entirely from those on the eastern flank of the same range.

It is for such reasons as these that geological surveys may be of very great utility, if they can be made before the districts have been exhausted and all the thousand and one experiments and failures have been tried and made; but of no direct and local value whatever if undertaken when the mining camp is wellnigh deserted, although perhaps useful in showing a comparison with other localities.

CHAPTER VIII.

MINERAL DEPOSITS OTHER THAN VEINS.

Succession of Formations.—As we have seen in discussing the filling of veins, it was not necessary in their case that the filling should have been derived from rocks which lay at a greater altitude than the deposits which were being formed, although without doubt a large portion of them may have been so situated, but in the formation of bedded deposits in stratified rocks only a very insignificent portion are derived from springs, thermal or otherwise. Deposits are laid down on the top of rocks already formed and covered up by others of a later date. While these latter must of necessity lie conformably on the deposit, or cover it horizontally, those on which the deposit lies were not necessarily so. A mineral formation may follow in orderly succession as one of numerous layers, or it may be laid down on the upturned edges of older strata, which have been tilted up and largely worn away before they sank again beneath the water and received a new covering. In pl. 2, fig. 1, the strata *E, C, D,* lie conformably on each other, but unconformably on the tilted series *A*. If there be also such a series as *B* we infer that it was laid down on *A*; that a gradual horizontal upraise brought *B* out of the water and permitted the destruction of most of the series; and that a subsequent depression, without tilting, allowed the deposition of *E, C, D,* which are also said to be unconformable to *B;* but it is evident that it will be much more difficult to trace the true relationship between *E, C, D* and *B* than between *B* and *A*, or between *E, C, D* and *A*.

The most important deposits to us, outside of clays and those which have formed building stones, are those of coal and iron ore; salt, gypsum, carbonate of soda, niter, and the allied minerals. The action of water is evident in the formation of all these, as the agent by which the material has been collected, except in the case of coal, whether they have been made by the ocean, to which the contained minerals have been carried by streams from higher altitudes, or in inland basins long since dried up, to the lower portions of which other rivers have carried in solution the materials derived from the ridges bounding the basin, and which are now in process of decay.

Solvent Capacity of Water, and Evaporation.—We have seen previously that heated waters have the power of holding in solution a larger quantity of any given material than those of lower temperatures, and that in cooling they are compelled to deposit a portion of their load, as in the case of hot springs, which build up masses of sinter around their orifices. The quantity of mineral matter which such springs may bring to the surface will be better understood by the statement of Prof. Ramsay that the hot springs at Bath, England, discharge annually sufficient solid matter to make a column 140 ft. high by 9 ft. in diameter. But whether hot or cold there is in any case a point at which waters have absorbed and hold in suspension the maximum quantity possible. This is called the saturation point, and such a solution is said to be saturated. If more solid matter is added to such a solution it falls to the bottom undissolved, or if the amount of water be reduced by evaporation the same result follows; a portion of the dissolved matter is squeezed out of the solution as its particles contract on each other, and falls to the bottom. The incrustation on boilers is the result of just such a process, and the principle is applied artificially in the production of salt from brine. In nature we see it in the drying of the ground after rain by the winds and sunshine, the ground losing and the air absorbing the moisture; but few persons realize that the loss from large reservoirs is equal to 36 in. annually over the entire surface; and is still greater in shallow waters, where, in excessively hot and dry climates, the loss by evaporation may rise to as much as 1 in. in 24 hours, still going on even during the night. So great indeed is this evaporation in the deserts of the Great American basin that all the rainfall is taken up in this manner, the numerous lakes having no outlet, but varying in size from month to month, and day to day, as the rainfall or sunshine gains the mastery, shrinking in hot and dsy and expanding in cool or wet weather, and always maintaining an area which is just large enough to enable the evaporating agencies to take up the exact amount of water flowing into the lakes. The popular notion of subterranean outlets for this water has no foundation in fact, as evaporation is sufficient to account for all the phenomena.

But in this process it is only the water which is lost; whatever minerals or solid matter it brought down from the mountains into the lakes is left there, accumulating slowly but surely, no matter how small the amount may be per gallon of water, until sooner or later the saturation point is reached, and a deposit begins to form of whatever salt may be least easily held in solution, if there be more than one. For a time the annual influx of water may be able to redissolve the precipitated portion, during the more rainy part of the year, but in the course of time this precipitate will exceed in quantity the amount soluble in the annual inflowing water and a permanent deposit will begin, the surface of which will suffer a partial resolution annually, but the mass itself steadily increasing in bulk. In this manner have gypsum, rock salt and carbonate of soda been deposited from saline waters; gypsum from sea water, saturated with the sulphate of lime, but able to hold all its chloride of sodium (common salt) in solution; salt from similar waters by evaporation, the salt in such cases containing the small amounts of sulphate of lime and other minerals which may be in solution and which constitute its impurities. Both of these substances are therefore purely mechanical precipitates. Natural evaporation has in this way produced enormous masses of rock salt, like those of Cheshire, England, and Cracow in Poland, both of which are extensively opened by underground works; or that at Sperenberg, near Berlin, which has been penetrated by an artesian boring to a depth of 3,907 ft. without the bottom having been discovered; or those which are exposed on the surface on the Rio Virgen (or Virgin River) in Nevada, which are described as follows: "A formation exists at this point composed of rock salt resting on, and to some extent intermixed with, sedimentary rocks, and of such magnitude that it may be said to constitute a notable portion of the hill in which it occurs. More than 60% of this entire mass appears to consist of hard rock salt, having the transparency of clear ice, and containing over 90% sodium chloride. This formation extends along the eastern bank of the Virgen, presenting a bluff face to the stream for a distance of 25 miles or more, and reaching in some places a height of several hundred feet."

These deposits are so enormous that we might even be disposed to question the power of so simple a cause to accomplish the results which are still, however, being reached at Carmen island in the Gulf of California and elsewhere, but the following description of the Karaboghaz sea (from Sir A. Geikie) will show them to be not only probable but possible: "Along the shallow pools which border this sea (the Caspian) a constant deposition of salt is taking place, forming sometimes a pan or layer of rose-colored crystals on the bottom, or gradually getting dry and covered with drift sand. This concentration of the water is still more marked in the great offshoot called the Karaboghaz, which is connected with the middle basin by a channel 150 yds. wide and 5 ft. deep. Through this narrow mouth there flows from the main sea a constant current, which Von Baer estimated to carry daily into the Karaboghaz 350,000 tons of salt."

This amount if all deposited would cover 250 acres to a depth of 1 ft.

Such deposits belong not only to the open sea, but mostly to inland seas or lakes which have originally formed a portion of it, and consequently partook of the general diffusion of the salts which are discharged into it by the rivers through its entire bulk. The deposits which result from the concentration of minerals in isolated fresh water lakes will naturally partake somewhat more of the character of the salts furnished by the rocks undergoing decomposition, and which are gradually water-borne to the deepest depressions or sink holes, there to be evaporated and concentrated or deposited. To such causes can we certainly attribute the lakes furnishing the carbonate of soda and sulphate of soda so common in the desert regions of Nevada, Utah and Wyoming, and the salines producing borax, and the nitrates of potassium (saltpeter) and of sodium (Chili saltpeter) in the same regions and also in the deserts of South America; and the bitterness of Mono lake and other waters due to the presence of sulphate of magnesia (Epsom salt).

With such an origin it is plain that the efflorescence or crusts of these easily soluble salts are to be sought for mainly in arid regions, where the rainfall is not sufficient to re-dissolve them after formation, and that chiefly during the hottest portion of the year when evaporation has done its work most thoroughly. The presence of these salts in streams need not be perceptible to the taste, for even good drinking waters may carry an average of 20 grains of solid matter per gallon in solution, but the constant accumulation of even this small amount, if carried on for a time sufficiently long, will produce all the phenomena we have been describing.

Alternate Evaporated Deposits.—It must not, however, be supposed that these deposits are always uniform in quality throughout. In many localities they consist of alternating beds of salt, gypsum and clays; or carbonate of soda, salt, gypsum, Chili saltpeter and boracic materials with clay partings, laid down as one or other of the materials predominated in the water supply, owing to changes in the character of the rocks from which the salts were drawn, and varying according to relative solubilities. It can also easily be understood that they will thin out in every direction round their boundaries, which are also apt to be mixed with impurities blown into the lakes from the dry sandy wastes, or forced in by the sudden rush of water caused by cloudbursts.

Sediment Mineral Deposits.—Besides the mineral salts carried in solution by water, it is likely that some bedded deposits owe a portion at least of their contents to particles of mineral brought in suspension by flowing water and deposited, like other finely divided suspended matter which goes to form shales, slates, etc., when the current was checked and no longer able to carry them.

Beds of Iron Ore.—It is evident that in all these cases there is not necessarily any chemical action taking place, after the water has once absorbed the material to be deposited, but such is not always the case in the formation of iron deposits.

While some iron ore is formed in lodes, or cavities in limestone as a deposit from ferric waters (waters carrying iron), probably the larger bulk of iron deposits have been thrown down in beds in the waters of swamps or lakes, through the absorption of oxygen from plants and diatoms (infusoria) accompanied by the liberation of hydrogen and carbon in the shape of marsh gas. Bog iron forms in marshy ground in such a manner at the present day, out of waters which have become charged with iron, collected from the sands and rocks through which they have traveled; and where the accumulations of nodules and concretions have been removed, the formation of others shows that the process is still in action. Such deposits will naturally be most impure round their margins, as in the case of coal and the minerals just under consideration, and may range from mere mixtures of sand and iron, or ironstone and clay, up to iron ores of great purity, according to the conditions under which they were formed. True, heat and pressure have modified many of them, eliminating the water from the brown, and converting them into red hematites, which by still further changes may have been altered into magnetites.

Many of these deposits covered so large an area that now that they have been uplifted along with the rocks which contain them, and have lost a portion of one of their edges by erosion, they present the appearance of true contact veins, and can be worked as such; but from the difference of their origin they are likely to maintain a uniform thickness for much greater lengths and depths than true veins, and also to retain a more uniform constitution.

Beds of Gold, Copper, Silver and Lead Ores.—The formation of beds of conglomerates containing gold, as in South Africa, or copper as in the Lake Superior region; of sandstones containing copper as in Europe, or silver as at Leeds in southern Utah, or shales containing galena, has in nowise differed from the formation of similar deposits in which minerals of value have not been found. It is only the presence of mineral in them which calls for attention. The native copper in both conglomerates, sandstones and amygdaloidal traps (or ancient eruptive rocks) of Lake Superior may have been subsequently introduced by the infiltration of waters carrying copper in solution, from which the copper was abstracted by the reducing and transforming agency of the iron in the rocks, or in other cases may have even been introduced at the time the beds of sandstone, etc., were laid down, and the same may be said of the grains of galena in shales, but it must be confessed that the true origin of these metallic or metalliferous grains is wrapped in some obscurity as regards the question of time. The same may be said of the chloride of silver associated with the vegetable remains in the sandstones at Leeds, the difficulty here being as in the other cases to account for the presence of mineral in one bed of sandstone and its absence from other similar formations. We can only suggest that in the Leeds sandstone waters carrying silver in solution were compelled by the nature of the stratification to traverse the band of sandstone, before its vegetable remains had become petrified, and in that condition acted as reducing agents on the argentiferous waters; or that the bed of sandstone was formed under such circumstances, from rocks containing silver, that the sediment was a compound of both materials, which subsequently underwent a chemical rearrangement through the action of percolating waters, in which the organic remains played the part just assigned to them, just as organic matter like charcoal will precipitate gold from its solution in chlorine.

The useful metals other than gold, iron, copper and manganese (which is also precipitated from sea water by organic remains such as bones), are, however, derived to so small an extent from ancient beds that their occurrence in them is more of a mineralogical curiosity than an important problem for the miner, who is chiefly interested in being able to distinguish between a bed and a true vein, on account of the greater certainty of permanence in the former and the probabilities of its position underground.

Dip of Mineral Beds—As a bed belongs to a series of strata which may have been uplifted, so that a portion of them has become visible on the surface as parallel outcrops, there is no certainty that the apparent dip of the strata (that is, what can be seen at any one point of exposure) will be the permanent dip of the entire deposit. The probabilities are altogether against such a supposition, and in favor of a flattening out as the dip is followed downward toward what must be the center of the basin, of which we see portions of the rim only as in the case of the strata seen on the left half of pl. 3, fig. 5, or the right hand halves of pl. 4, figs. 2 and 3. It does not, however, follow that all the strata exposed will reappear when the other edge of the basin is found and explored, because some of them may have thinned out and disappeared in the intermediate space, and their place be occupied by others, or the other edge of the basin may not be seen on the surface at any point, being covered up by rocks belonging to later epochs.

When strata thus dip together toward each other, forming a trough or basin, they are said to be "synclinal;" when they dip away from each other, as in the left hand side of pl. 4, figs. 2 and 3, or like the two sloping sides of a roof, they are said to be "anticlinal;" In the former case they may rapidly pass out of the limits of a surface claim and enter adjacent ground, in which they may be reached by shafts. In the latter case, they may pass out just as rapidly if only a small portion of the top of the anticlinal fold has disappeared and the location be based on an outcrop of the flat top of the arch or fold; but as more of the fold has been removed the dip will apparently be steeper, reaching its maximum half way between the top of the fold and the bottom of the adjacent trough if the folding be perfectly regular; such, however, is scarcely ever the case, but the principle involved is the same, as can be seen by a study of pl. 3, fig. 5.

Outcrops of Folded Mineral Beds.—The peculiarities of the outcrops of bedded deposits, when there has been folding of the strata, are well illustrated in pl. 4, figs. 1, 2, 3 (after Geikie), and should be carefully studied by those making locations of iron or coal deposits, as they may lead to wild conclusions as to the amount of ore or coal in the surface exposures. Figs. 2 and 3 show how, by lateral pressure, the beds laid down horizontally have been squeezed until any one of them presents the appearance of a piece of corrugated iron, or the troughs and crests of a series of waves. By the wearing away of the surface of such a folded mass the edges or outcrops of the different strata would be exposed as in fig. 1, of which fig. 2 is a cross section on the line *G H*, and fig. 3 on the line *C D B*. *B* forms the synclinal and *A*, *A*, the anticlinal fold of the exposure, the different beds of which are numbered so as to be recognizable in each of the figures. The dotted lines in figs. 2 and 3 indicate the position of that portion of the folds which has been worn away. Now, if we suppose the heavy black line between 12 and 13 to be a deposit of iron ore, it is morally certain that the majority of prospectors would report two veins forking at *B*, pl. 13, fig. 1, when instead of two veins, presumably dipping into the ground to unknown depths, there is merely a trough lying between the two outcrops, the boundaries of which can be absolutely measured and the area calculated similarly at *A* 4, fig. 1, two veins would be reported forking in a similar manner, whereas it is merely the same sinuous dipping away in all directions to unknown depths, and consequently more extensive than the beds *B*, *B*, but more difficult of access, and to be found below *B*, *B* if not buried too deeply under the strata 5 to 12 inclusive, to be reached by shafts. These remarks are intended to direct the attention of the prospector to the necessity of ascertaining the dip of such discoveries at the earliest possible moment, as a simple matter of self-protection, so that he may locate the requisite adjacent ground and prevent others from gathering the larger share of the fruits of his labors. Even the simplest tilting of a series of strata, combined with exposure of the outcrop by one stream running with the dip and another across it, may present the appearance of cross veins, particularly if some portions of the outcrop are covered with debris in such a way that it is not visible for its full length.

Caves, etc.—Where ore is found outside of fissure veins or contacts, the influence of the rock on the form of the deposit is yet more strongly marked. We have noted the influence which slates exert on lodes, converting them rather into metalliferous bands of rock. Limestones stamp their character upon the ore bodies by the formation of chambers connected together by thin seams or pipes. However irregular the series of chambers may be, they must have been formed by circulating waters (descending in the example shown by the arrowheads in pl. 6, fig. 8) which followed the bedding planes or joints, and we must consequently take these as our guides when searching for the continuation of an exhausted chamber.

In this connection it is instructive to note the great similarity between a map of the workings of the limestone contact lodes of Leadville and one of tortuous chambers of the Mammoth Cave in Kentucky, carved out of limestone by the action of water, the only apparent difference between them being that one set of chambers has been filled with ore and the other has remained open. The latter fact is further of interest as showing that it is possible for underground openings of large size to exist, as opposed to the theory advanced by some writers that such caves are impossible along the lines of a fissure on account of the enormous pressure of the surrounding earth mass, and that consequently all veins must be formed by gradual substitution of one mineral for another, at the time of removal. Many deposits are, however, undoubtedly formed by the substitution process.

Coal and Auriferous Gravel Beds.—Discussion of these deposits is reserved for Chaps. XV and XVI, respectively. "Masses" are noticed in Chap. IV., p. 81; "gash veins" and "segregations" in Chapter V., p. 95.

CHAPTER IX.

PROSPECTING.

Discretion in Taking up Ground.—Fortunate is the man who has the instinctive ability to recognize a "mine" when he sees it, and the courage to forbear locating every little seam of ore he may encounter. Nearly every prospector is "location poor;" loaded up with so-called mines, the bulk of which should never have been located; which he is confessedly unable to work, and many of which were simply considered "good enough to sell" when the notice of location was pasted. As a general thing, nothing is worth locating, and it is only in exceptional cases that anything is worth working, which has not a first-class surface showing either in quantity or quality of ore. "Extensions" of good and proved mines may be exceptions.

Accurate Observation and Description.—It is a common remark among prospectors, when the surface showing is not particularly promising, that it is only necessary to gain depth to make a mine. We shall soon see that there is no foundation for such a statement, when we come to consider the lesson of the outcrop. But first let us look at the points which a prospector should note about each of his locations as they are made, so that he may be able to intelligently explain their condition to those whose aid he may desire to develop them, remembering that all questions which can be answered positively should be so answered, and that on all other points an underestimate is infinitely better than an overstatement. If a man examining a mine for investment finds the representations honestly and accurately made, the first impression (always an important one) is favorable and likely to remain; but if first one discrepancy and then another is encountered, a feeling of distrust is created which may break off pending negotiations, while at the same time there has been no intention on the part of the owners to make a misstatement of facts. The trouble frequently arises from the use of terms in a loose way, so that they convey to the hearer a totally different impression from that intended by the speaker; or it may be altogether from a want of knowledge or misapprehension of the meaning of certain facts.

POINTS TO BE DETERMINED.

1. Distance for which the Vein or Deposit can be Traced.—Not infrequently we are told that the vein can be traced a mile, when in reality there are only a series of isolated outcrops in a more or less straight line, with intermediate barren or apparently barren spaces, often of considerable extent. Strictly speaking, the distance for which the outcrop can be followed without a break is all that should be called traced, but if the vein lie at the contact of two different kinds of rock, and on following this line of junction, even when no vein matter is visible, a second outcrop be found on the contact, both outcrops may fairly be considered as on the same lode. The same will be the case if the vein is formed on the wall of a dike, in which case all ore bodies lying on the same side of the dike may be called parts of the same vein. But as it seldom if ever happens that the vein for its whole length is ore-bearing, the distance the vein itself can be traced is of vastly less importance (except as indicating its strength and probable continuance in depth) than the distance the ore body, the really essential part of the vein, can be followed unbroken. This length should be determined even if it takes some trouble.

Following Dikes and Contacts.—In tracing an outcrop, or rather a vein, nature offers many indications. If following a dike, the latter is generally much larger than the vein and not infrequently harder than the rocks which it traverses, standing up above them, and can be taken as a guide. If the vein is on the contact of two rocks, and covered in places with earth or debris, it is only necessary to locate outcrops of the rocks on each side of the contact, and the search may safely be confined to the space between them. Narrow trenches through the surface dirt, run across the general line of the lode, will easily locate the contact and disclose the ore if it exists. The process is called "costeaning" by the Cornish miners.

Vegetation as a Guide.—Sometimes the vegetation on the two different rocks, especially when decidedly unlike in composition, is so different that the line of contact may be traced by it alone. In open countries free from heavy timber, like Arizona, this is strikingly the case. Probably the most distinctive vegetation in those localities is the various forms of "yucca," of which the "Spanish bayonet" is a sample; and the "ocotilla" (o-ko-te-ya). The yucca is confined to the granite or quartzite rocks, evidently liking a soil abounding in silica (quartz); the ocotilla is as decidedly confined to the clay-slate regions, the line of contact being often drawn on a hillside by these two plants as if defined by a fence; while the cactus frequents the limestone outcrops and the areas of eruptive rocks. In other words, for successful growth, the yuccas require quartz, the ocotilla clay, and the cactus lime. In the broad washes or beds of summer torrents, called "arroyos," where the rocks are mixed, all three may be found growing if the debris is of a suitable character.

A fissure may also be defined by the vegetation growing on it being different in character, or a line of contact may be traced by the same means, as in California, where the rim rock of the gravel channels, even where covered and obscured by dense brush (chaparral) can be followed along the mountain side by the elderberry bushes, the white flowers of which are very conspicuous in the gray brush in spring. These bushes require permanent water and have located themselves along the bed rock rim where the water in the gravel flows over it or on the top of the pipe-clay just below the lava cap.

Springs.—A lost vein may not infrequently be picked up again by examining the springs along the line of its general direction, as the extent of the fissure converts it into the most available underground water-course, which gives up its supply as a spring, if a ravine has cut down across it, to the permanent water level of the lode.

2. THICKNESS OF THE VEIN.—Here again there is often a confusion of the vein and the ore body. It is the thickness of the latter which is the important item to the intending investor; the total width of the fissure is only of interest as suggesting a possibility that at some point or other it may be completely filled with ore.

How Measured.—While the thickness of the ore body may be accurately measured at as many points as may be deemed desirable to get a fair average, the width of the vein (by which is meant the distance between the walls at right angles to them, not horizontally) may be very difficult to ascertain, and many statements are made on this score with the best intentions, which are misleading, because the parties have no true idea as to what really constitutes the vein.

Total Width and Ore Thickness.—On the Comstock lode the distance between the east and west walls on the surface in the Savage mine was fully 1,000 ft., of which only a small part was quartz and of that only a portion was available ore. The width was about the same at the Chollar-Potasi mine, some 1,600 ft. to the south, with several quartz bodies cropping parallel to each other, of which pl. 2, fig. 2, will give a fair idea in cross section. These were at first supposed to be separate veins, but at about 330 ft. below the croppings the Savage mine was reduced to a width of 800 ft., nearly all waste matter; and the Chollar-Potasi mine to a width of 150 ft., all quartz, of which about one-quarter was ore.

Veins on Dikes.—In cases where the ore forms on the walls of a porphyry dike (as in many of the mines of the Monte Cristo district, in Washington), the prospector generally calls the entire dike the vein, giving it a width of from 20 to 30 ft. or over, because he may be able to find traces of iron pyrite in the more decomposed portions of the dike, the bulk of which is, however, unaltered rock. Obviously the vein is only that portion of the decomposed dike which has been replaced by ore. To give the entire width of the dike as the vein, will create a very serious misunderstanding,as it is scarcely probable that it will have been converted to an ore body for its full thickness, at any point of its length.

False and Indistinct Walls.—In other cases, where there has been much motion in the fissure, its walls may have become much shattered and rotten, forming a series of slabs, each of which may present the smooth face of a true wall, even to the slickensides, but which will peel off one after the other, after a short exposure to the air, making it difficult to state positively when the true wall is reached

In slatey rocks there may be one wall well defined (if the vein is a contact) while parallel bodies of ore or barren gangue may lie in the slates for several hundred feet from the contact (pl. 6, fig. 1), as in the mother lode of California. Under these circumstances it is better to give the width of the ore, and if there is a decided difference in its appearance, the width of each portion, taking samples as described in Chapter II.

If the length and width of the ore bodies as they show on the surface were ascertained in this manner, a large number of locations would be abandoned, having failed to stand the test of working value; and while the prospector would have fewer locations on his hands, he would be saved the burden of the annual assessment work on worthless properties, and he could honestly ask capital to aid the development of those so carefully selected.

3. Samples of the Country Rock.—While a study of the chapter on rocks will have enabled even a beginner to speak of them with something like accuracy, it would be well to take a small hand sample of the rock on each side of the vein. We have seen what important differences there are in the shape of deposits in different rocks, and one of the first questions an expert will ask is on this subject, as it affects also the cost of working most seriously, a drift or shaft in soft slate costing very much less than one in hard granite. Should there be a doubt as to the judgment or knowledge of the prospector the specimens will speak for themselves, and are nearly as important as the ore samples. These samples need not be taken immediately from the walls themselves, as in such places the rocks are usually greatly decayed and unrecognizable in small pieces. It is better to take them a little distance from the vein (say from the nearest outcrop in place), as these are likely to be solid, being harder than their neighbors, and while taking these samples to note whether the outcrop of the vein occurs in a country which is badly broken up, or whether the hills are large and smooth. The latter appearance promises better than the former for a solid continuous vein without displacements. In selecting specimens the prospector should also ascertain whether the vein runs parallel to the general direction of the rocks, or whether it cuts across the formation—features which have an important influence on the probable perma-

nence of the lode in depth, the latter structure almost necessarily involving a deep fissure of considerable length as well as depth.

The names of even the common rocks seem to be a continual stumbling block to most prospectors, apparently for no other reason than a failure to realize the fact that each kind is made up of a definite combination of a few minerals. It would seem as though the trouble of learning to distinguish from ten to twenty kinds, which is about all that is necessary, ought not to be such a serious matter. Every business has its own language, and those who wish to excel must necessarily learn to speak in a language which will convey the same idea to all hearers, and each word of which will convey a positive idea, instead of a hazy nothing. The writer recently met a prospector who had some fair-looking specimens of ore, but when questioned about the mode of occurrence and the lay of the country, in an effort to get an idea of the facilities for working, in reply to a question as to whether it was a granite country he answered "Yes." When asked if there was slate, "yes" was the reply. And to fully satisfy any further inquiries which might be made for other rocks he added, "There is a regular jumble of them!" If this was really the case he had condemned his property, as such a condition necessarily involved a badly broken country, but it was evident that he knew nothing about the subject under discussion, while he simply cast a doubt upon every other statement he had made, showing that he was not a good observer. To make things worse he subsequently inquired what basalt was worth, and when informed that it was merely a black volcanic rock without value for any of the precious metals, he gently intimated that his informant might know what he was talking about, but that he had his own opinion on the subject. His basalt proved to be orpiment, a yellow compound of arsenic and sulphur.

4. Facilities for Working.—The faculty of locality, which must be well developed in a prospector to enable him to find his way through the wilderness, will usually also enable him to describe the best routes of access to his property and what can be done or has been done in the way of trails and roads. It will also enable him to answer questions as to the supply of timber for mining purposes (a most important item) and for fuel, if coal is not accessible, so that the water supply and the chances for economical development are the only questions to which we need allude in detail under this heading. If fuel is scarce and water abundant, the latter may furnish the motive power if the supply can be used under pressure, either directly or through the use of electricity, and to enable the prospector to readily estimate this power, a short chapter has been devoted to the measurement of water, and the method of calculating the horse power which a given quantity will develop. This depends on the quantity and the fall which can be secured, modified slightly by the distance it has to be taken to secure the fall, so that the prospector should be able to answer these questions approximately. A measurement of the supply taken in the dry season is most desirable as giving the supply which can be depended on all through the year without the use of reservoirs, which are costly and often impracticable.

In not a few mining camps water is scarce during the early stages of development, but while this scarcity may increase the cost of the earlier work, the defect is one that usually remedies itself before any considerable depth has been attained, an abundant supply being generally secured from the shafts and tunnels, even if the quantity does not prove excessive—as in Tombstone, Ariz., which in early days was a notoriously dry camp.

The manner in which the vein can be opened to the best advantage will depend on the shape of the country and the way the vein crosses it. If flat, shafts must be resorted to; if hilly, it may be better to adopt tunnels if they can be run on the vein, and the prospector should inform himself thoroughly whether this can be done to advantage, which will depend on the position of the outcrop. This question is more fully treated in Chapter XII., on early development, and attention is merely called to it here, as one of the things on which all possible information should be acquired.

5. LESSON OF THE OUTCROP.—All the foregoing remarks apply only to the surface observations, but in studying the outcrop we may gain some insight into the probabilities of depth.

Present Appearance not the Original—The first necessity is to disabuse the mind of the idea that the veins were all formed after the country had assumed very much its present shape and appearance. The remark so commonly made, that a vein which shows poorly on the surface will improve with depth, is based on this fallacy, the underlying idea evidently being, although probably not even thought out in the mind of the speaker, that the ore at that particular spot had not been able to reach the surface, a notion assisted by the other false idea that all the filling of the veins had been squeezed into them from below.

As a matter of fact there has been an immense change in the surface since the majority of the mineral deposits were formed. In the case of coal fields originally laid down horizontally and subsequently tilted to steep angles, whole sections of these fields have been worn away along with the inclosing rocks, or we should have no outcrop of them. In California we have absolute proof that the rocks which carry the gold veins have been worn away in places, even since the eruption of the basalt lavas which filled and covered up the old river channels to a depth of fully 2,000 ft., as in the cañons of Slate Creek, Cañon Creek and others in Sierra and Plumas counties. As these old river channels carry gold, in fully as great a quantity as the modern placers, which must have been derived from the wear and tear of the hills which formed their flanks, there must have been extensive erosion before the flow of the lava, to carve out these immense valleys, so that we may add an unknown quantity to the known 2,000 ft., and probably be within limits if we estimate the degradation of the mountains carrying the gold veins at 4,000 ft. or over. Writers on Abyssinia state that in the approach to Magdala gorges 4,000 ft. deep have been cut down through the basalt into the underlying rocks, leaving the basalt as table lands, much as in California, and if gold veins traversed the rocks of the Grand Cañon of the Colorado we should have their secrets exposed 3,000 ft. below the top of the plateau, through which the river has carved its stupendous gorge. It is therefore evident that in the great majority of cases the outcrops of veins may be called purely accidental exposures, which have been constantly changing in their appearance for thousands of years.

Increase or Decrease in Depth.—The erosion or wear and tear by air and water may have proceeded just far enough to uncover the top of the ore body, or it may have progressed so far that nearly all of it may have been removed. Are there any evidences in the outcrops themselves as to which stage has been reached? Before entering on this question, however, let us look at the probable increase or decrease in the value of the ore in depth.

In the case of veins which carry large quantities of sulphuretted ores which are easily decomposed, such as iron and copper pyrites, we may expect a decrease in value on reaching the permanent water level of the mine, below which the decomposition will not have extended. If these iron pyrites carry gold, the gold will have been liberated by their decomposition, and will accumulate in the cavities of the rusty quartz; and as the ore after the removal of its sulphur and part of the iron is lighter, bulk for bulk, than the undecomposed sulphides below, we have a greater bulk to the ton and also an enriched material, so that assays of the croppings are likely to be better than can be had after the water level is reached.

In copper veins the decomposition of the copper pyrite results in the formation of the red and black oxides of copper (just as in the former case the product of decomposition was oxide of iron) both of which are richer in copper per ton than the sulphide; and as they are practically concentrated surface deposits, not extending below the water line, and may result from the decay and leaching of very poor ores, we have another instance in which the vein would be poorer in depth.

But where no decomposition has taken place there is little or no proof of continuous improvement in depth, and more probability of impoverishment of the vein. If the former were the case the improvement ought to be continuous and there would be no limit to the increase of the deposit, which we know not to be the case; and it is more than likely that the quality of ore varies greatly in nearly all instances, sometimes improving and sometimes growing poorer as the earth is penetrated, being governed very largely by changes in the character of the rocks traversed by the vein, and accidental conditions which we have not yet learned to realize and understand.

But the prospector need be in no doubt on this point, as in most cases he can satisfy himself from personal examination as to the facts. If, as has been stated, the deposits were formed when the country was more elevated than at present, any ravine cutting across a vein or deposit explores it naturally as we do artificially by sinking a shaft, and if improvement follows with increased depth, the outcrop at the bottom of the ravine ought to be richer than one on the summit, as a descent of 100 ft. vertically below the top of the ridge would be equal to the 100 ft. level of a shaft sunk on the outcrop—200 ft. would equal the 200 ft. level,and so on. How little this accords with experience every prospector knows.

Nothing but actual work can positively determine the question whether we have merely the top or the tail end of an ore body, as if we look upon the ore body as a roughly shaped lens, two parallel lines drawn through it, one just below the top and the other just above the bottom, would each cut off a portion showing the same width and length; but if the ore is softer than the inclosing rock, and the vein crops in the bottom of a deep gorge, there is every probability that the gorge has been formed by the wearing down and removal of the ore body, that the outcrop found, if of small dimensions, is merely the lower end where the increased portion of country rock resisted the action of the stream to a larger extent and stopped further erosion. In a similar way, if the outcrop is on a steep hillside and of only limited length, it may in many cases indicate the termination of the ore body, as the erosion of the ravine which has exposed it has also disclosed some of the secrets of its penetration in depth, as just described in discussing the quality. But if the outcrop is of considerable length and thickness, this question need not trouble us, as there is sufficient justification for the expenditure of considerable money in development.

The condition of the mineral in the outcrop may also furnish a slight guide as to probable permanence in depth. Some of the common minerals in ore, especially the several varieties of pyrite,are easily decomposed under exposure to air and water, and where there is evidence in the rustiness of the outcrop, or the presence of a spongy looking mass from which the crystals have been perfectly removed, we may certainly infer that the drainage of the vein extends to some depth and involves a continuous fissure, as it is only by the presence of such conditions that the decomposition could have been effected. But if the pyrites remain in the croppings entirely undecomposed, we may infer that the walls of the fissure are so tightly in contact below as to prevent the percolation or seepage of water downward, and this may be taken as an unfavorable sign.

In soft and easily decomposed ore bodies the removal of the outcrop running along the face of a hill, instead of across it may result in shallow depressions, instead of a conspicuous ridge, in which the ore can only be found by digging; and when the ore is of this character, the search for it becomes a very laborious task, especially in moist and wooded countries, where the vegetation may be exceedingly rank and tangled.

Float.—From what has been said of the origin of veins and the subsequent carving out of the ravines and valleys as they exist to-day, it is evident that there must be on the hillsides and in the ravines of a country rich in minerals, many fragments of mineral detached from the ore bodies. These are called "float," and it is equally evident that the harder the material forming the gangue of the ore, the larger should be the number of fragments which have escaped the destructive action of air, frost, water and sunshine. Such minerals as decompose very readily, or are excessively brittle, may disappear altogether, or nearly so, as coal or some forms of galena; but quartzose varieties may survive a long journey and be found at considerable distances from their original source. Large fragments indicate this source to be much nearer than small ones. Gravity has constantly carried these fragments to a level lower than their source, so that when tracing float, as so often done, we look for this source above the place at which the float has been found. It may have reached this place either by rolling down the hillside in the immediate neighborhood, or it may have been carried down the bed of the ravine by water. The position of the float will generally indicate which has been the method of transport, but in either case we must trace it upward, and if we find the fragments increasing both in number and in size, we may conclude that we are nearing the source of supply. Sometimes these may lead to the discovery of well-defined lodes, and again, in the case of quartz, we may finally lose all trace of it, without encountering anything of value. This is especially apt to be the case in slate countries, which have been crushed and crumpled and subsequently filled with innumerable thin quartz seams. All the float may have been derived from these seams, and the float ceases because we have reached the limit of the slate formation, and enter a new series of rocks without quartz. This structure explains numbers of cases of "lost leads," but while there may be no well-defined vein or lode at the point where the ravine cuts the formation, if metal has been found in the float it shows that the region is worth prospecting and the search should be continued along the line of contact of the rock which has cut out the metal-bearing series.

Topography and Water System.—The reverse is just as likely to be the case where the ore body is soft, as nature always carves out a country on the lines of least resistance, which may be lines of faulting, or contact of a soft and a hard rock, or through soft ore bodies or between consolidated hard ones. For this reason the study of the water system of any particular mountain region affords a good insight into its physical structure. If all rocks were of uniform and equal hardness, the face of a country would be planed down to uniform smooth slopes. It is the varying resistance of rocks which diversifies the mountain regions, in combination with the dislocations they have undergone.

GENERAL HINTS.

What to Look for.—The importance to the prospector of knowing something about rocks becomes apparent. In a granite country it is evident that he may expect tin as well as a variety of other minerals, and should consequently know the ores of tin (and they often do not look like metallic ores) so as to be able to recognize them. In a limestone belt, galena, iron and zinc are specialities. In a country made up of volcanic and eruptive rocks, it is useless to look for coal; but in such a country, where a belt of hot springs follow the junction of eruptive rocks, especially basalt, with a group of sedimentary strata, the ores of quicksilver should be in his mind. In a belt of hornblende rocks he may devote his energies to asbestos, soapstone and chrome iron, as well as to the precious metals, and in sandstone and shale regions the outlook should be kept for coal, fire clays, iron, rock salt and gypsum. In a coal belt it is almost useless to expect mineral veins, for apparently no fissures made through a coal bed carry ore in the rocks above the coal, whatever they may do below. Any one who will take the trouble to put down the mineral occurrences in any extended region will soon discover that they resolve themselves into a series of belts corresponding with the rock formation of the country, indicating most unmistakably the little understood relation between them. In the large basaltic areas but little of interest or value need be expected, except such minerals as opal, etc.; nor is it any use to search for the soluble minerals, such as saltpeter, in any but excessively hot regions of depression, without drainage outlets, and surrounded by volcanic or eruptive rocks.

Where to Search.—Above all things the prospector's search should first be through all the accessible regions of a mineral country, for in such districts a much smaller ore body and a much lower grade of ore may be more valuable financially than greater size and richness in less accessible localities amid mountain fastnesses and eternal snows. It is time to enter these when all others are exhausted, though their fascination is so extreme that it is to them that the hopeful adventurer first directs his footsteps.

Prime Requisites.—What is wanted by the capitalist is a large ore body, fair average quality, good working facilities and reasonably easy access. Given these, there is usually no difficulty in securing all the capital necessary. The want of any of these qualities in the mine renders the task more difficult.

Outfit.—The extent of equipment will vary according to the character of the country to be traversed, the distance from supply points, and whether the prospector has any means of conveyance, such as a pack horse or burro, or has to carry everything himself. It is unnecessary to speak here of clothing, blankets, food, etc., further than to say that the lined and riveted canvas suits are perhaps the most serviceable, and that comfortable as well as strong boots are an important item.

Among the details of equipment the following may be mentioned. The horn spoon is preferable to the gold pan or batea for prospecting, as being more convenient to carry (it can go in a pocket) and in use requires very little water, and does not fatigue the user by causing prolonged stooping. A small bottle of quicksilver will be found useful when testing for gold in a very fine state. A compass with folding sights and a 3-in. needle will help in laying off ground and connecting a location with other monuments or landmarks. A tape is not necessary, as one can be improvised from well stretched linen cord, standardized by some measure before starting and knotted at 1 ft., 1 yd., 10 yds. and 50 ft. long. If a regular tape is taken that with steel wire interwoven is preferable to a heavy steel tape, or a small self-winding narrow steel tape can be had, which occupies less than the space of a watch. A small bar magnet is useful in cleaning up pannings. In this connection it may be noted that in the absence of a regular gold pan very good results can be obtained with almost any sort of a receptacle, such as a frying pan, tin dish, etc. For testing sulphurets and dark-minerals generally a white surface is preferable, such as that of a saucer or small bowl, in using which when taking samples from a wet-crushing battery care must be taken to avoid overflow and consequent concentration if quantitative results are wanted. When sampling placer ground two buckets are very handy, to be used by washing from one to the other. To examine ores, float, pan or horn residues and rock minerals a lens is almost indispensable, and the small powerful Coddington style is perhaps best. It can be hung to the watch guard.

Every prospector ought to have some knowledge of the use of the blowpipe in determining ores and minerals and making rough quantitative assays. The whole blowpipe kit necessary can go in the smallest size cigar box. The cheap black blowpipe answers as well as an expensive platinum-tipped one, and a tallow candle is for most purposes better than the alcohol or oil lamp. The half-dozen reagents suggest themselves. A small streak plate should be included in the kit.

As to tools, the selection will depend upon means of carriage and whether any real opening work is intended. In prospecting in a bare, rocky country where no digging is required, a light poll pick, with say a 3-lb. head or even lighter, is generally sufficient, as this tool combines pick with hammer. Regular geological hammers of peculiar shape and special steel can be bought or made by any good blacksmith, but are rather ornamental than necessary. Of course if there are two or more in the party each should take a different tool. If there is a pack animal, then a light working pick and small short-handled shovel will be taken.

However, as to all these matters prospectors of any experience do not need to be told what is necessary.

CHAPTER X.

MAKING LOCATIONS.

The object of making a location on a piece of mineral ground is, in the first place, to give notice to all other persons that the locator has found mineral therein, and has made a claim to a definite portion of the deposit and a definite amount of ground to work it to the best advantage. To secure this object he posts on the mineral deposit a notice of his claim, to be filed for record with the proper authorities at a later date; and erects such monuments as will define the limits of the ground claimed. This notice and the monuments secure to the locator a possessory title, which is good so long as the requirements of the United States government, and the local laws of the particular mining district in which the claim is located, in regard to the amount of work to be done on the claim annually and other conditions, are complied with. The ultimate object of making a location is to secure a patent to the ground from the United States, if the property prove to be worth the expense.

What is said here applied to the public domain of the United States, in the far West. In the Eastern States and in foreign countries the practice is different, and local regulations must be studied.

The basis of all proceedings to acquire patent to mineral ground (see Chap. XI) is a duly certified copy of the notice of location and the monuments which it describes.

Government Requirements.—The instructions issued to the deputy mineral surveyors, to whom the work of making surveys for patent is intrusted, are of the most stringent character. Under these instructions, the surveyor has to report the true position of all the original monuments, or give good reason for their absence, which will be acceptable to the examiners of the United States land office at Washington; he must make the end lines of the claim parallel (if it be a lode claim); and he must not include within the exterior lines of the survey any ground outside the corner monuments. Whether this always does justice to the locator is not the question; it is the ruling of the department and must be respected. Neglect to restore monuments in the spring which may have been destroyed by winter storms, may result in litigation and endless delay in securing title, as their presence is the only thing which will debar a second party from coming on the ground and making an adverse location. It is taken for granted that a person making a location will look for monuments as a sign of previous appropriation of the ground, and their absence justifies the supposition that the ground is vacant and locatable, or if previously located has been abandoned by the earlier claimants. A locator cannot plead ignorance of the absence of his monuments, because as they are the sole witnesses of the limits of his claim, and the essential means by which he holds possession, it is his duty as well as his interest to see that they are maintained in good order.

Imperfect Locations. — The number of locations which satisfactorily fill the requirements—that is, which have all the monuments standing and so located that upon survey they will not exclude some portion of ground to which the claimant feels that he is honestly entitled, because the location was made and held in good faith—is exceedingly small. The majority of original locations are very imperfectly made; not from lack of good intentions on the part of the locator, but from want of knowledge as to what is required, or how to do it, or the lack of proper instruments. As at present interpreted, the instructions issued to the deputy surveyors really call for nearly as great accuracy on the part of the prospector when making his location as they do from the deputy when making the final survey.

Theoretically the regulations are based on the idea that in parting with the absolute title to the mineral lands (which until a comparatively recent period were regarded as the inalienable property of the crown) the government is doing so on such extraordinarily low and favorable terms that it has the right to demand from the recipient of its bounty what it considers to be nothing more than a very moderate expenditure of time and money in return for its liberality. If the original location has been carefully made, and the monuments equally carefully maintained, the applicant for patent will have no difficulties or delay in the land office proceedings, as 90% or over of all such troubles arise from defective locations or the absence of monuments which the government claims should be in existence. A large proportion of the remainder are delayed by the imperfect character of the work on which the right to patent is based.

There seems to be a popular idea that it is within the scope of the authority of the deputy surveyor to restore such monuments as are missing, at the distance called for by the notice of location instead of in their original position, and not infrequently an implied feeling that he ought to do so because he had been favored by selection to do the work, and most deputy surveyors can testify to the difficulties which arise from this source, between the applicant for survey and the officers of the government, in which the deputy receives no support from the government and is very likely to secure the displeasure, if nothing more of the applicant.

WHAT CAN BE LOCATED AND IN WHAT MANNER.—Knowing then what is required by the government, let us proceed to make a good valid location, or rather see what is necessary to make it good, first stating that the extra time necessary to convert a defective location into a good one is so small as to be of no consequence when compared with the subsequent saving of time, money, and annoyance; remembering that if the ground is worth locating at all it is worth while to make the location absolutely secure.

Mineral Must be Found.—No valid location can be made until mineral has been found within the limits of the claim in the condition required by the character of the location made.

Placer locations may be made on ground in which valuable minerals, such as gold, tin, platinum, iridosmine, etc., are mixed with sand, gravel, clay or bowlders, the minerals having been removed by natural causes from their original position in the rock in place. Placer ground on unsurveyed land may be taken in any shape which the locator desires, provided the ground contains mineral as described, and provided the area does not exceed 20 acres to each locator or 160 acres to an incorporation. But if the land has been surveyed by the government, the claims must be made to conform to the smallest legal subdivisions (which in this case is 10 acres), the limits of the placer ground being first determined, and then so adjusted on the margins of the location that 10-acre tracts having less than five acres of placer ground are excluded, and those having more than five acres of available ground are included. When the final survey for patent is made on unsurveyed land, it will be made to conform to the original takes or monuments, no matter how irregular the shape of the track may be, regardless of anything except area, and this, if in excess, must be cut down to the limit allowed by law. When the ordinary land surveys are extended over such areas the section lines are adjusted to such surveys, just as in the case of lode claims.

Lode Locations.—In the location of mineral veins or lodes, whether they be of gold, silver, copper, lead, iron, tin, quicksilver or other minerals found in lodes, the United States laws grant to each locator the right to take in one location not more than 1,500 ft. in length on the lode, and not more than 300 ft. on each side of the center of the lode. A location cannot be made with 200 ft. on one side and 400 ft. on the other. There is nothing compelling the locator to make his location 600 ft. wide, the law simply says he may so make it.

Local Regulations.—Within these limits the width is optional with the locator, and by the action of a duly organized meeting of the miners in any district, may be limited to any quantity not less than 25 ft. on each side of the center of the lode, making a total width of only 50, instead of 600 ft. In Bodie, Cal., for instance, the width was fixed at 100 ft. on each side of the center line.

The local laws of a mining district may impose any other conditions which the miners may see fit, provided they do not grant better terms than are offered by the government. These may be just as much more stringent as the miners may think desirable for the welfare of the district, as, for instance, while the United States laws have been construed to grant the locator one year from the first day of January succeeding the date of his location in which to do the $100 worth of work by which he holds his title, the district laws may decide that work shall be commenced inside of 60 or any other number of days, or stipulate for other evidences of good faith on the part of the locator; but they cannot legally declare, as is sometimes attempted to be done, that a shaft 10 ft. deep, which only cost $50, shall be considered full value for the required annual expenditure of $100. Such a proposition is always open to contest. As the want of roads often greatly retards the opening of otherwise promising mining camps, a clause might very suitably be added to many local laws, stipulating that each location pay annually a definite sum to some authorized agent to accumulate as a road fund, in addition to the $100 work required by the government, but such payment could not be made to constitute a portion of the annual assessment work.

Mineral "in Place."—As previously stated, no location can be made which will be of any value until mineral has actually been found, and for a lode location it must be in the undisturbed rock, or "rock in place." Monuments or no monuments, any outsider can prospect over such a lode location, and if he succeeds in finding mineral in place before the earlier claimant, he can make an adverse location and will surely hold the ground. In Leadville, for instance, where the ore did not crop on the surface (lying nearly horizontally), the ground was covered with overlapping locations, but the shaft which first got down to and struck the deposit took the ground as against the other claimants.

Agricultural and Timber Rights.—No mining location, either lode or placer, or for iron or for coal, can be made on any ground for which a patent has been issued, unless it can be conclusively proved that the party obtaining such patent was aware of the existence of mineral on his claim at the time of "proving up" and falsely swore to the contrary. This applies to patents to agricultural and timber lands. A lode claim can be filed over a placer claim, as lodes are expressly exempted from placer patents, but across such placer claim, the lode camp has surface ground only 25 ft. on each side of the center of the lode.

Locations can be made on all other classes of land, provided mineral has been found thereon; but when made on land valuable for timber or agricultural purposes, are liable to contests before the land office to determine whether the ground is more valuable for mineral or for other purposes.

Monuments.—A monument should be conspicuous enough to be readily found. According to the character of the region, it may be either a tree with the side blazed; a small sapling cut off about 4 ft. from the ground with the top squared; a simple stake about 4 ft. long squared at the top, and driven not less than 12 in. in the ground, if there are no rocks convenient; or such a stake with a rock mound at its base; or even a simple pile of rocks where there are no trees.

Tree or Stake Marks.—In all cases where a tree or stake is used a sufficient space should be smoothed on which to write the designation of the corner intended to be represented. If a tree is used, it is not sufficient to simply bark it, because trees in falling often skin the bark off each other in patches, and such a "blaze" is easily overlooked; but the blaze should be made as in pl. 15, figs. 1 and 2, with a straight notch at the bottom, cut well into the wood and dressed smooth to write on with a soft pencil. Fig. 1 shows the front view of a proper blaze and fig. 2 the side appearance. Such a mark is unmistakable and immediately suggests the prior presence of men, which the other method does not.

Stone and stake monuments are easily overturned and destroyed, especially in snowy altitudes and on steep hillsides, but there would not be half as much trouble in keeping them in good shape if a little more care were exercised in building them. They are usually a heap of rocks, instead of a monument. It takes no more rocks to build a good than a bad one, and but little if any more time—all depends on the manner of placing the stones. If the monument is to contain a stake, this should be driven solid, with a rock for a hammer if necessary, and the ground roughly leveled off with the pick, which the prospector always carries, so as to get a good foundation. This is all important on a hillside. The necessary supply of rocks should then be got together, before starting the structure. The biggest and flattest should be laid in a circle round the stake, at a little distance from it, in such a way that their upper surfaces slope inward toward the stake. By taking this precaution with the bottom layer, the next layer will have a tendency to slide in toward the stake, thus making it almost impossible for the monument to tumble down, while the stake will be wedged tightly in place by the pressure; and if this principle is applied until the monument is completed, say three courses, with the inner space filled up solid with small rocks and dirt, there need be no fear of its destruction, except willfully or by snow-slides sweeping everything before them. If the latter are feared it is best not to have the central post too high, as it will then offer less resistance to the overturning action of the snow. Pl. 15, figs. 3 and 4, show a properly and an improperly built monument in cross section. In the latter there is every chance for the monument to fall apart and release the stake from its position. Every stone in a monument should be moved about until it has a perfectly solid bearing, and does not wobble.

Simple Rock Monuments.—In building a monument of rocks alone, the importance of a good foundation is even greater, for the absence of the central stake increases the liability to destruction. A moderately large base tapering somewhat rapidly will give the greatest stability.

Inspection of Monuments.—To emphasize the importance of building well, it will not be out of place to repeat that the owner of an unpatented claim should at least annually examine the corner monuments, and see that they are standing, for as they are often the only means by which a stranger can have knowledge of the existence of a location or its extent, and their object is to give notice to the world of an existing claim, their absence gives the stranger a perfect right to locate the ground as vacant lands of the United States.

Notices of Location.—These should accurately describe the monuments as actually set. Prospectors frequently take out a set of printed blanks in which a "mound of stones" is usually called for, and then simply fill in the blank spaces with the number of feet located, when it often happens that no mound of stones was made, but a tree blazed, or a small sapling cut off, in places where there is a scarcity of rocks suitable for a monument. Frequently the stake called for does not exist, and the writer has seen cases where the monument, so called, was nothing more than a small piece of a broken limb stuck in the ground, without any notice of what it was intended to represent, and absolutely not recognizable as a monument, and this in the midst of dense timber. Such negligence is inexcusable, and if trouble arises the locator has no one but himself to blame. It is, of course, allowable to use one of these printed blanks to make and post the original notice at the point of discovery, to hold the claim while the discoverer may be putting up his end and corner monuments, but the final notice, of which a copy is filed for record, should call for a blazed tree, describing its markings, if such were used, a sapling squared, a post without mound, a post with rock mound, or a rock mound only, as the case may be. Occasionally the notice of location calls for a monument of some kind, in a position which is inaccessible, and where none was actually set, so that when the deputy surveyor comes along and reports that he cannot reach the point called for, there immediately arises a question of veracity between the locator and the deputy, which may seriously delay the proceedings in the land office. If the point where the monument should be set is inaccessible, the location notice should say so, and give the reason for not setting the corner, and if set as a witness post to show the direction of the end line, the supposed distance to the corner should be written thereon. The absence of a post at any of the corners, if such cannot be set, does not invalidate a location, if the fact be so stated, as the law does not ask impossibilities, but the statement that a corner was set in an inaccessible place, when it was not so set, is sure to result in trouble.

Posting Notices.—In addition to fully describing the monuments in the notice of location, they should be so marked as to indicate what position they occupy with reference to the claim, as "north end center of Deadwood lode," "northwest corner of Deadwood lode" etc.; but if a stone monument be used the notice may be folded up and placed between two flat stones or in a tin can, with the mouth downward to keep it dry. Such a tin can is also very useful even when a post is used, as it can be tacked to the same (pl. 15, fig. 5) in a similar manner and forms a very noticeable and conspicuous object. If there are trees near the monuments, they should also be blazed and marked as witness trees.

The notice should distinctly state the name of the state, county and mining district in which it is made, the name of the miner, the name of the adjacent claims if they are known, the date of discovery, the date of location, with witnesses if possible, and reference should be made to prominent natural objects, so as to make the position of the claim ascertainable, if, after all precautions have been taken, the monuments should be accidentally destroyed, as by floods or snowslides. Such references may be, for instance, "on south side of Index Mountain," "on the north side of Crab Creek, 2 miles above its junction with Pole Creek," "2 miles northeast of Minersville," etc.

The exact wording of the notice of location is of but little consequence, so long as it gives the information previously stated, as a location of lode claim necessarily carries with it all the dips, spurs and angles, and all the privileges granted by the various acts of Congress, without a recital of such claims. All that is required is such a document that no one can misunderstand the intention of the locator. If this is clearly done, the shorter the notice the better.

It has taken some time to describe the requisites of a first-class notice of location, whereas it only takes a few minutes to write it out and secure the satisfaction which always goes with a job well done, but it is not intended to imply that a notice not so complete as here sketched would be invalid. But very few contain every item in detail, yet the nearer it approaches to the correct thing the more safely can the prospector leave his claim to the tender mercies of the elements.

HOW TO MAKE A LOCATION.—*Placer and Coal.*—In making a location of placer or coal ground on surveyed land the location notice should describe the ground by the usual legal subdivisions, and this will constitute a valid description because it can be immediately filed in the United States land office and become the best public notice obtainable; but if the placer claim is on unsurveyed land, a monument must be set at every change in the direction of the exterior boundaries and mentioned in the location notice. Coal lands can only be taken in legal subdivisions as platted on the ordinary land surveys, and cannot be purchased before survey of the township has been made.

Lodes.—In the case of lode claims it is customary to set the ends of the lode line and the four corners of the claim, but there have been decisions by the general land office in which, with only the end center stakes established, the locations were sustained. If this method be employed the discovery stake, as well as the monuments at the ends of the claim, should be most thoroughly established, and all of them should plainly show that the locator claims a definitely specified distance on each side of his lode line. Such decisions are based on the theory that the surface ground is granted only to enable the miner to work his claim to the best advantage, and on the further idea that a person finding a lode will naturally follow the outcrop in the course of his examination, and must consequently find any monuments already erected on the vein, thus gaining knowledge of the claims of any prior locators. But this would not occur if the locator were following a lode parallel to one previously located and say, therefrom, so that it is very much safer to establish all the corner monuments, this method having the additional advantage of defining the direction of the end lines, which is left open to interpretation in the other case, unless it is plainly stated that they are to be at right angles to the lode line. The following remarks will therefore apply only to claims having all corners established, except where they are evidently applicable to other locations also.

It may seem a very simple matter to make a lode location after finding ore—just measure off 1,500 ft. and set the corner posts—but there are many points to be considered, if we want to secure the full privileges granted by the mining laws. Should there be any mistake in the form or direction of the original location, and adjacent claims be taken either endwise or laterally before the mistake is discovered, it will be too late to remedy the defect by a new location; as, for instance; if the direction of the lode line as located does not follow the lode, which may be found to run diagonally across the location, and pass out of the side instead of the end lines. In such a case the side lines become the end lines, making the location on the lode much shorter than if the lode ran lengthwise of the claim. To avoid such errors, which may ruin an otherwise valuable mine, time enough should be taken to ascertain the true direction of the vein before measuring off the location. After establishing the initial monument or discovery stake on the ore body, and posting a notice of location thereon, so that there can be no doubt as to what vein is intended to be located, the prospector is entitled to a reasonable time in which to perfect his location.

Very often the notice of location is posted at one end of the claim (see *A*, pl. 15, fig. 10) and calls for "1,500 ft. on this vein, beginning at the post on which this notice is posted," or similar language, when there is no vein in sight at that particular point, leaving the intention of the locator uncertain, or to be interpreted only by finding the monument at the other end of the location, and ascertaining what outcrop may fall on a line drawn between the two monuments, which may or may not be the vein intended. As in pl. 15, fig. 11, if the notice be posted at either end of the lode line 1 or 2, a line connecting these points may show the outcrop of ore to be say 150 ft. from the line, in which case, in strict compliance with the law, in final survey for patent, the line from 5 to 6 should be run through the point 7, making the distance from 7 to the center of the outcrop not more than 300 ft. By establishing a discovery monument all doubt is ended.

Lode Line and Outcrop.—It is not absolutely necessary that the location should be made in a straight line, but the lode line should follow the outcrop with reasonable accuracy. This is often a very crooked line if the vein has a flat dip. If the vein is largely quartz and therefore generally harder than the surrounding country rock, it will probably crop boldly and can be traced without difficulty. If softer than the inclosing rocks, it may only crop on the steep sides of ravines, and be covered on the gentler slopes by earth and debris, in which case it may be necessary to dig a few cross trenches at short intervals apart, so as to disclose its course. (See Chap. IX., for method of tracing outcrop.) When all other signs fail it will probably be found to run parallel to the general direction of other veins in the district, or else nearly at right angles thereto. In the latter case it may prove to be only a spur of a larger vein, as shown on pl. 3, fig. 4, *E*. At any rate a notice at the point of discovery will hold a claim for a few days, while the true position of the end lines is being established, and with ordinary diligence and a little woodcraft the direction of the lode may generally be determined with a reasonable amount of accuracy, if the principles governing the outcrop of a vein have been mastered, and the vein is strong enough to be worth locating.

In cases where the vein does not crop distinctly for 1,500 ft., it will be good policy to make two locations, establishing one of the end lines of each location through the discovery stake on the outcrop as in pl. 15, fig. 9, which leaves a portion of the cropping on each location, *A* and *B*. This plan has the advantage also of lessening the chance of the rake of the ore body in depth carrying it beyond the end lines of the claim, and offers a better chance to develop both locations through the same tunnel or shaft. This plan is much preferable to the common one (pl. 15, fig. 10) of covering all the outcrop by the location *A* and making extension locations *B* and *C*, in which no outcrop is visible, as the latter locations are invalid until ore has been found in them. In the one case the locator has a good title to 3,000 ft. in the other to only 1,500.

Length and Extensions.—Having determined the direction of the lode line, and the manner in which he will make his locations, the locator can measure out any number of feet in either direction for his claim or claims, provided the total length of each one does not exceed the statutory limit of 1,500 ft., and the end monuments may be established. From the same point he can take one claim with say 500 ft. in one direction and 1,000 ft. in the other, or two claims of 1,500 ft. each, one in each direction from the discovery. If only one claim is laid off, it is good policy to be sure that the location is fully 1,500 ft. long; if a little more it will not matter, as on final survey the claim can be cut down to its proper length if in excess, but it cannot be lengthened beyond the original stakes, if they have been established too close together, and the claimant may lose a portion of ground to which he might have been legally entitled. If on the other hand, a series of locations are made on the same vein, it will always be policy to make the locations a trifle less than 1,500 ft. each in length (unless measured with the accuracy of a final survey), so as to avoid awkward gaps between them, as will be seen must occur in such a series as shown in pl. 15, fig. 6, where it is evident that the end lines of location *A* must be finally established at 1 and 2. If 2 has been taken as one end of *B*, the other must be set 20 ft. short of the original post at 3, or at 4. The ends of *D* can be set at 5 and 6, but if 5 be taken as one end of *C* there will be a gap of 60 ft. between 3 and 7, making a total of 80 ft. at this point to be relocated, and secured only by an expenditure of $500 for labor, in addition to the cost of survey and land office proceedings. Under other circumstances the gap of 20 ft. may occur near 2 and 60 ft. near 5. It is better to make the locations safe from this defect by making each of them a trifle short and making an additional one, if necessary to cover all the ground desired.

Even in the case of four claims of rather irregular length, but aggregating just 6,000 ft., all owned by the same corporation, the land office would not permit the adjustment of the dividing end lines to make four even surveys of 1,500 ft. each, but requires strict adherence to the original monuments.

Setting Corner Monuments.—In setting the corner monuments, be sure that they are, if anything, a little farther from the lode line than the distance called for in the notice of location, as the distance allowed on final survey cannot be greater than the position of the corner monuments calls for; in other words, the monuments govern and not the words of the location notice. No ground can be included in the final survey for patent which lies outside straight lines connecting the monuments as they exist on the ground, and the end lines must be parallel.

Having taken the precaution to keep the corner monuments far enough away from the lode line so that the finally established side lines shall fall within them, it is next necessary to see that they are so located that the end lines can be drawn parallel to each other, and yet pass through the end monuments on the lode line. It is here that the deputy surveyor usually encounters the greatest difficulty. The situation can best be explained by such a diagram as pl. 15, fig. 7, in which *Z* shows a defective location, because if *AB* represents the lode line, and *C,D,E,F,* the four corner monuments; the surveyor, to make the end lines parallel, must prolong *EB* toward *F* as in the dotted line, and then from *C* lay off a parallel line toward *D* thus cutting the lode line short by the distance *A H.* He cannot draw the end line *SS* through *A*, because it would include ground outside the posts or monuments, namely the triangles *S,D,A* and *S,C,A* not included in the original location. In the same figure *W* shows a well-made location, so far as the prospector's interests are concerned, as it is evident that the end lines *SS* and *OO* can be drawn through the lode line posts *A* and *J*, without shortening the length of the lode line, and can have a variety of directions given to them, while remaining parallel, a point of great importance, as will be seen shortly.

It follows almost inevitably that one satisfactory location must in common practice necessitate an adjacent location in bad shape, so that whatever may be said of the policy of making the lode line monuments of one location common to its extensions, the ordinary practice of making the corner monuments also common to adjacent claims should be abandoned by those who wish to avoid trouble on final survey. Independent posts should be established as shown on pl. 15, fig. 8. In this figure the corner monuments of location *A* are marked $a^3a^4a^5a^6$, while its corners of location *B* are numbered b^3,b^4,b^5, and b^6. The diagram explains itself, being only two locations like *W* in fig. 7, placed end to end. By adopting this system, the parallel end lines can be located anywhere in the ground covered by the overlapping corners, as shown by the heavy parallel cross lines.

End Lines.—The acts of Congress grant to the locator 1,500 linear feet on the vein, and call for parallel end lines, so that a uniform length on the vein shall be maintained at all depths, as the miners follow the vein downward on its dip, the end lines being extended downward vertically and prolonged indefinitely in the direction of the dip. If any other policy were allowed, the ownership on the vein in depth would be a variable quantity, diminishing in length if the end lines of the claim converged toward each other in the direction of the dip, and increasing if they diverged from each other, as can be seen by reference to pl. 15, fig. 12, which shows two locations on the lode *a b*, the dip being indicated by the arrow. The dotted lines show the non-parallel end lines prolonged in the direction of the dip, and it is plain that the location *C* would constantly be gaining, while *D* would be losing ground in depth. For this reason the end lines of a claim must be kept parallel in justice to both locators. It is not, however, always an easy matter to do this, the first locator usually getting in practice an advantage over his later located neighbor.

Surface Length and Actual Lode Length.—While the grant says "1,500 ft. on the vein" it is in reality 1,500 ft. on the line of the outcrop of the vein measured horizontally, and by varying the angle between the end lines and the lode line, the locator may acquire either less than 1,500 ft. measured horizontally on the real vein or a great deal more. Take for instance the case presented in pl. 14, fig. 1, in which *AB* shows a location of 1,500 ft. on the outcrop of the vein *AC*, a tunnel on the vein starting on the outcrop at *A* and terminating at *C*, on the prolongation of the end line of the location *DE*, which is made at right angles to the lode line. The dip of the vein in the direction of the arrow is 60° from the horizontal, and the rise of the mountain side on which the outcrop is located from *A* to *B* is 500 ft. Fig. 2 shows a cross section of the lode on the line *CDE* in fig. 1, and the dimensions just given make the horizontal distance from *BB*, which is vertically under the point *B* on the outcrop on the end line, to the tunnel at *C* 287 ft. (ignoring fractions). Returning to fig. 1, the line *AC*, or the actual distance owned by the locator on the lode horizontally, will therefore be longer than the length on the outcrop; viz., the square root of 1,500 squared plus 287 squared, or 1,527 ft. approximately.

If the rise of the outcrop is 33°, as is not infrequent, the height of *B* above *BB* or *C* will be 817 ft. and the distance *BC* 408.5 ft.; and *AC* will be 1,546.7 ft.

But if the dip of the vein be 45° and the slope of the outcrop is 33°, *B* will be 817 ft. above *C*; *BC* will be 817 ft. long, and *AC* 1,708.2 ft., or 208.2 ft. longer than the grant on the outcrop.

Hence it can readily be seen that the apparently unimportant question of the position of the end lines is really one of great importance to the owner, when the lode has a flat dip and crops on steep hillsides, cutting a smaller and smaller figure as the country becomes flatter or the lode more vertical. When perfectly vertical both lines would be the same length; as also in a level plain. (Pl. 14, fig. 1, is distorted to give better room for display.)

When making a single location on a vein, rectangular end lines may be undoubtedly the best; but the reverse may be true where a series of such locations are made, unless the outcrop of the vein follows a very straight line, which is only the case when it is nearly vertical. If sinuous or crooked, as in pl. 14, fig. 3, where *a,a′a″a‴* is the outcrop and the arrow shows the dip, a single location like *Z* will be satisfactory; but if we add another, as *W*, at a later date, *Z* will take everything in depth between the dotted lines *ab* and *a′b*, while *W* will only be able to follow the vein downward till it encounters the line *a′b*, and stops the shaded triangle between the lines *a′b* and *a″c*. If a third location *X* be made as shown, no one will own the gore between the lines *a″c* and *a″e*, nor can title be acquired thereto, because there is no vacant ground on the outcrop at *a″* on which to base a location. This is, of course, an extreme case, but if all the locations are made in the interest of the same parties, it is evidently better that the end lines should be made as in pl. 14, fig. 4, because the distance on a horizontal line between the end lines *ab* and *hh* would always remain the same, at any depth; whereas in fig. 3 the end lines *ab* and *a‴h* converge, and would ultimately intersect each other and cut out the ownership of the lode completely.

Puzzling Locations.—It may be well to call attention to some other defective forms which result from a vein with a dip, traversing a hilly country cut up with deep ravines, producing the results discussed in the subject of outcrops and illustrated in pl. 9, figs. 3 and 5, and from the frequent want of a continuous outcrop. If the ore chutes are as shown in pl. 9, fig. 7, the outcrops would be conspicuous on one side of the ravines as at *cc*, but would be scarcely visible on the other, as at *dd*. In a plan these outcrops would be seen as at *aa* in pl. 14, fig. 5, which shows two ravines with intervening hills. For want of knowledge how to trace a vein, a great number of locations are made by continuing the line of the visible outcrop as in the locations *ZZ* in a straight line, but if the dotted lines show the connecting portion of the vein, not exposed, it is evident that it will pass out of the side lines of the locations at *bb*. The complications which could arise from such a condition of things, on working the lodes, are almost endless, varying according to the priority of location and the direction of the dip of the vein.

Another form of trouble arising from the same causes is shown in pl. 14, fig. 6, in which *aa* are the outcrops of the same vein, on two sides of a ravine, the connection between the two not being visible on account of accumulated debris in the stream bottom. Instead of two locations crossing each other, a single location should have been made following the solid lines, but modifying the direction of the end lines as shown. Such a location, while having 1,500 ft. on the outcrop, would have a shorter length on the vein, but whatever this might be, it would remain uniform.

In granite countries, especially, the ore bodies may be short, lying in the vein somewhat as shown in pl. 6, fig. 5, where the peculiarity is exaggerated for illustration, and may present themselves as a series of short, more or less parallel outcrops, as in pl. 14, fig. 7, *aaa*. These are often made the basis of a series of locations as *XXX*, when the true line of the vein is shown by the dotted line, and two locations, as *ZZ*, might have covered the property at a saving of several hundred dollars.

CHAPTER XI.

PATENTS TO MINING GROUND.

In the States and Territories where the United States mining law is operative the acquisition of title in fee simple to mineral land is somewhat more complicated than to agricultural lands, as special surveys must be made in most cases to separate it from the latter, except in the case of coal and stone lands, which are sold by subdivisions of the ordinary land surveys; or in the case of placer ground where the government surveys have already been extended over the placer area, in which latter case the land can only be taken in the usual legal subdivisions, except that the selection can be made in as small quantities as 10-acre tracts. But in all cases of application for patent to mineral land a full description by exterior boundaries, or by legal subdivisions, must be published, so as to allow an opportunity for agricultural claimants or others to contest the application, if so inclined.

Except where special surveys have to be made to segregate the mineral land from the surrounding agricultural area, the proceedings originate in the United States land office for the district in which the land may be situated; but where surveys have to be made they originate in the office of the United States surveyor-general for the State in which the locations lies. Thus the United States surveyor-general deals only with those claims which require special surveys; and to these we will first give attention, as they include the much larger proportion of mineral locations.

Before going further it will be well to note the difference between a "location" and a "claim," as the words are often used indiscriminately, although in land office proceedings they have distinct and very different meanings. A lode location must not exceed 1,500 ft. in length by 600 ft. in width; and a placer location must not contain more than 20 acres, but may be of any shape necessary to cover the ground sought to be purchased. On the other hand a claim may include as many locations as the owner or claimant may have been able to purchase, provided they are adjacent to each other, and a patent for a single claim may contain many locations. In such a consolidated survey and patent the aggregate of say eight placer locations must not exceed 160 acres, and no one of the individual locations must exceed 20 acres; if any of the locations fall short of 20 acres, the loss cannot be made good by allowing an excess in some other location.

Procedure on all Lode Locations, and such Placer Locations as Lie on Unsurveyed Land.—In these matters a uniform process must be gone through and a rigid adherence to the routine of the surveyor-general's office, as well as that of the local land office, will greatly facilitate progress.

Duties of the Surveyor.—All mineral surveys intended to form the basis of an application for a United States patent must be made by a deputy mineral surveyor. These deputies are appointed by the United States surveyor-general for the State, and are placed under bonds for $10,000, with two sureties, qualifying in double the amount, for the faithful performance of their duties, which are carefully defined in the government instructions, and from which there can be no diviation without the risk of serious trouble both to the surveyor and the applicant.

Deputy Surveyor's Fees.—The deputy is paid for his services by the applicant, who has the right to select whomever he may prefer, and the compensation for the work is a matter of agreement between the applicant and the deputy, as there is no recognized scale of fees; such an arrangement being impossible on account of the widely different conditions under which the surveys are made as to accessibility of the locality, roughness of the ground and number of surveys to be made in any one locality. It is evident that the incidental traveling expenses will be just as great for the survey of one location as for ten, if they are in the same vicinity.

The following extracts from the instructions issued to the deputy mineral surveyors by the surveyor-general for the State of Washington will show the limit of their authority and furnish a guide to applicants for survey in preparing their case:

Field Work (7).—The survey made and reported must, in every case, be an actual survey of the ground in full detail, made by you in person *after* the receipt of the order, and without reference to any knowledge you may have previously acquired by reason of having made the location, survey or otherwise, and must show the actual facts existing at the time. If the season of the year, or any other cause, render such personal examination impossible, you will postpone the survey, and under no circumstances rely upon the statements or surveys of other parties, or upon a former examination by yourself.

The term "survey" in these instructions applies not only to the usual field work, but also to the examinations required in the preparation of your affidavits of $500 expenditure, descriptive reports on placer claims, and all other reports.

(4) No return by you will be recognized as official unless made in pursuance of a special order from this office.

Not to Act as Attorney (6).—You are precluded from acting either directly or indirectly as attorney in mineral claims. Your duty in any particular case ceases when you have executed the survey and returned the field notes and preliminary plat with your report to the surveyor-general. You will not be allowed to prepare for the mining claimant the papers in support of his application for patent, or otherwise perform the duties of an attorney before the land office in connection with a mineral claim. You are not permitted to combine the duties of surveyor and notary public in the same case by administering oaths to parties in interest. In short, you must have absolutely nothing to do with the case except in your official capacity as surveyor. You will make no survey of a mineral claim in which you hold an interest.

Survey and Location (8).—The survey must be made in strict conformity with, or be embraced within, the lines of the recorded location upon which the order is based. If the survey and location are identical, that fact must be clearly and distinctly stated in your field notes. If not identical, a bearing and distance must be given from each established corner of the survey to the corresponding corner of the location. The lines of the location as found upon the ground, must be laid down upon the preliminary plat in such a manner as to contrast and show their relation to the lines of the survey.

(11) In accordance with the principle that courses and distances must give way when in conflict with fixed objects and monuments, you will not, under any circumstances, change the corners of the location for the purpose of

making them conform to the description in the record. If the difference from the location be slight, it may be explained in the field notes, but if there should be a wide discrepancy, you will report the facts to this office and await further instructions.

From the foregoing it will be seen how important it is that everything should be in good order on the ground before the surveyor is sent on to it. There is a widely prevalent idea that the surveyor can rectify any irregularities which he may discover, and reestablish corners which may be missing, without any probability of future trouble, but this is not the case. It is true he can take testimony to ascertain the former position of missing corners, but this involves delay and extra expense for which, in the very large majority of cases, the applicants are unwilling to pay; and as the entire theory of the mining laws is based on the supposition that a party places no value on a neglected article the applicant should not be surprised if the authorities who have to pass on the legality of his location take that view, and make no excuses for things which ought to have been, and might have been, in better shape.

The duty of the surveyor is simply to report the facts as he finds them on the ground; if a stake or monument is missing he must so state, giving such reasons as may apparently account for its absence, at the same time leaving the examining authorities to judge whether such reasons are satisfactory; if the monument is in existence he must so report, and if not identical with the corner of a survey he must explain why it is not; he cannot increase the length of a claim if it has been made less than 1,500 ft. originally; and he must make the end lines parallel, though the side lines need not necessarily be so. In fact he is not allowed to be in any sense a judge of the equities of the case; he is simply employed to collect the information by which others can adjust them.

Duties of the Applicant.—The following extract is from the official instructions:

(4) . . . You are therefore advised, before filing your application, to see that your location has been made in compliance with law and regulations, and that it properly describes the claim for which patent is sought.

Office Charges.—There are certain charges for work in the office of the surveyor-general which are independent of the contract with the surveyor, and are intended to cover the cost of examining the filed notes of the survey and the preparation in quadruplicate of the maps and field-notes, one copy of which is sent to Washington to the general land office, two to the applicant, and the other is retained on file in the office of the local surveyor-general.

(5) With regard to the platting of the claim and other office work in the surveyor-general's office, that officer will make an estimate of the cost thereof, which amount the claimant will deposit with any assistant United States treasurer, or designated depository, in favor of the United States treasurer, to be passed to the credit of the fund created by individual depositors for surveys of the public lands, and file with the surveyor-general the duplicate certificate of such deposit in the usual manner.

(6) The following is the estimated cost of platting and other office work in connection with the survey of mineral claims:*

Lode claim	$35 00
Placer claim	35 00
Mill site claim	35 00
Mill site included in one survey with a lode claim	25 00
Each lode claim included in the survey of a placer claim	25 00
Several lode or placer claims in one survey, each location	35 00
Descriptive report on placer claim taken by legal subdivisions	10 00

(7) Should the office work, in any case, amount to more than the above estimate, an additional deposit will be required.

(8) In districts where there is no United States depository, you should deposit with the nearest assistant United States treasurer, or depository, and in all cases immediately forward the original certificate (of deposit) to the secretary of the treasury (at Washington, D. C.) and the duplicate to the surveyor-general, retaining the triplicate for your own use and security. Under no circumstances will the deposit be made with the surveyor-general.

The deposits for office work are not to be made until the applications for survey are received, and the parties notified by the surveyor-general.

The order of procedure is therefore as follows:

1. *Application Blanks.*—As applications for survey must be made on the blank forms adopted by the surveyor-general's office, the applicant, unless he can secure one from the deputy surveyor, should write to the surveyor-general for a blank form.

Particulars.—This application contains the name of the deputy who has been selected to make the survey,

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* This is the scale issued by the State of Washington, and is only given to convey a general idea of the cost.

and a request for an estimate of the office fees. It should also be filled out with the name of the claimant in full, as it is desired to appear in the application to the land office for patent; the name of the mining claim in full, stating whether it is a lode or placer claim; the name of the mining district, and the land office district in which the claim is located, and if the claim is made up of several locations, they should all be enumerated in detail.

With this application, there must be forwarded "a copy of the record of location of the claim, properly certified by the recorder having charge of the records of the mining locations in the county where the claim is situated." This may be either the recorder of the mining district, if one has been regularly organized, or the county recorder if no district has been formed, or the organization has been abandoned or fallen into disuse. When securing this certified copy of the notice of location, a second one should be secured and delivered to the deputy who is to make the survey, as he has to make the survey in conformity with the notice and return it to the surveyor-general as a portion of his field-notes. The deputy has also to file with his returns a copy of the laws of the mining district, if such be organized, and it is important that the location should conform to these laws and regulations. A local miners' organization may impose any conditions they see fit on a locator, provided they do not conflict with the general mining laws of the United States, and as long as such local rules are in force in a district, any application which takes an amount in excess of the local regulations is liable to be returned for correction.

2. *Deposit; Receipt; Order for Survey.*—When application for survey has been filed with the surveyor-general, he will notify the applicant of the cost of the office work, and this sum must be deposited as previously explained. On the receipt of the duplicate

receipt, showing that the charges have been deposited to his credit, the surveyor-general issues his order of survey to the deputy mineral surveyor, who can make no official move until he is in receipt of this authorization. The applicant has nothing further to do until the survey is completed, and has been examined and platted by the proper authorities.

As the surveyor has to make with his returns a statement of the value of the work done on the location, supported by the affidavit of two disinterested persons, the applicants should be careful that fully $500 has been expended in actual mining improvements, as if this has not been done, the papers are likely to be returned, involving loss of time and expense. The common notion that $5 should be allowed for each day's work on the location is erroneous; labor should be counted at its current rate, whatever it may be, and to estimate a man's labor at $5 per diem for the purpose of securing patent to the ground and only at $2 per diem for other purposes suggests a fraudulent intent, and may lead to trouble, as it is not carrying out either the letter or the spirit of the law. It is evident that if the location is worth patenting at all, it is worth honest returns as to the value of the improvement, by which is meant the actual amount of money spent upon the ground, in which estimate traveling expenses and such other items are not allowed.

3. *Publication.*—When the returns of the surveyor have been examined and approved by the surveyor-general, he forwards to the applicant two copies of the field-notes and two copies of the official plat. The applicant must then make an agreement with the nearest local newspaper for the publication of the notice of intention to apply for a patent, which notice must contain such a description of the ground, made up from the field-notes sent by the surveyor-general, as will fully identify the ground and give notice to all adjacent

owners and others of what ground is claimed. This notice must be published 60 days, or if in a weekly paper it must appear in nine consecutive issues. When this publication is decided on, the applicant must post one copy of the map and field-notes upon the claim, in some conspicuous place, in the presence of two witnesses, who must be disinterested parties, and this notice must remain on the ground during the entire period of publication.

During this period of publication, any one has the right to file an adverse claim to the ground, but if such claim is not filed during this period the adverse claimant is debarred from further proceedings. Such adverse claim when filed must be accompanied with a plat of the ground showing the conflict of interest, for the information of the prior claimant, and suit must be commenced within 30 days in the proper court, to determine the respective rights of the parties, and such suit must be prosecuted with diligence to a termination. Evident negligence to do this justifies the land office in taking steps to force it, or dismiss the adverse claim.

Documents to be Filed; Final Proof.—If there be no adverse claim filed, the applicant is then ready to proceed with his final proof before the United States land office for the district in which the claim is situated, and will be required to file the following papers in the case:

1. Application for patent, on the usual blank forms, which must be in the name of the party or parties, or incorporation, making the application for survey.
2. The copy of the surveyor-general's official plat, with the accompanying field notes.
3. A complete abstract of title, properly certified by the proper authorities.
4. Affidavit of citizenship, or in the case of an incorporated company, of such incorporation, as no patent can issue to an alien.
5. Affidavit by two disinterested parties of the posting on the ground of the notice to apply for a patent, giving date of posting and locality at which it was posted.
6. Affidavit by two disinterested parties that such documents remained continuously posted during the entire period of the publication of the notice to apply for patent in the newspaper.
7. Agreement with the publisher as to cost.

8. A copy of the notice of publication, cut from the paper.
9. Affidavit of the publisher that such notice was published the requisite number of times, giving the dates, name of paper, and place of publication.
10. Certificate of the clerk of the Superior Court that there is no suit pending affecting the ownership of a title to the ground.
11. Affidavit of two disinterested parties as to the value of the work done and its character. (These must be actual mining improvements. Houses, roads and trails are not considered necessarily mining works, unless they are connected with tunnels, shafts, or other mining excavations).
12. Affidavit by the applicant of the costs which have been incurred in securing the patent, including such items as monies paid the surveyor. publisher, attorney, etc. (The object of this is twofold: (1) To protect the applicant against exorbitant charges; and (2) to protect the government by disclosing whether prices have been paid which might be inferred to have influenced the judgment of the person receiving them.
13. Application to purchase.

Payment need not be made on the day on which the "final proof" is made in the land office, by the presentation and approval of all the papers in the case, but good policy involves prompt attention to this, as the payment of the money due the government is acknowledged by the issuance of a "duplicate receipt" which stands in the place of a patent, and answers every purpose of such a document, until the patent is issued, which is a matter of routine in Washington and may not be reached for a year.

Government Land Prices.—The price for lode locations and mill sites is $5 per acre; for placer ground $2.50 per acre; and for coal lands $20 per acre.

Contests.—The foregoing proceedings in the land office are practically applicable to all mineral lands, and apply to all simple uncontested cases. The United States land office is also the referee where there may be a difference of opinion as to the character of the land, as between mineral and agricultural claimants, the contestants presenting their individual views by testimony, but all questions of ownership are decided by the courts. These may include priority of location, overlapping of locations, intersecting or cross veins and so many other contingencies that in all cases of conflict the services of an attorney must be called in. This chapter is intended only as a guide in those cases where all is plain sailing. In all others a good special land lawyer should be consulted.

Further Instructions.—The following extracts from the circulars issued for the guidance of deputy surveyors may be of interest:

13. The order of approval of surveys of mineral claims is prescribed by general land office circular, dated March 3, 1881, as follows:

"The mining survey first applied for shall have priority of action in all its stages in the office of the surveyor-general, including the delivery thereof, over any other survey of the same ground or any portion thereof."

"When the survey first authorized is not returned within a reasonable period, and the applicant for a conflicting survey makes affidavit that he believes (stating the reasons for his belief), that such first applicant has abandoned his purpose of having a survey made, or is deferring it for vexatious purposes, to wit, to postpone the subsequent applicant, the surveyor-general shall give notice of such charges to such first applicant, and call upon him for an explanation under oath of the delay. He shall also require the deputy mineral surveyor to make a full statement in writing, explanatory of the delay; and if the surveyor-general shall conclude that good and sufficient reasons for such delay do not exist, he shall authorize the applicant for the conflicting survey to proceed with the same; otherwise, the order of proceeding shall not be changed."

"Whenever an applicant for a survey shall have reason to suppose that a conflicting claimant will also apply for a survey for patent, he may give a notice in writing to the surveyor-general, particularly describing such claim, and file a copy of the notice of location of such conflicting claim. In such case the surveyor-general will not order or authorize any survey of such conflicting claim until the survey first applied for has been examined, completed, approved and platted, and the plats delivered."

13. Your attention is directed to the first . . paragraphs of general land office circular dated December 4, 1884, viz:

"1. The rights granted to locators under section 2322, Revised Statutes, are restricted to such locations on veins. lodes or ledges as may be 'situated on the *public domain.*' In applications for lode claims where the survey conflicts with a prior valid lode claim or entry, and the ground in conflict is excluded, the applicant not only has no right to the excluded ground, but he has no right to that portion of any vein or lode the top or apex of which lies within such excluded ground, unless his location was prior to May 10, 1872. His right to the lode claimed terminates where the lode, in its onward course or strike intersects the exterior boundary of such excluded ground and passes within it."

"2. The end-line of his survey should not, therefore, be established beyond such intersection, unless it should be necessary so to do for the purpose of including ground held and claimed under a location which was made upon public land and valid at the time it was made. To include such ground (which may possibly include other lodes) the end-line of the survey may be established within the conflicting survey, but the line must be so run as not to extend any further into the conflicting survey than may be necessary to make such end-line parallel to the other end-line."

CHAPTER XII.

EARLY DEVELOPMENT OF MINES.

WHEN satisfied from thorough examination of the surface indications that a deposit of mineral is worthy of further exploration, the question arises as to what the character of these explorations shall be, to accomplish the best results in the shortest time and at the least expense.

"*Follow the Ore.*"—There is one rule from which there should be no variation, whatever plan may be adopted, in all preliminary works, and that is, to follow the ore wherever it may go, no matter how crooked the shape of the developments may be; as it is only by determining the shape and character of the deposit that later works can be laid out intelligently and economically. This plan has also the advantage of to some extent paying for the work of development; as, if the ore is rich enough to ship, it will furnish a certain amount of cash to continue the work, while at the same time such shipments will attract the attention of mining men, and go far toward effecting a sale if this is contemplated, or securing aid to prosecute the work on a larger scale. Even if the ore be too poor to ship, the dump may yet be a valuable asset, and the number of tons it contains will be evidence of the faith of the owners in their property, and will furnish a better evidence of the producing capacity of the property than any series of mere measurements.

Cross-cut Tunnels.—How often this rule is disregarded may be seen by the frequent newspaper notices that "so-and-so have started a tunnel to tap the vein 200 ft. deep," or some other attractive figure, when in all probability the deepest hole on the property may not be 10 ft. deep. Such schemes are usually based on the mistaken idea so often heard repeated, that the mine will "show up" in depth. Deep cross-cut tunnels are admissible for working purposes when the mine is proved to be worth the cost of driving them, but they are unadvisable at the beginning of operations, unless it is impossible to approach the ore body in any other way; and in such cases the surface showing must be more than ordinarily good to justify such a procedure. Such early works have two fatal defects: (1) A shaft must be sunk ultimately, connecting the surface and tunnel to give ventilation, and good policy would indicate the propriety of sinking the shaft first, and running the tunnel afterward to meet it, if the showing in the shaft justified it; and (2) such a cross-cut tunnel through the rocks which inclose the vein may cut the vein where it is barren or in a "pinch," and cause the abandonment of the property; and at the best, after months of work, it tells us the character of the ore and the thickness of the vein or deposit at the single point where it is encountered, when we ought to be learning something daily for every dollar expended. The point where the vein is cut may be much poorer than the ore on either side at comparatively short distances away, causing an underestimate of the value of the property; or the ore encountered may be a rich bunch, giving exaggerated ideas of value; or the ore may have thinned out and disappeared altogether, which fact would have been demonstrated much earlier in a shaft. Such a tunnel, unless followed up by explorations of the vein laterally, adds little to the value of a property which may be offered for sale, because it does not prove continuous ore from the surface to the depth at which it cuts the lode—it only renders it probable; while the same money spent in sinking on the vein might have produced a marketable proposition, or proved the smallness of the ore body at much less cost. A tunnel to tap the vein, 200 ft. deep, is not likely to be less than 300 ft. long, and when completed and without drifts, only exposes an area of the vein some 5 by 7 ft. in extent, while a shaft 80 ft. deep, and 220 ft. of drifts and cross-cuts (300 ft. of work in all) would demand the attention of anybody looking through a mining camp with a view to purchase. Sinking even small shafts or inclines is of course rather more expensive than tunneling, especially if the mine is at all wet; on the other hand, it is quite possible that the ore followed down and taken out as sinking progresses may make up the difference.

Depth of Tunnel Connections.—Many erroneous estimates are made of the depth at which a tunnel of a given length will tap a vein, unless actual survey has been made instrumentally, the tendency being almost always to overestimate the depth. The best guide is to note the condition of the surface. Long rock slides and mining dumps usually stand at angles varying from 30° to 35°, which figures give respectively a rise or fall of from 58 to 67 ft., or an average of about 63 ft. in 100. To get 200 ft. of depth in a distance of 200 ft., the angle will be 45°, a very steep climb, and this occurs only in very precipitous regions.

Tunnels in Foot or Hanging Wall.—Disappointment also results from running the tunnel in the foot wall of the vein, because in addition to the distance necessary to reach a vertical shaft sunk on the outcrop, if such existed, there must be added the additional distance caused by the lode dipping away from the mouth of the tunnel, which is often forgotten. Such tunnels, if they must be run in early development, should be run if possible in the hanging wall, so as to take advantage of the vein approaching the tunnel on its dip in depth.

Drift Tunnels.—Two other methods of early development are possible—one by sinking on the vein, the other by tunneling, or rather drifting on it, starting on the outcrop and following in on the lode. This last method is by far the most satisfactory, as it proves both length and depth, for if the ore is continuous in the tunnel and in the outcrop overhead, we are justified in considering that it is continuous to the depth of the tunnel, and below, if it shows in the floor of the drift, and the mine has then what is known as "reserves," or ore proved and merely waiting extraction. This method of development also possesses the advantage (which may often be an inducement to run the cross-cut tunnels just discussed) of one man being able to work alone, using alternately the pick or single-hand drill and wheelbarrow; and upraises can be made from time to time to the surface with ease, as the material mined falls of its own weight to the floor of the drift, and can be removed without additional labor. If timbering is to be done two men are almost essential, and it may not be advisable under any circumstances to work alone in a tunnel in loose ground, on account of the risk of accidents, but it can be done in an emergency.

Sinking on the Deposit.—There are, however, many cases where we cannot at once drift on the lode, as the desirable localities may be covered by heavy debris, and the exact location of the vein unascertainable, and we must then resort to sinking on the deposit. Here again we must follow the ore, whether it makes the shaft vertical or converts it into an incline. At first one man at the windlass will do, and two men can manage for a depth of 80 to 100 ft. When this depth is attained it may be profitable to drift on the lode toward daylight, through the accumulated surface debris, and having reached daylight, to continue operations by drifting on the vein; or if it is desired to sink deeper, a horse whim will be able to hoist from a depth of 200 ft. or somewhat more.

In sinking by hand regard should be had to the size of the barrel or spindle of the windlass on which the rope is wound, as it requires less power to raise a heavy bucket slowly than rapidly. The size of the spindle should therefore be smaller (say 6 in.) for deep work than for shallow pits, not only because a small spindle raises the bucket a shorter distance at each revolution of the crank and so relieves the strain, but because its diameter is rapidly increased by the winding of the rope upon it, making the strain greater and greater as the load approaches the top.

Water.—The appearance of water in a shaft may, however, modify all the conditions, and compel a resort to cross-cut tunnels, but if present in large quantities, and artificial drainage is possible, its presence may be considered a favorable indication, as it is evidence that the fissure on which work is being prosecuted is extensive and drains a large area, and may consequently contain larger bodies. Such a condition is certainly more promising than a dry hole in which the ore shows little sign of decomposition, or of the former circulation of water.

Position of Main Working Shafts.—Usually, from the nature of the explorations and the surrounding physical conditions, especially where the mine must be worked on a large scale by deep shafts, the location of such shafts in suitable relationship to the lode is a matter of much importance. When the dip of the vein or deposit is comparatively flat we may be compelled to adopt an inclined in preference to a vertical shaft, unless it be so flat that it can be worked like a coal mine, on an almost horizontal floor. But when the vein stands nearly vertical the greater facilities for operating a vertical shaft may make such a plan desirable. We must then remember that all mining expenses increase with depth, and if dead work has to be done to reach the ore in the lode it is better to do such work near the surface, while expenses are low or moderate, than at greater depths where they are high and constantly increasing. Pl. 9, fig. 2, illustrates this, showing a vein and two shafts *A* and *B*, in cross section across the lode. *B* is evidently better located for economical working than *A*, because in the latter the length of the crosscuts from the shaft steadily increases with depth, while in *B* the longest crosscuts are near the surface, and, for the depth shown, the total amount of dead work is much smaller than in *A*, with increasing advantage for greater depth.

The same principle is illustrated in pl. 9, fig. 4, as regards the position of the shaft lengthwise of the vein, *C* being the ore shoot, with a decided rake to the left. (The rake usually diminishes with the increase of dip, being least in vertical lodes; and is usually similar in all the veins of a district having the same general strike and dip.) Here *B* located near the center of the outcrop, would not be in as good a position as *A*, for the reasons just given.

Cross-Cutting.—In all explorations on the vein underground, the importance of intelligent cross-cutting is obvious. No ore bodies are fitted into a clean-cut fissure with mathematical accuracy. The crushing of the rocks which make the formation of a mineral vein possible also had a tendency to scatter the ore bodies when formed, and because one body of ore gives out in a drift it by no means follows that all the ore has given out in the mine. It may simply be shifted laterally to another plane of the "sheeting." The Keystone mine, Amador County, Cal., is cross-cut to a width of several hundred feet with profit; and it does not even do to assume a perfectly smooth, continuous rock face to be either the foot or hanging wall, as a case in Colorado shows, where such a wall was followed by a drift for several hundred feet, and when broken into under a change of management, proved to be only one side of a more valuable body of ore than had been extracted by the drift.

Usually the distance to which the cross-cut may be carried is indicated by the condition of the rock through which it is driven. As long as this shows evident signs of decay or change, or traces of mineral, so long it may be desirable to continue the cross-cut; but it should be stopped as soon as the rock assumes the character of the main body of the wall rock visible on the surface, and not in contact with the vein. If working in limestone where the ore occurs in pockets and chambers the little stringers of ore should receive especial attention.

System in Development.—In all these operations the watch word should be utility and economy. Unintelligent management may easily swamp an enterprise which in proper hands would have proved a success. Every bit of work done on a location should be the result of a carefully planned scheme, the portions of which will fit together when completed. Especially should this be the case with the annual assessment work. Too often the owner looks upon this work as a burden, and desires to do just as small an amount of it as will legally hold the claim until he can sell it. Such skimped work will seldom sell a claim. Few realize that only by putting work on a mining location can it, in most instances, be made a salable or valuable proposition; and in a large proportion of cases, for want of judgment, the work done leaves the property looking worse than if nothing had been done upon it.

Prospect Pits.—If only small sums of money are to be spent annually, these will be best expended in tracing the ore body by a series of shallow pits, rather than by starting short tunnels one after the other in places where work is easy, only to leave them in barren ground. As at present expended, most of the money spent on assessment work is practically thrown away, for want of system.

Large surface excavations, except such as are necessary to trace the ore, are not desirable, in wet or snowy countries especially, as they only serve to divert the rain and snow into the mine, from which it may later on have to be pumped at heavy cost.

Common Terms Used in Mining.—Definitions of a few of these may be in place here: A "shaft" is a vertical opening, either on or alongside of the vein if that is vertical, or outside of it (preferably in the hanging country) if the lode has a dip, but intersecting it in depth. An "incline" is a sloping shaft, usually made to follow the vein or ore bed. It may not be so convenient as a vertical shaft for working, but involves less dead work in opening a mine. A "winze" in a shaft connecting the interior workings, but not coming to daylight. It may be either vertical or an inclined winze. A "chute" (shoot) is a winze suitably lined to pass ore and waste from the workings to the cars on a lower level. ("Chute" is also applied to a pitching ore body.) The drain tunnel, or lowest horizontal opening by which water can be discharged from the mine, is the "adit." "Drifts" or "levels" run from the shaft from time to time as it is deepened; and are distinguished from "tunnels," which have one end open at the surface—the distinction between a tunnel and a drift being the same as between a shaft and a winze. The face of the drift is called the "head" or "heading;" ground from which ore is being taken between the different levels is called a "stope," and the ore may be removed either by digging downward, when the process is called "underhand stoping," or by working upward, in which case the operation is said to be "overhand" or "overhead." It is evident that by the latter method the material when broken down drops away from the workman more readily than by the former, and is usually the one employed, unless circumstances absolutely prevent its economical adoption. The timbers which are put in to keep the walls apart after the extraction of the ore, and also to form working floors for the miners, are called "stulls," and the filling done with the waste material (in Cornwall "attle"), which is never taken from the mine, if possible to utilize it, is called the "gob." When taken to the surface it forms the "waste dump." An excessively large dump of waste material indicates an excess of dead work in the mine; a small one on the other hand is by no means a bad gage of prosperity. The bottom of shafts, inclines and winzes into which the water of the mine drains, and in which the pumps are located, is known as the "sump," and is necessarily below the lowest working level, its depth being gaged according to the amount of water to be removed daily.

CHAPTER XIII.

ORES.

DEFINITIONS.—An "ore," strictly speaking, is a single mineral which is a chemical compound of a useful metal and some other element or acid. In common usage, however, complex mixtures of pure minerals are considered as single ores; while free gold, native silver and native copper, together with their accompanying gangue minerals, are also classed as ore. Among miners whatever will pay to treat or ship and sell is considered ore, as also low-grade mineral which might be utilized by concentration or improved facilities; but there is an indefinite shading off into material containing traces of ore minerals but hopelessly unavailable, and this is not considered ore; neither are gold gravel or platinum sands called ore. To avoid misunderstanding, it is best to distinguish between the "ore" (meaning thereby the whole bulk of the available product) and the "ore mineral" (usually very much smaller in quantity in all ores except those of iron, manganese, and some lead and zinc ores). In this connection will be mentioned only those minerals which produce the bulk of the useful metals. Mineralogists describe some 850 different mineral species, of which a considerable proportion might possibly be called ores; but only a comparatively few are of practical importance—the remainder are of interest only to the collector and scientist. It is believed that those here described will be sufficient to enable the prospector to recognize nearly all which are commercially valuable.

The descriptions are based on those in Dana's "Mineralogy," and are supposed to apply to the minerals in their pure, crystallized forms, but such items as hardness, weight, color and streak are common also to the massive forms. To make the descriptions short and compact a few terms and contractions are employed, which need explanation:

Adamantine, resembling a diamond.

Amorphous, not crystallized; without any special form.

Arborescent, resembling the growth of the branches of a tree.

Botryoidal, made up of masses of varying size with smooth rounded surfaces, like grapes.

Brilliant, applied to surfaces which are perfect reflectors of light.

Brittle, breaking easily.

Compact, very close-grained, not showing special crystals.

Conchoidal, as applied to surfaces of fracture, means resembling the inside of a clam shell in shape.

Concretionary, made up of particles which have apparently grown together into a solid mass.

Ductile, capable of being drawn out into wire, or elongated.

Flat, as applied to fracture, means smooth, like a board.

Fibrous, like a bundle of threads laid side by side.

Filiform, thread-like, not massed together as when fibrous.

Foliated, made up of thin leaves like a book.

Granular, made up of distinct grains like coarse sandstone.

Iridescent, exhibiting a play of changeable rainbow colors.

Malleable, flattening under the hammer without breaking.

Mammillary, made up of many small rounded surfaces like miniature breasts; usually applied to some forms of incrustations on rocks.

Massive, not crystallized.

Metallic, when descriptive of luster, means resembling polished steel, silver or other metals, as opposed to "earthy."

Micaceous, made up of thin plates, resembling flakes of mica.

Oölitic (o-o-litic), made up of rounded particles, like fish eggs.

Opaque, will not permit the passage of light.

Pisolitic, made up of rounded particles like peas.

Reniform, kidney-shaped.

Resinous, resembling resin.

Sectile, can be cut with a knife, like lead or easier.

Shining, opposed to "earthy," when describing the "streak."

Stalactitic, resembling the cylindrical masses found hanging from the roof of limestone caves, formed by dripping water.

Subconchoidal, resembling conchoidal, but flatter, more like the inside of an oyster shell in form.

Submetallic, with only a slight metallic luster, as a tarnished silver surface.

Translucent, not perfectly clear, but resembling an egg when held up before a strong light.

Transparent, permitting the perfect passage of light, like glass.

Uneven, breaking into a rough face, like a broken brick.

Vitreous, glassy.

Waxy, as applied to luster, not quite so bright as resinous, resembling the surface of clean beeswax.

It would not be possible to give a good idea of the forms assumed by the crystallized minerals without numerous diagrams, so that only occasional references are made to crystallization. The physical properties used are the luster, color, streak, hardness, weight, and manner of breaking. By the "streak," is meant the color of the scratch made by a penknife or the color of the powdered mineral. The weight is the specific gravity (in ratio to weight of equal bulk of water), indicated by the letter *G*, and is an important item in all concentrating operations or the sorting of ores. The hardness, indicated by the letter *H*, refers to a scale of hardness, in common use, in which crystallized varieties of the minerals mentioned are meant: 1, talc; 2, gypsum; 3, calcite or limespar; 4, fluorspar; 5, apatite; 6, feldspar; 7, quartz; 8, topaz; 9, corundum; 10, diamond; so that if a mineral is said to have a hardness of 4 it would scratch 3, but would not scratch 5.

GOLD—*Native.*—H. 2.5—3. G. 15.6—19.5. Yellow, malleable, sectile. The depth of the yellow color varies with the amount of silver present in the metal, being deepest in the purest gold. When the value in silver becomes equal to the value of the gold, the native alloy is white. Distinguished from all minerals which it resembles, by flattening under the hammer, instead of breaking. The minerals for which it is most frequently mistaken are iron and copper pyrites, but it may be distinguished from these, when in such a position that it cannot be tested by the knife or hammer, by turning the specimen completely round in the sunlight, when it will be found to maintain the same color and appearance in every position. This is not the case with the other minerals mentioned, which will also float on the top of quicksilver, while gold will sink. Insoluble in simple acids. Distinguished from yellow mica by not splitting.

Tellurides of Gold.—These minerals are not found in large quantities, but are associated with other ores, and from their want of resemblance to gold often puzzle the prospector, who will get very large assays from samples which show no free gold. The four forms may be distinguished by the following characters. Three of them greatly resemble lead, and none of them are common enough to have local names. The important tellurides carrying gold are:

Sylvanite.—H. 1.5—2. G. 7.9—8.3. Luster metallic. Streak and color steel-gray to silver-white, sometimes brass-yellow. Fracture uneven. Approximate composition: gold 30, silver 10, tellurium 60%.

Nagyagite.—H. 1—1.5. G. 6.8—7.2. Luster metallic, brilliant. Streak and color blackish lead-gray. Opaque. Sectile. Composition: 6 to 12% of gold with lead and tellurium.

Petzite.—H. 2.5. G. 8.8—9.4. Color between steel-gray and iron-black, sometimes tarnished with peacock tints. Streak iron-black. Brittle. Approximate composition: gold 25, silver 41, tellurium 34%.

Calaverite.—Massive, without crystalline structure; color bronze-yellow; streak yellowish gray; brittle. Fracture uneven. Approximate composition: gold 41, silver 3, and tellurium 56%.

SILVER —*Native.*—H. 2.5—3. G. 10.5. Luster metallic. Color and streak silver-white. Ductile. Tarnishes easily to grayish black. Malleable. Occurs as wire silver, crystallized (arborescent) or massive, up to 800 lb. in weight.

Argentite, Silver Sulphide, Vitreous Silver, or Silver Glance.—H. 2—2.5. G. 7.2—7.4. Luster metallic. Streak and color blackish lead-gray; streak shining. Opaque. Perfectly sectile. Occurs crystallized, amorphous, arborescent and filiform. Approximate composition; silver 85, sulphur 15%. Gives silver when heated on charcoal before the blowpipe.

Pyrargyrite, Dark Ruby or Antimonial Ruby Silver.—H. 2—2.5. G. 5.8. Luster metallic. Color black, sometimes approaching dark or purplish red. Streak cochineal-red. Translucent to opaque. Fracture conchoidal. Powder purplish red. Approximate composition: silver 60, antimony 22, sulphur 18%. Decomposed by nitric acid.

Proustite, Light Red or Arsenical Ruby Silver.—H. 2—2.5. G. 5.5. Luster adamantine. Color cochineal-red. Streak cochineal-red sometimes brighter. Subtranslucent. Fracture conchoidal, uneven. Powder bright red. Approximate composition; silver 65, arsenic 15, sulphur 20%. Decomposed by nitric acid.

Freieslebenite or Gray Silver Ore.—H. 2—2.5. G. 6—6.4. Luster metallic. Color and streak light steel-gray, inclining to silver-white, also blackish lead-gray. Yields easily to the knife, and is rather brittle. Fracture uneven. Powder steel-gray. Approximate composition; silver 22, lead 30, antimony 28, sulphur 18, iron and copper 2%.

Stephanite, Brittle or Black Silver.—H. 2—2.5. G. 6.3. Luster metallic. Color, streak and powder iron-black. Fracture uneven. Approximate composition; silver 68.5, antimony 15, sulphur 16.5%. Soluble in heated dilute nitric acid.

Cerargyrite, Horn Silver or Chloride of Silver.—H. 1—1.5. G. 5.5. When nearly pure, looks like wax. Luster resinous. Color pearl-gray, grayish green, whitish, rarely violet-blue, sometimes colorless when perfectly pure; brown, or violet-brown after exposure. Streak shining. Translucent. Sectile, cuts like wax. Not soluble in nitric acid. A fragment placed on a strip of zinc, and moistened with a drop of water, swells up, turns black and finally is entirely reduced to metallic silver, which shows the metallic luster on being pressed with the point of a knife. Composition: silver 75.3, chlorine 24.7%.

Embolite or Bromide of Silver.—H. 1—1.5. G. 5.5. Resembles horn silver. Luster resinous. Color usually greener than horn silver, often dark, becoming darker on exposure. Composition: silver 67, chlorine 13, bromine 20%.

(Besides the above, there are some 20 other silver minerals of small importance commercially.)

PLATINUM—*Native.*—H. 4—4.5. G. 16—19. Luster metallic, not very bright; color and streak whitish steel-gray; shining. Opaque. Ductile. Malleable. Occurs usually in small grains; occasionally in masses of several pounds weight. Infusible. Soluble only in heated nitro-muriatic acid.

IRIDOSMINE—*Native.*—H. 6—7. G. 19—21. Luster metallic. Color tin-white and light steel-gray. Opaque. Malleable with difficulty. Composition: the metals iridium and osmium in varying proportions, in combination with small amounts of rhodium, platinum and ruthenium. Occurs as small flattened grains in gold washings.

QUICKSILVER OR MERCURY—*Native.*—G. 13.56. Fluid. Luster metallic. Color tin-white. Opaque.

Cinnabar or Sulphide of Mercury.—H. 2. G. 9.0. Luster adamantine, inclining to metallic when dark colored, and to dull in friable varieties. Color cochineal-red to brownish red and lead-gray. Streak scarlet; subtransparent to opaque. Fracture uneven. Powder bright scarlet, being the article known as vermilion. Composition: quicksilver 86.2, sulphur 13.8%.

Metacinnabarite.—A dark to blackish variety of cinnabar. H. 2.5. G. 8.19. Luster metallic to dull. Color steel-gray or blackish lead-gray. Streak nearly black. Opaque.

There are a number of combinations of mercury with selenium, chlorine and iodine which are of small commercial value.

COPPER.—All the following minerals marked with an asterisk (*) are dissolved in nitric acid, and will deposit red metallic copper on polished iron dipped into the solution.

**Native.*—H. 2.5—3. G. 8.84. Luster metallic. Color copper-red. Streak metallic and shining. Ductile and malleable.

**Chalcopyrite or Copper Pyrite.*—H. 3.5—4. G. 4.2. Luster metallic. Color brass-yellow; subject to tarnish and often iridescent. Streak greenish black—a little shining. Opaque. Fracture conchoidal, uneven. Powder greenish-black. Varies in the intensity of the yellow color, when massive, according to the amount of iron pyrite in the ore, becoming paler in proportion. It may be distinguished from iron pyrite also by being much softer and easily scratched with a knife. Composition when pure: copper 34, iron 30, sulphur 36%.

**Cubanite, a Copper Pyrite.*—Similar to chalcopyrite. H. 4.0. G. 4.0. Cleavage rather more distinct than in ordinary pyrite. Massive. Color between bronze and brass-yellow. Streak dark reddish bronze to black. Composition; copper 21, iron 39, sulphur 39% with a little silica.

**Barnhardite, a Copper Pyrite.*—Similar to chalcopyrite. H. 3.5. G. 4.5. Compact, massive. Luster metallic. Color bronze-yellow. Streak grayish black, slightly shining. Fracture conchoidal, uneven. Brittle. Tarnishes easily to peacock tints, or becoming brown. Composition: copper 48, iron 22, sulphur 30%.

**Bornite, Purple, Variegated, Horseflesh or Peacock Copper.*—H. 3.0. G. 4.5—5.5. Massive, structure granular or compact. Luster metallic. Color between copper-red and pinchbeck-brown; tarnishes easily to red, blue and purple tints. Streak and powder pale grayish black. Brittle. Easily scratched with a knife. Approximate composition: copper 58, iron 15, sulphur 27%.

**Chalcocite or Vitreous Copper.*—H. 2.5—3.0. G. 5.6. Luster metallic. Color, streak and powder dark lead-gray; often tarnishes blue or green. Streak sometimes shining. Resembles some silver ores, but gives copper instead of silver when heated on charcoal. Approximate composition: copper 78, iron 2, sulphur 20%.

**Tetrahedrite or Gray Copper.*—H. 3.0—4.5. G.

4.5—5.1. Luster metallic. Color between light flint-gray and iron-black. Streak and powder generally the same, sometimes inclining to brown and cherry-red. Opaque. Rather brittle. Fracture subconchoidal, uneven. This is a very complex ore, carrying not infrequently a valuable amount of silver. Ordinary composition: copper 30 to 40; antimony 15 to 25; sulphur 20 to 25%; with iron, arsenic, zinc, silver, and sometimes mercury. In forty-seven analyses given by Dana, the silver contents range from a trace to 17%, and in one instance 31%, replacing copper or iron.

**Cuprite or Red Oxide of Copper.*—H. 3.5—4.0. G. 5.8—6.0. Luster adamantine or submetallic to earthy. Color red of various shades, particularly cochineal-red; occasionally crimson red by transmitted light. Streak and powder several shades of brownish red. Streak shining. Subtransparent to subtranslucent. Brittle. Fracture subconchoidal, uneven. Composition when pure: copper 88.8, oxygen 11.2%.

**Melaconite or Black Oxide of Copper.*—H. 3.0. G. 6—6.2. Usually massive or as an earthy powder. Luster metallic, and color steel or iron-gray when in thin scales; dull and earthy, with a black or grayish black color, and ordinarily soiling the fingers when massive or powdery. Composition: copper 79.85, oxygen 20.15%.

**Malachite or Green Carbonate of Copper.*—H. 3.5—4. G. 3.7—4. Luster of crystals adamantine, inclining to vitreous; of fibrous varieties, silky; often dull and earthy. Color bright green. Streak paler green. From translucent to opaque. Fracture subconchoidal, uneven. About 62% copper; remainder carbonic acid, oxygen and water.

**Azurite or Blue Carbonate of Copper.*—H. 3.5—4.2. G. 3.5—3.8. Crystallized or massive, also dull and earthy. Luster vitreous. Color various shades of azure blue passing into dark blue. Streak blue, lighter than the color. Fracture conchoidal. Brittle. Partially translucent when crystallized. About 61% copper, remainder carbonic acid, oxygen and water.

Chrysocolla or Copper Silicate.—H. 2.0—4.0. G. 2.1. Slightly crystalline; often opal-like or enamel-like in texture; earthy. In seams or crusts. Sometimes botryoidal. Luster vitreous, shining, earthy, Color green, bluish green passing into sky and turquoise-blue; brown to black when impure. Streak when pure, white. Translucent to opaque. Rather sectile; translucent varieties brittle. Resembles the green carbonate, but is paler green, usually has a coarser texture (is never fibrous), a smoother surface, somewhat waxy luster, and is usually an incrustation upon other ores. About 35% copper; remainder silica, oxygen, water and small amount of iron oxide.

Atacamite or Chloride of Copper.—H. 3.0—3.5. G. 3.7—4.3. Luster adamantine to vitreous. Color various shades of bright green, rather darker than emerald, sometimes blackish green. Streak apple-green. Somewhat translucent. Composition: about 58% copper; remainder oxygen, chlorine and water.

Chalcocite, Sulphate of Copper, Bluestone.—H. 2.5. G. 2.2. Crystallized. Luster vitreous. Color shades of blue from sky to darker; sometimes greenish blue. Streak uncolored. Taste metallic. Brittle. Subtranslucent. About 38% copper; remainder oxygen, sulphuric acid and water. Soluble in water.

(In addition to the foregoing, there are of the rarer copper minerals some 21 combinations with sulphur and arsenic; two with silica; 26 with phosphoric, arsenious or sulphuric acids; and two other carbonates. They are, however, only mineral curiosities. The total number of copper-bearing minerals is about 65.)

Lead—*Native.*—H. 1.5. G. 11.44 when pure. Luster metallic. Color lead-gray. Malleable and ductile.

Galenite, Galena or Lead Sulphide. — H. 2.5. G.

7.2—7.7. Luster metallic. Color and streak lead-gray. Surface of crystals occasionally with bluish tarnish. Fracture flat, subconchoidal or even. Very brittle. Soluble in nitric acid. Yields lead or charcoal. Crystallizes in cubes. Composition: lead 86.6, sulphur 13.4%. The chief ore of lead; usually carries some silver, often some antimony.

Cerussite or Lead Carbonate.—H. 3.0—3.5. G. 5.4—6.4. Crystallized or earthy. Luster adamantine, inclining to vitreous or resinous; sometimes pearly; sometimes submetallic if the colors are dark or from superficial change. Color white, gray, grayish black, sometimes tinged blue or green by traces of copper. Streak uncolored. Fracture conchoidal; very brittle. Subtranslucent; usually opaque when massive. Results from the alteration of galena, which often forms the core of massive varieties. Composition: lead about 70%, remainder oxygen, carbonic acid and impurities.

Pyromorphite or Lead Phosphate.—H. 3.5—4.0. G. 6.5—7.1; when containing lime 5.0—6.5. Luster resinous. Color green, yellow and brown, of different shades; sometimes wax-yellow and fine orange-yellow; also grayish white to milk-white. Streak white, sometimes yellowish. Subtranslucent. Brittle. Fracture subconchoidal, uneven. Occurs only with other ores. Composition: very variable, containing phosphates of lead and lime, chloride of lead, fluoride of lime and arsenic.

Anglesite or Lead Sulphate.—H. 2.75—3. G. 6.2. Luster highly adamantine, sometimes inclining to resinous and vitreous. Color white, tinged yellow, gray, green and sometimes blue. Streak uncolored. Transparent to opaque. Fracture conchoidal. Very brittle. Occurs massive, crystallized or stalactitic. Composition: lead, about 64%; remainder oxygen and sulphuric acid. Easily fusible.

Massicot or Lead Oxide.—H. 2.0. G. 8.0—9.0.

Luster dull. Color between sulphur and orange-yellow, sometimes reddish. Opaque. Massive or earthy. Composition: lead 92.83, oxygen 7.17.

Minium or Red Oxide of Lead.—H. 2.0—3.0. G. 4.6. Powdery. Luster dull or slightly greasy. Color bright red, mixed with yellow; streak orange-yellow. Opaque. Composition: lead 90.66, oxygen 9.34%.

These oxides do not yield much commercial lead, but are given as they often occur as powdery matter in the so-called "chloride" ores of the miners.

(Besides the above there are some 40 non-commercial lead minerals, in which lead is combined with sulphur, antimony, chlorine and oxygen; or with arsenious, antimonious, phosphoric, tungstic, molybdic, vanadic, sulphuric, chromic, selenious and carbonic acids. Several of these, such as the molybdate of lead (wulfenite) and the vanadate of lead, are beautiful waxy minerals of various shades of color from lemon-yellow to red, occurring usually in crystallized forms, making beautiful cabinet specimens but not otherwise specially valuable).

ZINC—*Smithsonite, Drybone or Zinc Carbonate.*—H. 5.0. G. 4—4.4. Occurs crystallized, reniform, botryoidal or stalactitic and as incrustations; also granular and sometimes earthy and powdery. Luster vitreous, inclining to pearly. Color white, often grayish, greenish, brownish white, sometimes green and brown. Streak white. Brittle. Fracture uneven. Approximate composition: zinc 52%, remainder oxygen and carbonic acid. Usually carries small quantities of lead and iron.

Calamine or Zinc Silicate.—H. 4.5—5.0. G. 3.5. Occurs crystallized, stalactitic, botryoidal and fibrous; also massive and granular. Luster vitreous. Color white, sometimes with a delicate blueish or greenish shade; also yellowish to brown. Streak white. Fracture uneven. Brittle. Contains 67.5% oxide of zinc.

(The last two minerals are very much alike in their general appearance, but smithsonite is soluble in muriatic acid, while calamine forms a gelatinous mass under the same conditions, and is soluble in strong caustic potash.)

Zincite or Red Zinc Oxide.—H. 4.0—4.5. G. 5.6. Usually in foliated grains, or coarse particles and masses; also granular. Luster subadamantine. Color orange-yellow to deep red. Streak orange-yellow. Brittle. Fracture uneven. Subtranslucent. Composition: zinc 80.26, oxygen 19.74%, usually containing small quantities of manganese.

Blende, Zincblende, Zinc Sulphide or Blackjack.—H. 3.5—4.0. G. 3.9—4.2. Luster resinous to adamantine. Color brown, yellow, black, red, green; white or yellow when pure. Streak white to reddish brown. Powder nearly white, even in dark varieties. Fracture conchoidal. Brittle. Translucent to opaque. Crystallized or massive. Composition: zinc 67, sulphur 33%. Distinctly clearable.

Franklinite.—H. 5.5—6.5. G. 5.60. Crystallized and massive, either granular or compact. Luster metallic. Color iron-black. Streak dark reddish brown. Opaque. Brittle. Fracture conchoidal. Acts slightly on the magnet. Soluble in muriatic acid. Approximate composition: zinc oxide 18, manganese oxide 16, iron oxide 66%, the proportions of zinc and manganese varying considerably.

Willemite, a Zinc Silicate.—H. 5.5. G. 4.0. Crystallized massive or in grains; sometimes fibrous. Luster resinous. Color whitish or greenish yellow when purest; apple-green, flesh-red, grayish white, yellowish brown; often dark brown when impure. Streak uncolored. Transparent to opaque. Brittle. About 58% zinc; remainder oxygen and silica. Carries small quantities of iron and manganese.

(Besides the above there are some 15 other zinc-bearing minerals of minor importance.)

Iron—*Magnetite or Magnetic Iron Ore.*—H. 5.5—6.5. G. 5.18. Luster metallic to submetallic. Color and streak iron-black. Opaque. Fracture subconchoidal, shining. Brittle. Strongly magnetic, sometimes possessing polarity, like the needle of a compass. Composition: iron 72.4, oxygen 27.6%.

Hematite or Red Oxide of Iron, or Specular Iron Ore.—H. 5.5—6.5. G. 4.2—5.3. Crystallized, columnar, granular, botryoidal and stalactitic, as well as micaceous and compact. Luster of crystals metallic, sometimes brilliantly so; sometimes earthy. Color dark steel-gray or iron-black; when earthy inclined to red. Streak cherry-red or reddish brown. Opaque. Fracture subconchoidal, uneven; sometimes slaty. Sometimes attractable by the magnet. Composition: iron 70, oxygen 30%. Varies considerably in its mode of occurrence and outward appearance. When excessively lustrous and brilliant it is known as "specular iron ore;" when in thin flakes and foliated, "micaceous iron ore;" when compact or fibrous with a reddish brown or iron-black color, "red hematite;" or "clay iron ore" when mixed with earthy impurities, and possessing an earthy appearance and no luster, with not infrequently a deep dull red color.

Limonite, Brown Hematite or Bog Iron Ore.—H. 5.0—5.5. G. 3.6—4.0. Usually in stalactitic and botryoidal forms, having a more or less fibrous structure; also concretionary, massive and occasionally earthy. Luster silky, often submetallic; sometimes dull and earthy. Color of surface of fracture various shades of brown, commonly dark, and none bright; sometimes with a nearly black varnish-like exterior; when earthy, brownish yellow to yellow ocher. Streak yellowish brown. Composition: differs from hematite in carrying about 16% of water. The term "bog" ore is applied to the modern formations found in marshy places, which usually contain manganese as an impurity.

(The three foregoing minerals produce the bulk of the iron of commerce. They can readily be distinguished from each other by the streak, which is respectively black, red or yellowish brown. The following minerals, while strictly iron ores, are valuable chiefly for their other constituents such as zinc, chrome, sulphur, arsenic, etc., and the precious metals found in their company.)

Franklinite.—Described with the zinc minerals.

Siderite, Spathic Iron or Iron Carbonate.—H. 3.5—4.5. G. 3.8. Occurs crystallized; also in botryoidal and globular forms, somewhat fibrous within, occasionally silky. Often massive. Luster vitreous, more or less pearly. Color ash-gray, greenish gray, also brown and reddish brown, rarely green; sometimes white. Fracture uneven. Brittle. Streak white. Composition: oxide of iron 62.1, carbonic acid 37.9%. Usually carries manganese, magnesia and lime as impurities. A sparry looking ore, distinctly cleavable, turning brown to black on exposure. A good ore of iron when abundant.

Pyrite, Iron Pyrite or Iron Sulphide.—H. 6.0—6.5. G. 4.8—5.2. Crystallized or massive. Luster metallic, splendent to glistening. Color a pale brass-yellow nearly uniform. Streak greenish or brownish black. Opaque. Fracture conchoidal, uneven. Brittle. Strikes fire with steel. Composition (omitting impurities): iron 46.7, sulphur 53.3%. Crystallizes in cubes. The pyrites of gold regions usually carry gold, which may be occasionally seen projecting from the faces of the crystals. Other varieties carry small quantities of nickel, cobalt, silver or tin. Pyrite is one of the commonest of minerals, and aside from the precious metals it contains, is chiefly used in the manufacture of sulphuric acid, the acid being produced more cheaply by this method than from sulphur direct.

Marcasite.—Similar to ordinary pyrite in composition, but differs in the form of the crystals, which are often flat and crested. H. 6.0—6.5. G. 4.8. Crystallized, globular or reniform; often massive or granular. Luster metallic. Color pale bronze-yellow, sometimes inclined to green or gray. Streak grayish or brownish black. Fracture uneven. Brittle. Often carries gold.

Pyrrhotite or Magnetic Iron Pyrite.—H. 3.5—4.5. G. 4.6. Commonly massive or granular. Luster metallic. Color between bronze-yellow and copper-red, and tarnishing easily. Streak dark grayish black. Brittle. Magnetic, being attracted in fine powder by a magnet, when not affecting a magnetic needle. This ore is valuable chiefly for the nickel it contains, which in some cases ranges from 3 to 5%, and furnishes the bulk of the nickel of commerce. Composition: iron 60.5, sulphur 39.5%.

Mispickel or Arsenical Pyrites.—H. 5.5—6.0. G. 6.0—6.4. Luster metallic. Color silver-white, inclining to steel-gray. Streak dark grayish black. Fracture uneven. Brittle. Composition: iron 34.4, sulphur 19.6, arsenic 46.0%. This mineral is the source of the bulk of the arsenic of commerce, as well as cobalt, and is associated with and frequently carries silver and gold in small quantities.

Ilmenite or Titanic Iron.—H. 5.0—6.0. G. 4.5—5.0. Massive or as loose grains in sand. Luster submetallic. Color iron-black. Streak submetallic, powder black to brownish red. Opaque. Fracture conchoidal. Slightly influencing the magnetic needle. Composition: oxide of iron with varying amounts of titanium, 3 to 30%. Not a true iron ore.

(Besides the above there are nearly 40 other non-commercial iron minerals, consisting of silicates, sulphates, phosphates, arsenates, carbonates, etc.)

MANGANESE—*Manganite.*—H. 4.0. G. 4.3. Occurs crystallized, stalactitic, seldom granular. Luster submetallic. Color dark steel-gray to iron-black. Streak and powder reddish brown, sometimes nearly black. Opaque. Fracture uneven. Composition: manganese 62.5, oxygen 27.3, water 10.2%.

Pyrolusite, Manganese Dioxide.—H. 2.0—2.5. G. 4.8. Luster metallic. Color iron-black, dark steel-gray, sometimes bluish. Streak black or bluish black, sometimes submetallic. Opaque. Rather brittle. Composition: manganese 63.3, oxygen 36.7%. One of the most important ores of manganese; it is easily distinguished from psilomelane by its inferior hardness, and being usually crystalline; from manganite, by the color of the streak and powder. Often soils the hands.

Psilomelane or Black Manganese Oxide.—H. 5.0—6.0. G. 3.7—4.7. Occurs massive and botryoidal, reniform and stalactitic. Luster submetallic. Color iron-black, passing into dark steel-gray. Streak brownish black, shining. Opaque. Composition: an oxide of manganese (variable in quantity) with oxide of barium, and several other impurities in minor quantities. Not being found crystallized the exact nature of the species is yet doubtful.

Wad or Bog Manganese.—The ores included under this name occur in amorphous and reniform masses, either earthy or compact, and sometimes incrusting. They are mixtures of different oxides and cannot be considered a distinct species. H. 0.5—6.0. G. 3.0—4.2, often loosely aggregated and feeling very light to the hand. Color dull black, bluish or brownish black. Composition: manganese oxide, with iron, barium, cobalt and copper oxides in varying proportions.

(There are, in addition to the above, some 20 other unimportant manganese minerals.)

TIN—*Cassiterite or Tin Oxide.*—H. 6.0—7.0. G. 6.4—7.1. Occurs crystallized and massive. Luster adamantine, and crystals usually splendent. Brown or black; sometimes red, gray, white or yellow.

Streak white, grayish, brownish. Crystals nearly transparent, sometimes opaque when massive. Fracture subconchoidal, uneven. Brittle. Composition: tin 78.67, oxygen 21.33%. Furnishes the tin of commerce. Does not look much like a metallic ore and is often confounded with the valueless mineral epidote. Only slightly acted on by acids. Detected usually by its weight.

Stream tin is nothing but the ore in the state of sand, as it occurs in the gravel derived from the decomposition of the rocks carrying the ore.

Wood tin is an irony-looking mineral, a variety of cassiterite, very heavy, occurring in rounded, botryoidal or reniform shapes, concentric in structure, and radiated fibrous internally, although very compact, with the color brownish, and the rings of mixed shades, looking somewhat like dry wood. Occurs in the gravel of streams.

Stannite or Tin Sulphide.—H. 4. G. 4.4. Commonly massive, granulated, or disseminated through the rock in small grains. Luster metallic. Color steel-gray to iron-black, the former when pure. Streak blackish. When copper pyrite is present in the ore the color is often yellowish. Opaque. Brittle. Fracture uneven. Composition: tin 27.2, copper 29.3, sulphur 29.6, iron 6.5, zinc 7.5%. It frequently has the appearance of bronze or bell metal, and is hence called "bell metal" ore.

(Tin is found in small quantities as a component of several other ores.)

CHROMIUM—*Chromite or Chrome Iron.*—H. 5.5. G. 4.4. Usually occurs massive; structure fine granular or compact. Luster submetallic. Streak brown. Color between iron-black and brownish black. Opaque. Brittle. Fracture uneven. Sometimes magnetic. Composition: oxide of chromium 68, oxide of iron 32%. Usually with alumina and silica as impurities when massive. The ore has usually green incrustations in the seams which distinguish it readily from the other iron ores. Affords the chrome of commerce, not being used as an iron ore.

(Several other ores contain chromium, but not in available quantities.)

NICKEL—*Pyrrhotite or Magnetic Iron Pyrite.* (See iron ores).—The chief source of nickel.

Niccolite, Copper-nickel or Arsenical Nickel.—Usually massive, no visible structure; also reniform and arborescent. H. 5.0—5.5. G. 7.5. Luster metallic. Color pale copper-red, with a gray to blackish tarnish. Streak pale brownish black. Opaque. Brittle. Composition: nickel 44.1, arsenic 55.9%; sometimes part of the arsenic is replaced by antimony, with small quantities of lead, cobalt and sulphur. Resembles pyrrhotite or magnetic iron pyrite, but is not magnetic.

Gersdorffite or Nickel Glance—Crystallization cubic; also lamellar and granular massive. H. 5.5. G. 5.6—6.9. Luster metallic. Color silver-white to steel-gray, often tarnished gray or grayish black. Streak grayish black. Fracture uneven. Composition: nickel 35.1, arsenic 45.5, sulphur 19.4%, with part of the nickel often replaced with iron or cobalt. Out of 18 analyses the nickel ranges from 19 to 40%.

Genthite or Silicate of Nickel.—Not crystallized, occurring usually as incrustations. H. 3.4. G. 2.4. Luster resinous. Color pale apple-green or yellowish. Streak greenish white. Translucent to opaque. An unimportant compound of nickel and silica, often associated with chrome iron.

Annabergite or Nickel Ocher.—In slender crystals; also massive and disseminated through the gangue. Soft. Color fine apple-green. Streak greenish white. Fracture uneven or earthy. A compound of nickel and arsenic. Unimportant.

Zaratite or Emerald Nickel.—Incrusting, also massive and compact. H. 3.0—3.2. G. 2.6. Luster vitreous. Color emerald-green. Streak pale green. Translucent. Brittle. A carbonate of nickel. Unimportant.

(The last three minerals, with several others of similar green color, include the green minerals found in nickel ores, and which usually attract the attention of the prospector from their bright color, resembling the green carbonate of copper.)

Cobalt—*Mispickel or Arsenical Pyrite.*—(Described under iron ores).

Smaltite, Smaltine or Cobalt Arsenide.—Crystallized and massive. H. 5.5—6.0. G. 6.4—7.2. Luster metallic. Color tin-white, inclining when massive to steel-gray, sometimes iridescent or tarnished. Streak grayish black. Fracture granular and uneven. Brittle. Composition: cobalt 9.4, nickel 9.5, iron 9, and arsenic 72.1%. In some varieties the nickel is absent and the cobalt runs up to 23% or over, replacing the nickel and part of the iron.

Cobaltite, Cobaltine or Cobalt Glance.—Crystallized, massive, granular and compact. H. 5.5. G. 6.0—6.3. Luster metallic. Color silver-white, inclined to red; also steel-gray with a violet tinge, or grayish black when containing much iron. Streak grayish black. Fracture uneven and lamellar. Brittle. Composition: cobalt 35.5, arsenic 45.2, sulphur 19.3%. The cobalt is sometimes largely replaced by the iron, in which case the percentage may run down as low as 9%.

Erythrite, Cobalt Bloom or Red Cobalt.—Crystallized, also in globular and reniform shapes; also as incrustations and powdery. H. 1.5—2.5. G. 2.9. Luster pearly to vitreous; also dull and earthy. Color crimson and peach-red, sometimes pearl to greenish gray; red tints incline to blue. Streak a little paler than the color; the dry powder deep lavender-blue. Subtranslucent. Sectile. Composition: oxide of cobalt 37.55, arsenic acid 38.43, and water 24.02 %. The delicate peach-red of this mineral is very characteristic.

(The above are the chief cobalt ores. There are a few others of less importance. Cobalt is a frequent associate in nickel ores, and both nickel and cobalt often occur in copper ores.)

ANTIMONY—*Stibnite, Antimony Sulphide, Gray Antimony or Antimony Glance.*—Occurs crystallized or massive. When massive, not infrequently more or less fibrous or radiated. H. 2.0. G. 4.5. Luster metallic. Color and streak lead-gray, inclining to steel-gray; liable to blackish tarnish. Fracture small subconchoidal. Sectile. Composition: antimony 71.8, sulphur 28.2%. Resembles some manganese ores, but is distinguished by being easily fusible. Furnishes the bulk of the antimony of commerce.

(Native antimony and the oxides do not occur in quantities to make them valuable as ores of the metal.)

ARSENIC—*Realgar or Red Sulphide of Arsenic.*—Crystallized or granular and compact. H. 1.5—2.0. G. 3.5. Luster resinous. Color aurora-red or orange-yellow. Streak similar. Translucent. Fracture uneven. Composition: arsenic 70.1, sulphur 29.9%.

Orpiment or Yellow Sulphide of Arsenic.—Crystallized or massive. H. 1.5. G. 3.5. Luster pearly on the faces of cleavage, elsewhere resinous. Color several shades of lemon-yellow. Streak a little paler than the color. Subtranslucent. Subsectile. Composition: arsenic 61, sulphur 39%.

(The above minerals do not occur in large quantities. Artificially-made orpiment is used as a paint. Commercial arsenic is usually a by-product from the working of mispickel and the ores of nickel and cobalt.)

BISMUTH—*Native.*—Crystallized, foliated or granular. H. 2.0.—2.5. G. 9.7. Luster metallic. Streak and color silver-white, with a reddish hue; subject to tarnish. Opaque. Sectile. Brittle when cold, but somewhat malleable when heated. Very fusible.

(Bismuth occurs in some dozen combinations, but usually in small quantities with other compounds in mineral veins. The native metal furnishes the bulk of the commercial article.)

TITANIUM—*Rutile or Titanium Oxide.*—Crystallized or massive. H. 6.0—6.5. G. 4.2. Luster metallic-adamantine. Color reddish brown, passing into red; sometimes yellowish, bluish, violet, black; rarely grass-green. Streak pale brown. Subtransparent to opaque. Fracture subconchoidal, uneven. Brittle. Composition: titanium 61, oxygen 39%.

(Ilmenite, titanic iron, etc., are described with the iron ores.)

TUNGSTEN—*Wolframite, Tungstate of Iron.*—Crystallized or massive. H. 5.0—5.5. G. 7.1—7.5. Luster submetallic. Color dark grayish or brownish black. Streak dark reddish brown to black. Opaque. Composition: tungstic acid 76%, in combination with iron and manganese in variable quantities.

(The tungstates of lead and lime are of minor importance.)

CADMIUM—*Greenockite or Cadmium Sulphide.*—H. 3.0—3.5. G. 4.8. Luster adamantine. Color honey-yellow, citron-yellow, orange-yellow, bronze-yellow. Streak and powder between orange-yellow and brick-red. Nearly transparent. Composition: cadmium 77.7, sulphur 22.3%.

MOLYBDENUM—*Molybdenite or Molybdenum Sulphide.*—Usually foliated, massive, or in scales; also fine granular. H. 1—1.5, being easily impressed by the nail. G. 4.4—4.8. Luster metallic. Color pure lead-gray. Streak similar to color, slightly inclined to green. Opaque. Laminæ very flexible, but not elastic. Sectile, and almost malleable. Fine gray mark on paper. Composition: molybdenum 59, sulphur 41%. Resembles graphite, but is decomposed by nitric acid.

URANIUM—*Uraninite, Oxide of Uranium, Pitchblende.*—Usually massive and botryoidal; also in grains. H. 5.5. G. 6.4—8. Luster submetallic to greasy or pitchlike, and dull. Color grayish, greenish, brownish, velvet-black. Streak brownish black, grayish, olive green, a little shining. Opaque. Fracture conchoidal, uneven.

Autunite, Uranium Phosphate.—H. 2.0—2.5. G. 3.0—3.2. Luster pearly to subadamantine. Color citron-yellow to sulphur-yellow. Streak yellowish. Translucent.

Torbernite, Uranium Phosphate, Copper Uraninite—H. 2.0—2.5. G. 3.5. Luster pearly to subadamantine. Color emerald and grass-green, and sometimes leek, apple and siskin-green. Streak somewhat paler than the color. Translucent. Sectile.

(The above are usually associated with silver ores.)

VANADIUM—*Vanadinite or Vanadate of Lead.*—Usually in implanted globules or incrustations. H. 2.75—3.0. G. 6.6—7.2. Luster of surfaces of fracture resinous. Color light brownish yellow, straw-yellow, reddish brown. Streak white or yellowish. Subtranslucent to opaque. Fracture uneven. Brittle.

CHAPTER XIV.

USEFUL EARTHY MINERALS, ETC.

I.—INSOLUBLE.

The value of the deposits of the various minerals grouped under this heading depends on the purity of the article, the quantities in which it is found, the cost of labor and the facilities of transportation, defective conditions on any one of these points taking the deposit out of the list of commercially available propositions, as the market value per pound of most of them is exceedingly low, and the number of localities in which they are found proportionally great; while for some of them there is only a limited demand.

Asbestos is one of the few well-known minerals, its white or greenish white or bluish fibrous appearance being so characteristic as to be familiar to all prospectors. In silkiness it may range from long flexible fibers like flax to brittle earthy masses. It is a widely diseminated mineral associated with rocks which contain large quantities of hornblende or augite, it being one of the products of the metamorphism or decomposition of these rocks, and is consequently common among the hornblende-schists and serpentines, which also produce chrome iron and soapstone, all three minerals usually occurring in the same locality.

The great difficulty connected with the mining of this substance is the large quantity of material which must be handled to secure any quantity of asbestos, as it usually occurs in small threads, stringers, seams or pockets, irregularly scattered through the containing rock, so that it must be worked in open quarries, and the asbestos sorted by hand from the rock. It varies greatly in character, from short earthy fibers which are brittle and separate with difficulty, the structure running across the seam and not parallel to it, up to long fine silky threads of a pearly white color very much resembling flax. The term "amianthus" is applied to this last variety. The longer and more flexible the fiber, the more valuable the mineral. Asbestos is infusible, but the common notion that articles made of it can be thrown into the fire and thus cleansed of accumulated dirt, is erroneous, as at a red heat the fibers lose their flexibility and become brittle.

It is used in the making of fireproof paints, roofing, piston packing, valve packing, covering steam pipes and boilers, fireproof cement, sheet and rolled millboard, flooring felt, textile fabrics, etc., being often used in combination with hair felts and other substances. It derives its value for these purposes from its indestructibility in ordinary fires, and the resistance it offers to the radiation of heat, a property which it possesses in common with wool, cotton, feathers and other substances which cannot be safely used in the presence of high temperatures. For fireproof paints the length of the fiber is not essential, but is a desirable quality for packings and the covering of steam pipes and boilers, while it is essential in all textile fabrics.

Asbestos being associated with well-marked belts of rock the prospector should familiarize himself with the character and appearance of these rocks at any locality where he may find asbestos, and having done so, trace this belt along the mountain range, as it will be comparatively useless to spend time on the rock strata which lie either above or below it, excepting so far as they may help him to locate the position of the asbestos belt, where it is covered up by earth or debris, or not otherwise traceable.

Asphaltum.—Amorphous or without crystalline structure. G. 1—1.8, sometimes higher from impurities. Luster like that of black pitch. Color brownish black and black. Odor bituminous. Melts usually at about 194° to 212°, and burns with a bright flame. The more solid kinds graduate into mineral tar, and through this there is a gradation to petroleum. Asphaltum appears to be a residual deposit, derived from the evaporation of petroleum products. In the United States the production is confined to the Western States, the deposits (which are always found on the surface or near it) occurring in California, Utah and Colorado, being either fairly pure or mixed with earthy matter. The principal source of foreign supply is the island of Trinidad in the West Indies, where, at a place called La Brea, there occurs an asphalt lake of about 100 acres in extent, the product of which is shipped to Europe and the Atlantic seaboard of the United States. In Europe a limestone, naturally and evenly impregnated with bitumen (or asphalt), is largely used with good results.

It is used for many purposes where a surface impermeable to water is required, combined with toughness. Natural asphalt rock, and asphaltum in combination with other materials, are used in the surfacing of streets and sidewalks, and the finishing of roofs. Asphaltum makes a durable coating for water-pipes.

Barytes.—This mineral, also called "heavy spar," because of its great weight, is a sulphate of barium. Its specific gravity is about 4.5, while that of limestone is only 2.5. It is an earthy mineral resembling limestone, ranging in color from white through shades of yellow, gray, red and brown to dark brown, according to the amount of impurities present, but when crystallized has a vitreous or glassy luster and a white streak when scratched. Some samples when rubbed give off a fetid odor. It is not affected by acids, and may thus be readily distinguished from the limestones with which it may be associated, as well as by its weight, which is much greater than any of the similar minerals, such as gypsum and carbonate of magnesia.

It occurs in veins and beds associated with limestones, sandstones and trap rocks, and not infrequently forms the gangue, wholly or in part, of metallic veins, especially those of lead. The mineral is widely distributed, occurring in beds in sandstones in Connecticut, and at Isle Royal, Lake Superior; in beds in limestone in Iowa and New York; and in limestone and associated with lead ores in Missouri, North Carolina, Tennessee and Virginia. On the northern shores of Lake Superior veins occur in trap rocks.

Barytes is used very extensively in the arts, but almost altogether for purposes of adulteration, for which its leading use (about 90%) is in replacing to a greater or less extent white lead in paint. The claim is made that a mixture of one-third white lead, one-third oxide of zinc and one-third "floated" barytes makes a better paint than pure white lead. It is also employed as a "filling" for general purposes, in pulps and in making putty and pottery. The value of ground barytes being not much over one cent per pound it is evident that only the purer deposits and those best located for dressing and transportation can be made available. It must be free from grains of quartz, iron rust and other impurities, and of a good white color.

Bauxite.—G. 2.5. Color whitish, grayish to yellow ocher, brown and red. Occurs in round concretionary disseminated grains; also massive oölitic; and earthy, clay-like. Bauxite occurs in the United States in the Coosa Valley, Georgia and Alabama, in clay beds along the line of an extensive fault in limestone rocks, the beds having apparently accumulated in depressions eroded along this fault, no eruptive rocks being present; also in Arkansas, in regularly stratified beds near the contact with eruptive rocks, and in France as a residual deposit from the decay of basaltic rocks. In Styria, a deposit 12 ft. thick occurs at the junction of the Triassic and Jurassic formations. The favorite associations appear to be limestone and eruptive rocks.

From the large amount of alumina present in bauxite it forms a valuable source of aluminum, and the purer varieties are largely used in the production of that metal, being known as "aluminum ore." On the Continent of Europe the product of the quarries at Baux in France, from which the mineral takes its name, is also used as a flux in iron smelting.

It is difficult to give a concise description of this valuable ore, but the following extracts from "Mineral Industry," Vol. II., will probably be sufficient to call attention to its chief peculiarities, and to suggest the desirability of submitting suspected samples to analysis: "Bauxite has few specially distinctive characters except its usual pisolitic (pea-like) or concretionary character, which perhaps accounts for its having been so long overlooked, and for the comparatively few localities where it is known to occur. The red variety of bauxite was thought to be pisolitic iron ore until its true character was shown by analysis.

"Bauxite is usually a concretionary or pisolitic mineral, though sometimes it is a hard, compact, homogeneous, fine-grained rock, commonly oölitic (made up of round egg-like fragments), and sometimes an earthy, clay-like material. It may therefore be hard, or soft and friable, compact or porous, but the best grades are hard and have a metallic ring. The concretions vary in size from small peas to large bowlders, which are cemented together by fine-grained hard bauxite, bauxite clay or silicious material. In nearly every case, however, the concretions or nodules are better mineral than the cementing material. The concretions, also, are usually harder than the cementing material, especially in the surface ores.

"On the surface, bauxite beds are generally marked by hard, rough bowlders or loose nodules and pebbles in the top soil. Below the surface, however, the nodular and pebbly ores are often comparatively soft and crumbly, and the compact oölitic and fine-grained ores are sometimes a soft powder.

"Bauxite varies in color from almost pure white to a deep red or black. It is also of cream and pearl-white color, grayish, yellowish, amber, pinkish, and speckled or mottled. . . . These colors often shade into one another, sometimes suddenly and sometimes gradually, and it is seldom, if ever, that a bank or deposit is wholly or uniformly of one color."

Clays are essentially silicates of alumina with combined water (hydrated aluminum silicates), but vary immensely in composition, not only from differences in the amount of silica and alumina present, but also from the presence of impurities such as lime, soda, potash, sand, magnesia and iron oxides which affect the fusibility of the mass. It is these differences which render them suitable for different purposes. For commercial use they may be classed as fire clays, pottery and kaolin clays and brick clays.

Fire Clay.—The presence of alkaline matter and iron oxides tend to promote vitrification, and an excess of alumina causes shrinkage in burning, so that a good fire clay should consist practically of silica and alumina, with the smallest amount possible of iron and alkali, it being possible to counteract the contractibility or shrinkage by the addition of quartz sand. The presence of an excess of alumina, however, renders the clay more tenacious and plastic, but this is not essential in a firebrick, though desirable in pottery clays. The following table shows the relative composition of five English fire clays and 14 American samples:

ANALYSES OF FIRE CLAYS.

	Silica.	Alumina.	Water.	Iron Oxides.	Alkalies.	Magnesia.	Lime.
	%	%	%	%	%	%	%
English...........	66.80	21.70	6.66	2.60	1.29	0.32	0.49
American.........	48.38	38.81	15.29	1.19	0.68	0.06	0.02

The English examples are all from the older coal measures and show as compared with more recent clays a much less percentage of alumina; the American samples are from the clay deposits of New Jersey, Pennsylvania, Maryland, Illinois and Missouri. The great essential in fire clays is that they should not contain over 4% of impurities.

Brick Clays.—From the most refractory all grades occur to those which fuse or vitrify with the greatest ease, and the adaptability of any deposit to a special purpose is best determined by trial, it being, however, important, if the bed is to be worked on a large scale, to ascertain if its composition is uniform throughout. For brickmaking, the presence of lime is a detriment, as if insufficiently ground the nodules of lime, having been converted into quicklime while burning, will afterward absorb water, expand in the process and crack the brick.

Pottery Clays.—Kaolin, which when pure is composed of silica 46.3, alumina 39.8 and water 13.9%, is the result of the decomposition of the feldspars in granite rocks and porphyries, and furnishes the material for the finer grades of chinaware and porcelain, after a thorough preparation by washing and settling, until the residue is an impalpable creamy paste. Very large areas of these rocks, in some localities, have been thus decomposed; but the presence of an excess of iron oxides, which would color the finished product, or other impurities, render the bulk of them suitable only for inferior grades of chinaware.

CORUNDUM AND EMERY.—"H. 9. G. 3 to 4.1. When crystallized the luster is vitreous; color blue, red, yellow, brown, gray and nearly white; streak uncolored. Transparent to translucent. Fracture conchoidal, uneven. Exceedingly tough when compact." (Dana.) "These substances (corundum or sapphire and emery), so nearly allied mineralogically, are sharply distinguished in the trade. Mineralogically the former is a nearly pure alumina, while the latter contains a large proportion, from 20 to 33%, of iron oxide. The trade distinctions are somewhat as follows: Emery is always black, while corundum is of various colors, though more frequently gray and never black. It is much harder than emery (taking the sapphire at 100, Dana gives the abrasive power of corundum at 62 and emery 46) and sharper, cuts deeper and more rapidly, but is on the other hand more brittle and consequently less durable." (Gannett.) These minerals are associated with crystalline rocks such as granular limestone, gneiss, granite, mica and chlorite schists. The emery of Asia Minor occurs in granular limestone. All of the corundum used in the United States is of domestic production, from localities in the Appalachian range, extending from Maine to Georgia, and from some western points as Colorado and other States; but these latter are recent developments, and as yet comparatively small producers. Both corundum and emery are chiefly used for grinding and polishing metals and other hard substances.

CRYOLITE.—"H. 2.5. G. 2.95. Luster vitreous or glassy; slightly pearly on some faces of the crystals. Colors now white, sometimes reddish or brownish to brick-red and even black. Subtransparent; immersion in water increases the transparency. Brittle. Fusible in the flame of a candle. Occurs sparingly in the crystal beds near Pike's Peak, Colo.; but is a rare mineral in the United States. The principal foreign locality is at Evigtok, in West Greenland, where it constitutes a large bed or vein in gneiss, and contains galena, zincblende, carbonate of iron, iron pyrite, arsenical pyrite, fluorspar, tin ore and columtite, all of them frequently in fine crystals. Taylor states that the cryolite is not white, except within 10 to 15 ft. of the surface, and that below this it becomes dark-colored and even black. The contained ores and other minerals are most abundant near the junction with the gneiss."

Cryolite is a compound of fluorine, alumina and soda, and is used in the manufacture of the latter article, and also in the production of aluminum (along with bauxite), as well as an ingredient of a white, porcelain-like glass. The main supply is at present derived from the Greenland deposits.

FLUORSPAR.—H. 4. Specific gravity 3.2. Streak white. Fluorspar is a glassy-looking mineral, nearly transparent when pale in color, which crystallizes in square cubes. In color it has a wide range, varying from white to yellow, green, blue, violet and red, the commonest colors being white, pale green and violet. The green varieties look very much like bottle glass. When crystallized, the specimens are very beautiful. It occurs in veins either by itself or as the gangue of lead ores, and as beds or masses in limestones, and is found in varying quantities in almost every State of the Union, but not very frequently in workable quantities. While apparently preferably found associated with limestones, it also occurs in veins in granite, gneiss, sandstones and slates, and as a component of such rocks as rhyolite. Fluorspar is used as a flux in some lead and copper smelting operations, in the manufacture of hydrofluoric acid for etching on glass and seals, as a glaze for pottery, and in the production of aluminum.

Graphite or Plumbago (also often called "black-lead").—A soft steel-gray to black mineral with a metallic luster, and greasy feel; opaque; streak black and shining; can be easily cut with a knife and soils the fingers in handling. It is nearly pure carbon (containing no lead as the common name might imply) and resembles no other mineral except molybdenite, which is lustrous lead-gray in color, with a streak inclining to gray, and marks paper gray instead of the pure black of graphite. Graphite occurs in veins, beds, and disseminated in fine particles through some schistose rocks, called graphitic schists. It is confined to the older rocks, but is a widely disseminated mineral. The veins are true fissures in gneissoid and eruptive rocks. The veins produce the soft crystalline and foliated forms, which are the purest and most valuable. Graphite also occurs in beds, but is usually more or less contaminated with impurities, and less valuable commercially, the ores generally being of such a character that purification is impossible. The graphitic schists which are found in the same regions as the veins are metamorphosed sandstones or slates with foliated graphite very evenly distributed through the mass in small flakes, giving a deep black color to many of the slates. The localities where graphite occurs in more or less quantity are very numerous, but from this fact it is only those which produce the very best kinds which have any commercial value.

American graphites come into competition with those of Canada and Ceylon. In the latter island the mineral occurs in veins of immense size and great purity and is shipped without any preparation except sizing. Graphite is used in the manufacture of crucibles, stove-polish, lubricating compounds, foundry-facings, lead pencils, packing, paint and electrical supplies, and also in electrotyping, etc. The first three industries consume 75% of the production, the consumption for pencils being only about 3%.

GYPSUM (SULPHATE OF LIME).—H. 1.5—2.0. G. 2.3 for pure crystals. Luster shiny, pearly to vitreous. Massive varieties often glistening, sometimes dull, earthy. Color usually white, sometimes gray, flesh-red, honey-yellow, ocher-yellow, blue; impure varieties often black, brown, red or reddish brown. Streak white. Transparent to opaque. In addition to the above characters it may be mentioned that the crystals are flat or tubular, and that the crystallized varieties known as selenite split readily into thin transparent sheets which are flexible, but not elastic; and that when burned it forms plaster of paris, which hardens promptly on being mixed with water, thus differing from ordinary limestones, which also require a much higher temperature in burning.

Gypsum in one or other of its forms is found in large quantities in most of the States of the Union, in connection with deposits of rock salt, being impregnated with sulphur. The association with rock salt is due to the fact that gypsum is a product of the evaporation of sea water; as well as a product of lime-bearing minerals under the action of decaying iron pyrite. This latter action explains its presence in vein matter and in clay beds in a crystallized form. The name plaster of paris is in allusion to the large production of that article at the gypsum beds of Montmartre near Paris, which are mined on a very extensive scale. "Selenite" is the term applied to the transparent crystallized varieties; when silky and fibrous it is known as "satin spar;" fine-grained varieties, delicately tinted and suitable for the manufacture of ornaments, are known as alabaster or onyx, the latter term being erroneously employed. "The principal use to which gypsum is devoted is an agricultural one. The ground rock, or land plaster, is applied as a top dressing to the soil; and although it does not enter directly to any extent into the composition of plants, it has still an extremely beneficial action upon plant life and growth, from the chemical changes which it induces in the soil. Stucco, plaster of paris, or calcined gypsum, is used for making cornices, friezes and other forms of interior decorations, the finishing of walls, etc. The finer grades are used in taking casts of natural objects, making models, etc."

INFUSORIAL EARTH, tripoli, or mountain meal, consists entirely when pure of the silicious skeletons of microscopic vegetable organisms called diatoms, and in this respect differs from chalk, which is similarly made up of the infinitely minute shells of animal organisms called foraminifera, but which are composed of lime instead of silica, and consequently effervesce when treated with acids, which is not the case with infusorial earths. Deposits of infusorial earth often cover many square miles and may be pure white and chalky in appearance, like the deposit at Red Mountain, north of Virginia City, Nev., the origin of which must be of comparatively recent date, geologically speaking, as the writer has found in it remains of insects now living in the neighborhood; the deposit at Santa Fiora, Tuscany, consists of a grayish white, loose, earthy meal, and similar material is also found in Spain. Tripoli, or polishing slate, is a fragile, slaty or thinly laminated variety, often much mixed with impurities such as clay, magnesia, etc. Other considerable deposits of differing character are found in Nevada and California. Infusorial earth was at one time largely used as an absorbent in the manufacture of giant powder, but has given place to wood pulp of late years, and is now used almost exclusively to give body to soap, and as a polishing powder. The Red Mountain deposit is simply pulverized and put on the market under the name of electro-silicon, being an exceptionally pure article of silica, showing less than half of 1% of impurities. The demand is limited.

The harder, compact varieties, such as that found in Newton County, Mo., are quarried and shaped into water filters, which are of excellent quality.

Limestone, in its various forms of ordinary stone or marble is too well known to need further description, and is found abundantly in all the States of the Union. The production of quicklime for building purposes amounts to over 60,000,000 bbl. of 200 lb. each, involving the quarrying of over 12,000,000 tons of rock. This does not include that mined as flux for smelting operations, or quarried as building stone. Provided the lime is free from iron in appreciable quantities the color is of little consequence to the burner, as it disappears under the action of heat, and the product of blue limestone and white marble are not to be distinguished from each other. The presence of iron is objectionable, as it would rust in the mortar and when leached out by rain would stain the building. Magnesian limestones, or dolomite, have usually tinges of yellow, buff or drab, instead of tending to blue tints, and are used in the manufacture of hydraulic or quick setting cements. The value of marble depends largely on the fineness of the grain and the purity, beauty or peculiarity of the coloring, but with all the good qualities at a maximum the deposit may be valueless if unfortunately situated as regards cheap transportation.

It is desirable that limestones used as flux for iron smelting should be free from phosphorus, just as the same quality is desirable in the fuel, because nearly the whole of the phosphorus present, both in the ore, fuel and flux, will be concentrated in the pig iron produced, decreasing its value materially and rendering it totally unfitted for many purposes, especially the production of Bessemer steel, which requires a practical absence of phosphorus in all the material which goes into the blast furnace.

Impurities in the limestone used for making quicklime, especially silica and alumina, have a tendency to vitrify, or melt into more or less glassy particles, during the process of burning, and the product does not slake into as smooth a paste as that produced from purer rocks, but these "poor" limes are said to make a mortar which is able to resist the destructive action of atmospheric agencies better than the "rich" ones, being apparently less soluble in rain water.

Limestone is so abundant a material in nature that we need in this place call attention only to one particular variety, used for lithographic purposes. There is no absolute chemical composition, analyses showing a varying amount of carbonate of magnesium (2.50 to 17.32%) along with the carbonate of lime and various small quantities of other substances. The stones in use are usually shades of drab or gray, and they must be absolutely of uniform composition throughout, somewhat porous and soft enough to work easily under the engraver's tool, but tough enough to bear considerable pressure in the printing press. Such a stone will be very fine-grained and break with a shell-like (conchoidal) fracture. Only actual trial will prove the suitability of a particular stone, but localities which can produce good stones of large size, say 40 by 60 in., are extremely valuable.

Magnesite is a carbonate of magnesium, white in color when pure, but shading into brown when iron is present. It is moderately hard, tough, and breaks with flat conchoidal surfaces, and is somewhat heavier than quartz. It looks something like limestone, but is only feebly acted on by cold acids, though when powdered it dissolves readily in warm muriatic acid with effervescence. It is usually found in connection with serpentine rocks, talcose schists, and consequently with soapstone and asbestos, all of which are magnesian products. The ore is used chiefly in the manufacture of paper from wood pulp, and as a refractory lining for furnaces using the basic process for steel making.

Mica ranges in color from white and very pale greenish and brownish shades through dark brown to black. It splits easily into very thin sheets, sometimes as many as 160 to the inch, which in the paler colored varieties are transparent, but only partially so in the dark ones. These thin plates or laminæ are flexible and not easily fusible, and in this respect differ from crystallized gypsum or sulphate of lime, which while separating into very thin flakes is not flexible, and when heated crumbles into a fine powder, the plaster of paris of commerce. The two are often mistaken for each other and confounded under the common name of "isinglass," which is really fish glue or a compound prepared from gelatine, and an organic product. When scratched or crushed the result is a whitish powder even in the case of the dark varieties.

Mica is a common constituent of granite, gneissic and schistose rocks, and is found in many localities in crystals of larger size than those usually forming an essential ingredient of the rocks mentioned. Such crystals have been reported from North Carolina and the other South Atlantic States; Maine, New Hampshire, Pennsylvania, South Dakota, New Mexico, Wyoming, California and elsewhere. It has been found in almost all the Pacific States but not in workable quantities of good quality. South Dakota has produced plates 12 by 18 in. in size from a vein which is said to be 14 ft. wide, and to consist of a central mass of feldspar and porphyry, with a casing of mica, which varies in width from 3 to 4 ft., on each side. The country rock is granite. Clear, transparent and tough mica plates are used in various ways, the principal utilization being for stove and furnace doors. A small amount of specially fine mica is used for compass plates. The inferior varieties not suitable for the above uses are largely used as an insulating substance in electrical machinery; while the scrap trimmings of the better kinds, as well as large quantities of the inferior sorts, are pulverized and used as an absorbent for nitro-glycerine explosives, and also in the composition of lubricating compounds; as well as for various ornamental purposes in the arts.

Mica only in plates of large size and good color has any high commercial value. For such plates the price increases more rapidly than the size of the plates, which may be said to range in value from 25c. to $5 per lb., with occasionally higher prices for exceptionally large and good plates. The industry in the United States fluctuates very greatly both in the quantity produced and its average value, chiefly owing to the uncertain character of the deposits, which may suddenly become worthless.

From the peculiar conditions of the mica trade it is evident that good, large plates can bear somewhat high rates of freight, and can be worked in out of the way localities, but if of only small or moderate size, the necessity for cheap labor in dressing and cutting the blocks, and freight charges, may render the deposit valueless, especially if the cost of mining is high, as large quantities of material must often be moved to secure a few pounds of plates, the conditions being very much the same as surround mining for asbestos.

The scales of yellow mica, found in the streams of granite and schistose mountains, are frequently mistaken for gold by the uninitiated, but can easily be distinguished by their softness and light weight, as well as by their loss of the yellow color when ground to powder.

OZOKERITE.—Like wax or spermaceti in appearance and consistency. G. 0.85—0.90. Colorless to white when pure; often leek-green, yellowish, brownish yellow or brown; and when brown, sometimes green by transmitted light through thin shavings. Greasy to the touch. Melts at 133° to 146° F. Burns readily in thin shavings or at the angles of specimens, when ignited with a match. (Dana in part.) Ozokerite, or native paraffin, is not a common product in nature. It occurs in beds of coal or associated with bituminous substances. In the United States it is found in Utah. Abroad it occurs at Slanik, Moldavia, beneath a bed of bituminous clay shale; in masses of sometimes 80 to 100 lb., at the foot of the Carpathians, not far from beds of coal and salt; that of Boryslan in a bituminous clay, associated with calciferous beds in masses. It is also reported from the Carpathian sandstones in Transylvania and other less important localities. Ozokerite, mineral wax or native paraffin is used in the manufacture of candles and heavy lubricants, very extensively as an insulator for electrical wiring, and generally as a substitute for most of the uses of beeswax.

PUMICE STONE is an exceedingly porous, spongy-looking lava in which the air bubbles are so numerous that it will float on water, and varies in color from dirty white to pearly gray. It, aside from its use as a toilet article, is chiefly employed in polishing marble. The bulk of the article is imported in the lump for use in the Eastern States from Italy, where it is found abundantly on Mount Vesuvius; while most of that used on the Pacific Coast is produced in California from deposits at Lake Honda, a few miles south of San Francisco. Other deposits of good quality also occur in California, near Mono Lake, which is the crater of an extinct volcano, and at Little Owens Lake and other localities in Inyo County. The annual consumption is not large and the price low, so that cheap transportation is essential.

QUARTZ.—H. 7.0. G. 2.6. Luster vitreous or glassy to nearly dull. Colorless when pure; often various shades of yellow, red, brown, green, blue, purple and black. Streak white of pure varieties; when impure often similar in color, but paler. Transparent to opaque. Quartz takes many forms, and is one of the commonest minerals, but is chiefly used commercially in the condition of sand, sandstone or quartzite.

Beds of sand and sandstone are common everywhere, but they are not all available for the same class of work on account of the associated impurities, and their value for any particular purpose can only be thoroughly ascertained by working tests.

The finest kinds of transparent quartz, known as "rock-crystal," are or rather were extensively used in the manufacture of spectacle glasses, but the improvements in glass making have diminished this application. Similar quartz is used extensively in glass and pottery making, and as a grinding and polishing powder. Ground quartz is also used in the manufacture of sandpaper. In addition to these a peculiar variety of sandstone called "ganister" is largely used in the lining of vessels used in the manufacture of steel on account of its excessively refractory character. In England the ganister preferred for lining is a peculiar silicious deposit found under a thin coal seam near Sheffield, of almost conchoidal fracture, thereby differing from ordinary sandstone, and containing a few tenths per cent., or sometimes a little more, of lime, and the same amount of alumina, with small quantities of iron oxide and alkalies, the rest being silica; analagous substances are found, however, in other localities in the northern coal fields. Beds of such quartz in the vicinity of steel works are valuable.

For mortar making, river sand is preferable, as salt from sea sands will certainly make its appearance on brickwork where it is used, spoiling the looks of the building as well as being objectionable on account of absorbing moisture; it is also sharper, with less rounded angles, as in rapid streams much of it is carried down suspended in the water and the angles scarcely suffer any abrasion.

STRONTIA, STRONTIANITE, ETC.—The metal strontium occurs as a carbonate, under the name of strontianite, and as a sulphate, under the name celestite. When crystallized strontianite has a hardness of 3.5—4, and a specific gravity of 3.65, with a vitreous or resinous luster, and white streak. In color it is pale asparagus-green or apple-green; white, gray, yellow and yellowish brown. Transparent to translucent. (Dana.) It occurs in the United States in granular and columnar masses in hydraulic limestones at Schoharie, N. Y.; and at Muscalonge Lake in the same State, a massive and fibrous variety of a white or greenish white color is found associated with fluorspar. In Scotland it occurs in veins traversing gneiss, along with galena and baute (barytes). (Dana.)

Celestite has a hardness of 3—3.5 and sp. gr. of 3.95, being somewhat softer and heavier than strontianite. The luster is vitreous inclining to pearly when crystallized, and the streak white. The color white, often bluish (from which it takes its name) and sometimes reddish. More or less transparent. (Dana.) Celestite is usually associated with limestone or sandstone, and occurs also in beds of gypsum, rock salt and clay. (Dana.) In the United States it is reported from the limestones about Lake Huron; from New York and Pennsylvania, and also from Green or Strontian Island, Lake Erie.

Nitrate of strontia is used to a considerable extent by the makers of fireworks for the production of red fire. The use of strontia has also been proposed in the treatment of beet sugar, and in the manufacture of tuyeres for blast furnaces. Sicily furnishes the bulk of the mineral at the present time, but little search for it having been made in the United States on account of the small demand.

SULPHUR cannot be mistaken for any other mineral, its brilliant yellow color, and characteristic odor on burning, separating it instantly from all others. Wherever found it appears to be associated with volcanic action and hot springs, having been deposited by such agencies in vast beds both in Europe and America. In boring for petroleum near Lake Charles, Calcasieu Parish, Louisiana, "at a depth of 423 ft. the drill passed through 100 ft. of pure sulphur and 148 ft. of gypsum mixed with sulphur, the former mineral being a common associate of sulphur deposits, by the conversion of ordinary limestone into the sulphate through the action of sulphuric acid. In Nevada, the beds near Silver Peak are traversed by seams of alum, formed in a similar way by the decomposition of aluminous or clay-forming rocks. In California, at the Sulphur Banks in Lake County, the deposits are associated with cinnabar or mercury and borax. In Southern Utah the occurrence is evidently in what was formerly a crater of a volcano, about three miles from Fort Cove Creek. The crater forms a small basin surrounded by low hills with a narrow ravine opening into the plain—probably a breach in the old crater walls—which consist mainly of andesite with some pale whitish trachyte (both porphyries) with obsidian splinters scattered over the surface. As far as explored the sulphur beds extend over an area of at least 1,800 by 1,000 ft. across. The sulphur shows upon the surface over part of the basin, but is mostly covered with sand, or rather the disintegrated andesite of the surrounding hills. A curved cut through the western end of the deposit exposes a vertical wall of rich yellow sulphur 34 ft. high, from which in many places, as well as in other prospect-holes, gases escape, together with water holding various salts in solution." "At the Mammoth claim in the same neighborhood, the slates and limestones are impregnated with sulphur, gypsum being also found as a product of altered limestones; while at the Sulphur King claim the andesites are similarly saturated."

The deposition of sulphur is constantly going on at volcanic vents and many hot springs. "Mount Purace, in Colombia, wears a cap of sulphur (derived from its own crater) which accumulates at the rate of 2 ft. per annum—its superficial area amounting to 1,435 sq.

yards;" and the sulphur forming in the crater of Popocatapetl, in Mexico, is regularly worked by the Indians. The salfatara of Bahara Saphinque on the Red Sea is said to yield 600 tons of sulphur annually. American sulphur comes into sharp competition with that produced by the Sicilian deposits (which have been worked to a depth of over 300 ft. and turn out annually 400,000 tons of clean sulphur), and can consequently only be profitably exploited under the most favorable conditions of labor and transportation aided by local demand, which it fostered by the high rates of freight on sulphuric acid on account of its dangerous character. Native sulphur is also met in the market by acid produced from iron and copper pyrites, which are now mined in enormous quantities for that purpose, as the contained metals furnish a valuable by-product.

The larger portion of the entire product of sulphur is used in the manufacture of sulphuric acid, the consumption of which in manufactures is extending daily. Outside of this it is employed in the production of vulcanized rubber goods; in the manufacture of "bluestone," or sulphate of copper, which is largely used in metallurgical operations; as a preventative of and cure for mildew on plants by horticulturists, and many minor uses.

Talc and Soapstone.—H. 1—1.5. G. 2.65. Luster pearly. Color apple-green to white, or silvery white; also greenish gray and dark green; brownish to blackish green and reddish when impure. Streak usually white; of dark-colored varieties, lighter than the color. Easily cut with a knife. Thin sheets flexible, but not elastic. Feels greasy. (Dana.) The foregoing description is of the purer and softer varieties, from which the harder kinds are separated as "soapstone," to the best kinds of which the term "French chalk" is applied. The mineral is soft enough to leave a whitish mark on cloth, and is used by tailors in drawing their patterns. The various forms of talc are of very common occurrence, and steatite or soapstone forms extensive beds in some regions, being often associated with serpentines, chloritic or talcose schists, in which latter rock thin flakes of talc take the place of mica, and impart to it a certain greasy feel, which is characteristic of the entire series of minerals associated under the name, which is often applied by miners and prospectors to any soft white earthy substance in the gouge of veins, whether greasy or not. Talc is used extensively in soap making, and in dressing fine sheep-skins, leather, gloves, etc. The finer, soft, foliated variety is used in the manufacture of paper, and small quantities enter into the composition of some lubricating compounds. "Soapstone," on account of its refractory nature in the presence of intense heat, and the facility with which it can be sawn into bricks, slabs or any desirable shape, is extensively used as a lining for stoves, furnaces, etc. It can be easily turned in a lathe, and the writer has seen on the Mexican border a very ancient tuyere for a blacksmith's forge made out of such material. It was found in grading for a ditch, and from the size of the trees growing over the spot must have been buried for at least 100 years, and may possibly be a relic of the early missionary days of California.

II. SOLUBLE MINERALS.

With the exception of common salt, which is of general distribution, and Stassfurt salt and its associates, the balance of the useful minerals of this group all occur in arid regions, where the climatic conditions favor the evaporation of the water which dissolves the various salts and holds them in suspension. Many of them are found in foreign countries where the price of labor is extraordinarily low, and from which ocean carriage is remarkably cheap, so that the products of the United States being found far inland, in thinly populated regions and often in consequence far from convenient lines of transportation, can with difficulty compete with the imported articles. The efflorescences or crusts of borate of soda, carbonate of soda and salt greatly resemble each other, but can be separated by the tests given in the description of these minerals, the presence of carbonate of soda being indicated by effervescence if citric acid be added to a solution of the incrustation. The compact massive deposits found underlying these incrustations may also be tested in the same manner, and while under existing conditions of trade and transportation they may not be available for other than local consumption, they may possibly supply a mineral which will render others available, just as cheap soda is necessary to make quartz sand valuable for the production of glass.

Borax.—H. 2—2.5. G. 1.7. Luster vitreous to resinous, sometimes earthy. Color white, sometimes grayish, bluish or greenish. Streak white. Translucent to opaque. Rather brittle. Taste sweetish-alkaline. Imparts a clear green color to the flame. Boiling water dissolves double its weight of borax. (Dana.)

Borate of Lime, Ulexite or Hayesine.—H. 1.0. G. 1.65. Color white. Tasteless. Loose in texture, fibrous and silky, usually in rounded masses.

Crystallized borax (or borate of soda) is found in the mud of certain lakes both in California and Asia, but the great bulk is produced from the borate marshes of Nevada and California, of which the general character is well described in the Geological Survey reports of 1883. "The borate fields are situated in the extensive salines known as Teel's marsh, Rhodes's marsh, the Columbus marsh and Fish Lake Valley, all in the southeasterly part of Esmeralda County. These salines consist of oval-shaped alkali flats occupying the centers of immense basins, and cover from 10,000 to 20,000 acres each. These basins are surrounded for the most part by a broad margin of sage plains which rise gradually to the base of the hills and mountains which inclose them on every hand. They have no outlets, and, receiving the drainage of the country around, retain everything brought into them, including the borates and salts of various kinds. From midsummer till late in the spring, when the snow commences to melt on the mountains, these saliniferous lands are, as a general thing, apt to be dry, only shallow lakes occupying sometimes their points of greatest depression. At other seasons of the year portions of them are covered with water to the depth of a foot or two. Heavy rains, though these seldom occur in these regions, convert these alkali flats into beds of tenacious mud, even a slight shower rendering their passage by teams difficult for the time being. Water can be obtained on these salines almost anywhere by digging from 2 or 3 to 10 or 15 ft. below the surface. It is generally brackish, however, often so much so as to be scarcely fit for drinking. By digging to much greater depths good water is obtained a short distance back from the edge of the marsh. Over large sections of these flats exist deposits of common salt, carbonate of soda, and borax. This latter mineral does not, however, occur here, as at Clear Lake in California, in the shape of compact, semiopaque crystals imbedded in mud, but generally in the form of borate of lime or soda. The former is found at many spots imbedded in these marshes from 1 to 4 ft. below the surface. It crystallizes in long silky fibers which gather into balls from an eighth of an inch to 2 or 3 in. in diameter. These globular masses have the luster of white satin, and when dug up readily separate from the inclosing earth. The borate of soda mixed with sand and other impurities accumulates on the surface in the shape of a dark-colored incrustation an inch or two thick. This crust when dry, being hard and brittle, can be easily detached from the moister ground beneath and broken into fragments."

While Nevada and California are the only producing States in North America, there are extensive deposits in Europe, India, Peru and Asiatic Turkey, and competition has reduced the price from the old standard of 25 or 30 c. per lb. to a very low figure, the reduction having, however, opened up new avenues of use.

The leading uses of borax are in welding (for which the greater part is consumed in iron and steel manufacture); in refining metals as a crucible flux; in enamelling; by packers, in preserving meat; and as a detergent for household purposes.

Carbonate of Soda or Trona.—H. 2.5—3.0. G. 2.10. Luster vitreous, glistening. Color gray or yellowish white. Translucent. Taste alkaline. Not altered by exposure to a dry atmosphere. (Dana.) Soluble in water and effervesces with acids. Trona is another of the minerals occurring as the result of the evaporation of water in dry inland basins without drainage outlets. The following description of one such deposit will convey a good idea of them all:

"This mineral abounds throughout most parts of the Great Basin, the extensive alkali flats which form a feature of that region constituting the principal sites of these deposits, which occur usually in the form of an efflorescence an inch or two thick on the surface, but sometimes in strata a foot or more thick imbedded in the earth, and separated from each other by thin seams of clay. When found in the form of a thin incrustation on the surface it is never pure, being always admixed with salt, borax, lime, magnesia and other minerals. The heavier deposits are comparatively free from foreign matter, carrying generally about 90% carbonate of soda. One of the most remarkable repositories of this mineral known consists of a circular basin, the bed of a former lake, situated on the southerly margin of the Forty-mile desert, Churchill County, Nev. This basin, which covers an area of 10 or 12 acres, is depressed 60 ft. below the common level of the country adjacent. Its bottom, usually dry, though in wet seasons covered with a few inches of water, is composed of a compact mass of the carbonate of soda so hard that it has to be broken out with crowbars, and so pure that it can for many purposes be used to advantage in its natural state. This substance occurs here in layers about 1 foot thick, separated from each other by thin seams of clay. Large quantities of the crude material are extracted every year.'' This deposit has been worked over an area of several acres to a depth of 10 or 12 ft. without showing any signs of exhaustion. A portion of the product from the above locality is used in the working of the neighboring silver ores, but the greater portion is refined and sold for other purposes, soda being very extensively employed both in the arts and manufactures.

NITRATE OF POTASH, NITER OR SALTPETER.—H. 2.0. G. 1.9. Luster vitreous. Streak and color white. Subtransparent. Brittle. Taste saline and cooling. Deflagrates vividly on burning coals, and detonates when mixed with combustible substances. (Dana.) Dissolves easily in water and is not altered by exposure. Colors the flame violet when burned. It occurs as an efflorescence on the surface or in the surface stratum of the soil in many parts of the world, but especially to a great extent in the valley of the Ganges and other parts of India, as well as in Spain, Egypt and Persia. It is also obtained in a semi-artificial manner in nitaries or saltpeter plantations. These consist of heaps of decomposing animal matter, mixed with lime, ashes, road scrapings and other rubbish, covered over from rain, and from time to time damped with the runnings from stables and other urine. Such heaps develop within them small proportions of the salt, and other nitrates, and are in effect artificial imitations of the saltpeter-bearing soil of India.

Niter requires for its formation dry air and long periods without rain, and is produced most abundantly during hot weather succeeding rain. The potash comes mainly from the débris of feldspathic rocks in the soil. (See chapter on rocks for the percentages of potash in various kinds of rocks.) It also forms abundantly on the walls of caverns and in the loose earth floors of the same, which abound in the limestones of the Mississippi Valley in Kentucky and Tennessee. It is now prepared artificially from Chili-saltpeter and the German chloride of potash, by mutual decomposition, producing chloride of sodium or common salt and nitrate of potash, or saltpeter, and this product has largely supplanted the native article, being a much superior material.

India furnishes the bulk of the imported niter.

NITRATE OF SODA OR CHILI-SALTPETER.—H. 1.5—2.0. G. 2.0—2.3. Luster vitreous. Color white; also reddish brown, gray and lemon-yellow. Transparent. Rather sectile instead of brittle. Taste cooling. Deflagrates with less violence than niter, and colors the flame yellow; also absorbs water on exposure to moisture and deliquesces. (Dana.)

Chili-saltpeter occurs on exceedingly dry and arid plains in North and South America chiefly. In South America in the district of Tarapaca, Northern Chili, the dry pampas for 40 leagues, at a height of 3,300 ft. above the sea, is covered with beds of this salt several feet in thickness, along with gypsum, common salt and glauber salt, with remains of recent shells indicating the former presence of the sea. The arid plains of the Great American basin present almost identical conditions as regards altitude, climate and rainfall (on the Nevada deserts only about 4 in. annually), and as might have been expected, this mineral is found on the 40-mile desert near Lovelock's Station, crystallized in the crevices of rocks and imbedded in the earth from 2 to 30 in. below the surface. Its occurrence is also reported in a similar country near Calico, San Bernardino County, Cal.; and in the southern part of New Mexico, near the Chihuahua line, the mineral is said to be deposited by springs in considerable quantity.

Nitrate of soda is used extensively in the production of nitric acid and saltpeter or nitrate of potash, the latter product entering into the composition of gunpowder.

SALT is sufficiently well known to be distinguished from other similar minerals, when in comparatively pure condition, by its taste alone. Rock salt occurs as immense beds formed by the evaporation of sea water, associated with deposits of gypsum and other marine products. Percolating waters dissolve these accumulations and supply the brines for the salt wells of Michigan, New York and other Eastern States, which vary in depth from a few up to 1,000 ft., the average depth in Michigan being 882 ft.; in New York, 322; Ohio, 932; Pennsylvania, 883; and Virginia, 1,042 ft. The shallowest wells are in Utah, Texas and Kansas. Some brines are obtained not from beds of pure rock salt, but from strata of salt-bearing rocks such as sandstone, shale, etc. The brines from these wells are evaporated by artificial heat. In California, solar heat is extensively used in the neighborhood of San Francisco in the evaporation of sea water; while in Nevada salt is abundant in all the interior basins either as beds of rock salt, as incrustations on the surface, which are renewed as often as they are removed, and that so rapidly as to afford several crops annually, or as massive deposits, covered with slight deposits of sand or clay.

SULPHATE OF SODA.—H. 2.0—3.0. G. 2.6. Luster vitreous. Color white to brown. Translucent. Wholly soluble in water. The occurrence is very similar to that of carbonate of soda just described, the material being found extensively in lakes and beds in the States of Wyoming and Colorado, and in smaller quantities in New Mexico. Well known localities are the lake near Independence Rock and the lake seven miles from St. Mary's Station, both in the Sweetwater valley; and Burdsall's Lake near Morrison in Colorado. While outwardly appearing much the same, analysis develops the occurrence in the deposits of carbonate of soda, and common salt, in varying proportions, as well as various impurities such an silica, lime and magnesia. Available in the manufacture of soda, glass and gunpowder.

III. LIQUID.

Petroleum.—Crude petroleum varies considerably in composition and density, the latter varying from 0.60 to 0.80, forming the so-called light and heavy oils. The light oils give proportionately more illuminating oil (kerosene); the heavy, more lubricating oil and residue. It is a hydrocarbon, standing intermediate in the series ranging between the asphaltum group of minerals at one end to the lightest naphthas at the other. Its exact origin is in dispute, but is probably the decay of animal and vegetable substances under peculiar conditions. It is usually dark greenish brown in color, and is easily recognizable by its peculiar fetid odor. Its inflammability varies and is not always a reliable test, as some specimens (of the heavy or impure varieties) do not ignite very readily. In the United States the light oils are found mainly in the eastern fields; from Ohio westward the oils are usually of the heavy variety. It occurs in porous sedimentary rocks of all kinds, as in sandstones, shales and some limestones; and in point of geologic age all the way from the Silurian to the most recent. At the surface it appears as springs, pools and as a scum floating upon the water. The surface prospecting consists merely in following streams showing such oil films up to the source of the petroleum spring or oil-bearing rock outcrop. Borings for oil in depth are generally directed in accordance with the results found in existing wells of the neighborhood; though sometimes bore holes are put down in localities far from any previously sunk wells, where geologic reasoning shows the probability of the presence underground of oil-bearing strata which have been proved elsewhere. Boring for oil is a special trade, based partly upon theoretical and geological considerations but more especially upon local experience.

IV.—GASEOUS.

Natural Gas also is a hydrocarbon, something like the "marsh gas" which sometimes rises from swamps, and also related to the "fire damp" of coal mines. It is colorless and odorless, and is lighter than ordinary illuminating gas. Its discovery in a new locality usually results from accidental ignition; in regions where it is already known to exist borings for it are put down in accordance with the indications given by earlier gas wells, or to strike a stratum which has been gas-bearing elsewhere.

CHAPTER XV.

COAL.

THE literature of coal is so extensive and complete, and coal mining is so essentially a business in itself, that in a work intended chiefly for the use of the prospector for ores a long account of coal would be useless and out of place. This chapter will therefore be devoted to the presentation of only those points which may be serviceable to the prospector who may come across outcrops of coal while searching for other minerals, so that he may be able to estimate their value as aids in the reduction of metallic ores.

ORIGIN.—The general origin of all coal beds is the same. Masses of vegetation were laid down in water in a horizontal position, or nearly so; and then, owing to geological changes, covered up and buried by the rocks we now find above them, undergoing in process of time, through pressure and heat, certain chemical changes, which, according to the period of time which has elapsed since their formation, have been more or less extensive; so that to-day we recognize several varieties, distinguished chiefly by their percentages of carbon and volatile matter, imparting to them different qualities. The character of the rocks on which beds of salt, gypsum, iron ore, etc., are deposited is purely accidental and unimportant, but in the case of coal the wide marshes demanded a retentive bottom to prevent drainage, and we consequently usually find a floor of clay, often fire clay, without which we cannot imagine the formation of such enormous accumulations of vegetable matter, which before compression reduced them to their present condition must have had a thickness from ten to twenty times that which they now exhibit. The edges of coal deposits are likely to be largely contaminated with sand and clay or other waste matter; and it is easy to see, if the deposit be of small area, how this worthless margin may form a much larger proportion of the whole bed than in those of greater extent, as in the case of coal we must picture to ourselves immense level marshy tracts, covered with a dense, luxuriant vegetation which would certainly intercept any wind-blown debris before it had traveled far from the margins of the swamp, or would entangle in its roots the sediment brought down by streams, the velocity of whose currents would be promptly checked, and consequently they would drop their burden.

Composition.—As a general proposition the percentage of carbon is greatest in those coals which are the oldest geologically. Coal contains a certain amount of "fixed" carbon, or that which remains after coking, and also a certain amount of carbon in combination with hydrogen, oxygen and nitrogen, forming the volatile portion; the remainder is earthy matter (forming ash) and moisture. The following table, from André's "Practical Treatise on Coal Mining" (which may be consulted for all details), is very instructive, showing that with age, in the sense of geologic time, coal loses the gaseous elements, particularly oxygen and nitrogen, consequently containing a larger percentage of carbon, and steadily increasing in specific gravity. An important exception is found in the case of comparatively recent coals which have been heated and altered by the proximity (not actual contact) of igneous dikes or overflows, producing the same effect as age. Colorado and other anthracites are examples. The percentages are calculated irrespective of ash and moisture.

COMPARISON OF CARBONACEOUS SUBSTANCES.

Substance.	Specific Gravity.	Carbon.	Hydrogen.	Oxygen and Nitrogen.
	Per. Cent	Per Cent.	Per Cen	Per Cent.
Wood—mean of 12 kinds	0.91	49.00	6.25	44.75
Peat—mean of 12 samples	0.99	59.30	6.52	34.18
Lignite—mean of 12 samples	1.25	72.37	5.18	23.45
Cannel coal	1.27	80.07	5.53	13.50
Bituminous coal—mean of 3 divisions	1.30	86.17	5.21	8.62
Semi-bituminous coal—mean	1.37	91.00	4.75	5.25
Anthracite coal—mean	1.50	92.50	3.75	3.75

Classification.—The classification and names of coal are based on the foregoing percentages. A portion of the gases are combined to form water, while the remainder of the gases are combined with a portion of the carbon in the form of volatile matter, leaving a balance of carbon, which is known as the "fixed" carbon, and is that portion which is left as coke when the volatile matter has been extracted by distillation. The varying proportions of these materials render the different kinds of coal suitable for different purposes. Water in all cases is a detriment to the coal, as it must be driven off in the form of steam at the expense of a portion of the carbon, which is thus lost for heating purposes.

The following classification of coals is taken from André, and is based on the amount of coke produced by distillation. The "coke" in this case does not mean commercial coke, but the residue left in laboratory tests. Neither anthracite at one extreme nor lignite at the other make true coke.

CLASSIFICATION OF COALS.

Name of Coal.	Coke, Per Cent.	Volatile Matter, Per Cent.	Character of Coke.
Anthracite	92–88	8–12	Brittle and powdery.
Semi-bituminous	88–82	12–18	Brittle and powdery.
Bituminous—			
1. Clear-burning	82–74	18–26	Good.
2. Flaming	74–68	26–32	Good.
3. Smoky or fuliginous	68–60	32–40	Porous, friable.
4. Gas coal	60–50	40–50	Soft, powdery.
Lignite or brown coal	50	50	

DISTINGUISHING CHARACTERS OF COALS.—*Anthracite*——Its structure is perfectly homogeneous, its density greater than that of other kinds of coal, and it has a more completely mineralized appearance. Its color is a jet black, with a somewhat vitreous luster, often exhibiting a powerful play of colors. It does not (easily) soil the fingers when handled, being very hard and firm. In the harder examples, the fracture is distinctly conchoidal, but when of a more tender character it frequently breaks into small cubical lumps. Anthracite burns with a feeble flame, blue when the supply of oxygen is insufficient, and often decrepitates much in burning. It ignites with difficulty, and is slowly consumed, but when in a state of perfect combustion it evolves intense heat. The quality of hardness possessed by anthracite enables it to be transported from place to place without injury, while that of evolving great heat without smoke renders it peculiarly suitable for many purposes, as in the generation of steam, and employment in distilleries, breweries, or in lime or brick kilns. In America it is largely used for domestic purposes; also for steam-making on naval vessels at times, and in cities where "anti-smoke" ordinances prohibit the use of bituminous.

Semi-anthracite is a term sometimes used to indicate a grade between strictly anthracite and semi-bituminous.

Semi-bituminous Coal occurs next above the anthracites in geological order. Occupying a higher position, it has been less exposed to the action of heat and other metamorphic agencies, and has consequently retained a larger proportion of its volatile matter. Between the anthracitous and the semi-bituminous classes, however, the line of division is purely arbitrary, since from anthracite to cannel there is every grade of composition. Its color is usually a dull black and its fracture subconchoidal. It frequently exhibits a peculiar fibrous structure, passing into a remarkable toothed arrangement of the particles, called "cone-in-cone" or crystallized coal. It burns with a slightly more abundant flame than coals of the anthracitous class, and evolves more smoke, but not in dense volumes. It possesses the dry character of the latter class, and from its freedom from a liability to cake together, it is sometimes called "free-burning," and "steam coal."

Bituminous Coal (Clear-burning 1).—"The varieties of the clear-burning division are the poorest in volatile matter. They are similar in texture to those of the preceding class, but generally of a duller luster. They are very tender, and break with an even or an irregular fracture, and in consequence of the very perfect development of the cleat* have always a tendency to break up into small cubical lumps. These coals kindle with difficulty, and burn away slowly with a short, clear, bluish flame, and very little smoke. When reduced to a powder and heated in a close vessel they fuse and agglomerate into a dense and strongly coherent coke, a property which renders them extremely valuable for manufacturing purposes. Both in quality and quantity the coke obtained from the clear-burning coals is superior to that obtained from any of the more bituminous varieties."

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* Cleat is the system of parallel joints at right angles to the bedding of the coal.

Flaming Coal (Bituminous 2).—"The coals of this class are richer in volatile matters than the foregoing, a circumstance to which they owe their characteristic flaming quality. Their structure is distinctly laminated, and their color black and glossy. When reduced to powder, however, their color is a dark brown. They kindle without difficulty, and burn away somewhat rapidly with a long white flame. Coals of this class become partially fused when strongly heated, and while in a fused state swell into a spongy mass, giving off bubbles of gas, which burns with a bright flame. This property of agglutinating in the fire allows the small coal to be burned which would otherwise be useless, or to be converted into coke, of which it produces an excellent quality. To this property, also, these coals owe the name of 'caking' coal, which has been applied to it in common with some other varieties of the same class."

Fuliginous Coal (Bituminous 3) "contain a very large proportion of volatile matter. Hence they kindle readily, and burn away rapidly with a long yellow smoky flame. They are somewhat hard and strong, and their fracture is rather shaly. Coals of this character fuse in the fire like the flaming varieties but they do not agglomerate or cake into so compact a mass. The gas obtained from them is abundant and of a high illuminating power, but the coke obtained from this division is friable and porous, and unfit for many purposes."

Gas Coal (Bituminous 4).—"All of the foregoing coals occur in the so-called Carboniferous period, but some of the present section are found in beds of later geological times. They are distinguished by the very large proportion of volatile matter which they contain, and to this circumstance it is due that they do not cake when heated. Experience has shown that coal becomes caking when the proportion of carbon reaches 80%, and that of the hydrogen descends below

15%; on the other hand, when the proportion of hydrogen becomes very small and that of the carbon large, as in the anthracites, the same non-caking qualities result. The gaseous coals are of a brownish black color and of a dull luster. When reduced to powder they are quite brown. They are generally hard, compact and strong; their fracture is even to conchoidal. Coals of this class kindle even more readily than the fuliginous varieties, and they burn away rapidly with a long flame. The coke obtained from coals of this class is of a soft and pulverulent or powdery character and useless for commercial purposes."

Cannel Coal "naturally falls under the head of a gaseous coal, though differing much in appearance. It is a very hard compact coal, of a black or brownish black color, sometimes glossy, but more frequently dull in luster. It does not soil the fingers when handled, and it is capable of taking a high polish. It breaks with a flat conchoidal fracture, and is distinguished from ordinary coals by the absence of a laminated structure. This is a mark of its highest perfection, for when it comes earthy and impure the laminated structure is developed. It kindles very readily, and burns away in the hand with a very abundant white flame. It is now employed almost exclusively (except for grate fires) for gas making, for which purpose it commands a high price. Seams of cannel occur in certain districts with ordinary coal, and often form the upper portion of a seam of bituminous coal, and occasionally of a bed of black-band ironstone." The splint coal of West Virginia and other States somewhat resembles cannel in appearance and qualities, but is higher in the scale of fixed carbon.

Lignite or Brown Coal "occurs in the more recent geological formations. The processes of mineralization having been less completely effected than in the older coals, they exhibit their vegetable structure more completely, and as an effect of the same cause they retain a much larger proportion of the volatile matters. In color they vary from brown to pitch black. Their luster is generally dull, but sometimes resinous; the fracture is various. They burn readily with a dull flame, emitting much smoke, and an unpleasant odor. In consequence of the small proportion of carbon and the large quantity of water which they contain, the brown coals do not possess great heating power. They are largely developed in the western States of America. On account of the large amount of water they 'slack' into small fragments when exposed to the air and sun, the large blocks soon showing a multitude of cracks."

IMPURITIES IN COAL.—In all the foregoing remarks the coal is supposed to be free from impurities, but as a matter of fact this is seldom the case. "The impurities may be classed as essential and accidental; the former being those which entered into the composition of the vegetable substances from which the coal was formed, and the latter those which have been intermixed with these substances. The essential impurities consist of silica, alumina, lime, magnesia and oxide of iron, to which may be added water. The accidental impurities may consist of any substance other than the elements mentioned. Some of these have been introduced by the infiltration of water holding the substances in solution. In general the accidental impurities consist of earthy matters, which were probably deposited from water flowing among the coal vegetation, or blown thither by the winds. The quantity of earthy impurities present in any given sample of coal is estimated by weighing the ash after combustion. When the weight of the ash so left does not exceed 5% of that of the coal, the latter is considered very pure. Above that proportion it begins to lose in quality and becomes hard and shaly in structure.

"A common impurity is iron pyrite, or sulphuret of iron, a substance known to coal miners as 'brasses.' Pyrite occurs sometimes as a deposit filling the cracks and fissures in the coal; sometimes as thin beds. It is not infrequently met with running with a line of parting, or it occurs as crystals disseminated throughout the mass; and more often as minute particles imperceptible to the naked eye. The presence of iron pyrite detracts greatly from the value of coal by rendering it unsuitable for many important purposes. Coal containing this mineral is totally unfit for [iron and steel] metallurgical purposes [though available for other metallurgical uses, as in roasting and smelting certain metals], and it cannot be burned anywhere in contact with iron without serious injury to the latter. Hence it cannot be employed for the generation of steam, as its corroding action would rapidly destroy the fire-grating and the lower plates of the boiler. Moreover, pyrite is decomposed by moisture and converted into a sulphate, and the expansion which takes place during the process tends to break the coal into very small lumps and even to powder. This decomposition is often accompanied by great heat, and spontaneous combustion is not infrequently occasioned thereby. Heaps of brassy small coal and rubbish lying as refuse on the pit bank often take fire from this cause in wet weather, and, which is of far more disastrous consequence, the exposed coal in the workings will sometimes become ignited."

While no coal is free from impurities, the variation is great both as to the amount of ash left after burning and of water. From the nature of the origin of coal, as has been already seen, there must be a thin edge to the bed entirely round its circumference, and this will naturally contain a larger percentage of impurities than the central mass, where they may be scattered through the entire thickness of the seam or consist of thin alternate layers. Sometimes one or more of these layers will extend over a large area and frequently assist materially in mining the coal. In such cases the upper seam may have quite a different character to the lower one and may be mined separately.

TEST FOR COKING QUALITIES.—Some coals which appear to contain the requisite ingredients to make good coke refuse to coke except under particular treatment, and only a series of analyses, followed by working tests, can determine the ultimate value of a field, or to what purpose the product may be best adapted; but the prospector may readily ascertain for himself by the camp fire, whether his find comes within the coking series by the following means: Take a clay pipe with a moderately long stem; fill the bowl with clean powdered coal, and then carefully lute, or stop the top with stiff, well-worked clay. It is not advisable to fill the bowl too full, as if the coal should prove to coke, it will swell on heating, and raise the clay cap, admitting air, and the experiment will be a failure, as the coal will take fire. When prepared, place the bowl of the pipe in the fire, heating it gently at first to dry the clay without cracking, and then more rapidly to a white heat. Smoke and gas will be given off (through the stem), which will burn freely, being made up of the volatile matter, water and sulphur. When this ceases the operation is complete. Take the pipe from the fire, and if the coal will coke, the bowl will be found to contain a solid mass of coke of a bright dark gray color, hard and compact, if good; but easily crumbling to powder if of poor quality. If the luting or stopper of clay has cracked it may be partially burned up, but a few experiments will easily give the requisite skill to make the test. A large portion (practically all) of the ash, of course, goes into the coke.

The ash is determined by weighing the earthy matter left after burning a definite weight of dry coal in the open air (by which the carbon as well as the volatile matter is consumed), and calculating the percentage. Analysis alone can determine this accurately and furnish the information whether it is a high or low grade coal, in case it refuses to coke.

COMMERCIAL VALUE.—The prospector's interest in a coal discovery centers in the question whether it will become a business success on development. This depends on the number, thickness and dip of the workable beds; on an abundant supply of cheap labor, to keep the cost of mining, sorting and washing at a low figure; cheap transportation by land or water; and freedom from competition with coals of its own class, thus filling a vacant place in the market. Many or all of these items may be largely modified if the coal is found in a region otherwise largely devoid of fuel, as many of our interior mining districts, in which the price might be greatly enhanced, and the product yet have a ready sale; but the conditions become emphasized, especially as regards coal for domestic purposes, in densely wooded districts like western Washington.

But with all conditions apparently favorable, the exploration of the field may result in failure, from excessive and unexpected "faulting" of the coal largely increasing the cost of working; by the intrusion of eruptive rocks into the coal seams, destroying the coal; by a change in the character of the coal; by the thinning out of the beds; or the opening of other mines better located with regard to some item which gives them an advantage in the market.

PROSPECTING.—There is not much to be said on this subject. The first discovery is likely to be purely accidental, but when made a few simple rules will assist in tracing the outcrop. The first thing is to get a good knowledge of the rocks between which the coal is found and their relation to other rocks above and below them, keeping a sharp lookout while doing this for any fossils such as shells or plants. After acquiring this knowledge, the search must be confined to the region occupied by these floor and roof rocks, and the knowledge gained of the associated rocks will tell the searcher in which direction he must look, if he accidentally has wandered beyond the limits of the coal-bearing series, because, from the way in which the beds were formed originally, they are now found more or less parallel to the junction of two different kinds of rock.

If the country has been much tilted the outcrop may follow quite a wavy line or even apparently run in a semicircle, but having by the means just stated defined the limits of the area in which coal is likely to be found, the search may be continued by following up the ravines which cut this formation. In a densely wooded country this kind of exploration is difficult, but as the coal is softer than the rocks in which it is found, there is usually a sharp break or drop in the bed of the ravine at the point where the coal crosses, and all such places should be carefully examined. Beyond this the prospector must use his own judgment.

As coal suffers from exposure to the elements, it is likely that the outcrop will be inferior to the coal found at a little depth below, but whenever the roof and floor become solid and show no signs of decay, the coal there found may be taken as a general, but very rough, sample of the deposit.

Provided all the surroundings appear satisfactory a complete series of borings should be made to prove the condition of the beds as regards "faulting," but at this point the work of the prospector ends, and that of the engineer begins.

CHAPTER XVI.

GOLD GRAVEL DEPOSITS.

Gravel Mining or washing is carried on to obtain placer gold, platinum, tin, diamonds and some other less important substances, which are found during the search for the more valuable ones. When the water used in the process is applied under pressure, the term "hydraulic mining" is applied to the operation.

The deposits operated upon may be glacial drift; the beds and hillsides of modern streams, which are generally called "placers," and the operation "placer mining;" or the gravel accumulated in the beds of ancient streams, long since dry, and not infrequently located high on the mountain sides above all the present rivers, may be attacked by hydraulic methods, when not covered with a lava cap; or "drifted" by means of tunnels, in a manner similar to coal mining, when the cap of the mountain is too hard to be removed economically, or the top gravel too poor to pay for washing, or water too scant in supply or with too small a head or pressure to admit of hydraulicking. The working of ordinary placers by ground sluices or by sluice boxes is so well known that it is not necessary here to enter into any details.

In studying gravel deposits we must remember that the laws governing the operations of nature have been the same for all time; that the forces have been the same, though they may have operated with greater activity; and that any explanation of the phenomena which is not in strict accordance with these laws must inevitably be erroneous and defective. This caution is the more necessary as we have to deal largely in our explorations with things that we cannot see and can only base our surmises as to their condition on the laws which we know to govern the same circumstances in the world which is open to our inspection. Any proposition which is in direct opposition to these laws should be laid aside promptly as worthless. The importance of this is especially apparent in the opening of "drift" mines.

ORIGIN OF GRAVEL DEPOSITS.—All accumulations of gravel and sand have been made by the action of water, either as running streams or sea waves, or by ice as glaciers and icebergs, and result from the wearing away of rocks by the action of the air or rain or frost, or all three combined. The nature of their contents must therefore depend on the character of the rocks which have been destroyed and the width, depth and velocity of the streams which carried the material to its resting place, or the area over which ice sheets and glaciers or floating ice could carry its burden of soil and rocks before melting and depositing its load.

As we have seen in studying the filling of mineral veins, the minerals are disseminated through a variety of rocks, and the presence of veins is not necessary, as is so generally supposed, to "feed" the stream. When a stream ceases to show gold in the bed on following it upward, it does not follow that there must be a rich vein in that vicinity, for which we constantly find the miners searching; it may be simply an intimation that the upper limit of the gold-bearing rocks has been reached. We can indeed have good placer diggings in regions where well-defined veins are scarce. If we once thoroughly realize this general distribution of gold in certain belts of rock, the origin of gravel deposits carrying gold, tin or platinum becomes much more easily intelligible.

When the rock is decomposed by the ordinary action of frost or air and rain, the detached particles are constantly descending by the steepest line, under the action of gravity or water, and this is usually more or less at right angles to the stream into which they finally find their way. During this descent the particles of gold suffer but little abrasion, as their progress is excessively slow, and they undergo no sorting into sizes, other than what would result from the greater momentum of the larger particles, causing them to travel further on a steep side hill where but little surface water and rivulets acted; but if there were much water coming down the side hills, the reverse might occur, the larger gold particles resisting more than the light flaky ones. On entering the water their fate depends on the depth of water and the velocity of the stream. If the latter is great, the finer flaky particles, which even in still water descend to the bottom very slowly, will be swept away with the sand on their seaward journey, only the heavier pieces reaching the bottom, where they will continue to sink into the river bed by their superior weight as long as the surface is very soft or slightly agitated. The less the velocity, the smaller will be the amount thus swept away. In cases where the gold has not been much subject to the action of water for continuous periods, it may retain its crystallized or angular form, and this is usually an indication of the vicinity of a vein, especially if portions of quartz are still attached to the specimens. The smoothing and flattening of nuggets and grains of river gold is probably due to a large extent, if not altogether, to the impact of heavy rocks and the polishing action of sand and gravel as they are swept over it in the river bottom, just as such material polishes and wears away the angles of bowlders or solid masses projecting from the bottom of the stream. It does not seem probable that the coarse gold has ever traveled very far from the point where it first found lodgment in the river, but the very finest particles may be transported many miles. Gold derived from the decay of either iron or arsenical pyrites may be so excessively fine that it will never find a lodgment on the bottom until the sediment with which it is mixed reaches quiescent or perfectly tranquil waters.

RIVER DEPOSITS.—All rivers and streams may be compared to immense sluice boxes in which the heavier particles have been retained, and the lighter ones washed away, while nature has been carving out the river basins with all the forces at her command, presenting for our final clean up the contents of an immense mass of material so inexpressibly poor in gold, platinum, tin, etc., that human efforts could not have undertaken the task. Some idea of the extent of this concentration may be obtained when we remember that we have absolute evidence that some of the river channels in California have been cut down fully 2,000 ft. below the surface as it exists to-day. In such a valley with a width of 6,000 ft. from rim to rim, 6,000,000 cu. ft. of rock have been removed (6,000 × 2,000 ÷ 2) to carve out one running foot of its length, and all that remains may be a deposit 400 ft. wide by an average depth of 20 ft., or 8,000 cu. ft. to the running foot of the valley, or in other words 222,222 cu. yds. have been concentrated down to about 300 in round numbers (say 740:1). If the value of this be $1 per yd. the original material would only have contained about one and a third mills in the same quantity ($0.00135).

During this process a portion of the finer gold has been carried down the stream to flatter regions by the strength of the current, but the coarser has been retained, probably not far from its source, the extent of the deposit varying considerably with the character of the bottom of the channel, the bowlders in which act the part of riffles or lining in the artificial sluice box.

Modern Streams.—In the case of the modern mountain streams, the velocity and quantity of water have been so adjusted to the amount of material brought down, that the bulk of the finer debris or waste has been carried down to the valleys below, leaving only the coarser gravel and bowlders in the beds of the ravines filled in with a certain percentage of fine material in the interspaces, making the deposits comparatively shallow and rich, and there does not appear to have been much change from time to time in the conditions under which they were made.

Ancient Rivers.—When we come to study the ancient or buried streams, as they existed prior to the last great outbreak of lavas, in which the deposits are sometimes 400 ft. thick or over, we shall find evidences of great alterations in the flow of water from time to time, and the character and quantity of the material carried by it in suspension. If we trace the history of one of these old river channels, as read by the records it contains within itself, construed by the laws of nature in operation to-day, as in the past, we shall get a clearer idea of their structure than in any other way and be better prepared to open them for successful mining.

Bedrock; Rim; Grade.—The rock on which the gravel deposits lie is called the "bedrock" (see pl. 10, figs. 1 to 6), and the point where the bedrock and gravel or lava are seen in contact on the surface the "rim," as in pl. 10, fig. 4, *a,g;* fig. 5, *a.* The inclination of the bottom of the stream in the direction of its flow is known as the "grade" of the channel. By comparison with known mountain ranges, it will be seen that all streams have steep grades near their sources, becoming flatter and flatter as they approach the lowland valleys.

Bottom Gravels.—The first stage was similar to the conditions surrounding our modern streams. The wearing away of the hills was carried on comparatively slowly, the streams were of moderate velocity, carrying off the waste and leaving the coarse gravel and gold in the river beds. Large quantities of material brought down in flood time were gradually panned out during the drier seasons, as we know by the thin layers of iron sand, such as we see cleaned up by the lap of the stream on our present river banks and sea beaches, leaving the contained gold to enrich the bottom deposits. In this way the so-called "bottom" gravels, which are the exact counterpart of the modern placers, were formed, by the alternate flood deposits and slackwater panning. These bottom gravels are usually the only ones which will pay for the slow process of drifting; and sometimes, when too poor for this method of working, the entire "top dirt" has to be removed, even if it barely cover expenses.

The Deep Beds.—Then commenced a change in the surroundings. The quantity of sediment sent down had been so great that the streams at the mouths of the mountain valleys became filled up and the sediments began to accumulate in the valleys themselves, and from that time the material deposited assumed a flat grade, and the filling up of the bed of the stream proceeded at a rapid rate, creeping upward as the lower portions became more and more choked, until in some cases we find the thickness of these beds running up into the hundreds of feet. The gold in such material is naturally fine, and not having undergone the process of concentration to such an extent as the bottom gravel is much less in quantity for equal bulk of material; but there is no sharply defined line between the two, although the depreciation takes place rapidly until the general average value of the upper fine beds is reached. This results from the fact that there is to some extent a combination of both conditions at or near the point where the flat grade of the valley met the steeper slope of the mountain stream. As the valley filled up the river channel naturally became wider, the sheet of water thinner and in consequence less and less able to carry any burden in suspension, and it is easy to picture a wide sandy bottom with changing channels, bars and stagnant pools obstructed by snags and log jams. All the conditions are beautifully shown in the deep gravel workings at Sailor Flat in Nevada County, Cal. Pl. 12, fig. 7, shows a portion of the gravel bank at this place, and the constant changes of the channels can be read in the various deposits of sand and gravel lying unconformably on each other. The black marks in this figure show the position of pieces of petrified wood, which is found in enormous quantities in every conceivable form of petrifaction. Sometimes the trees are imbedded singly; at other points they have accumulated on bars and are massed together as we see them in modern streams after floods. In the shallow pools, the falling leaves have accumulated in the fine silt or mud, which now splits in very thin layers, and reveals a wonderful variety of leaves, the imprints of which are in an excellent state of preservation.

That there were occasional periods of drought when the water was comparatively free of sediment, yet with a velocity sufficient to pick up and remove the finer sand to a certain extent, is shown by the thin beds of fine gravel which can be seen on the face of the bank, and which by their superior richness indicate a certain amount of concentration, as in the bottom gravels. In a few cases these beds have become sufficiently thick and enriched to pay for drifting, as in the case of the Breece & Wheeler mine in California, of which a generalized cross section is shown in pl. 11, fig. 2. The upper tunnel was run on such a deposit, so cemented together by the iron which remained among the gravel, as a part of the concentrates, that it had to be crushed in a mill to save the gold. On pl. 10, figs. 1, 2 and 3, the so-called top dirt is shown by *c*, the bottom dirt being indicated by the solid black at *g*. The modern placer deposits are shown at *e*,*e*,*e*.

Pipeclay.—The beginning of the third stage commences with the renewed volcanic activity. The deposition of sand and gravel ceased and immense beds of clay, called by the miners "pipeclay," sometimes reaching a thickess of 200 ft., as at Cherokee Flat in Butte County, were laid down. At other points we have deposits of rounded bowlders like cobblestones, and it is not unlikely that these deposits were derived from the earlier outbreaks of the volcanoes, accompanied by excessive rainfall, which washed the ejected matter into the ravines, the finer material, as in all other cases, being carried furthest from its source. Most of the bowlders in ordinary placer ground are merely waterworn fragments of local rocks; the large proportion of quartz bowlders being due to their hardness. It is certain, however, that immediately succeeding these bowlders and clay, immense outbursts of lava poured into the river bottoms and filled them from bank to bank. A case where a bed of sinter (volcanic ash) separates unconformable gravel beds is shown in pl. 12, fig. 6, where the sinter bed appears to have been tilted after deposition.

Lava Cap.—Some of the lava beds are over 100 ft. in thickness and form to-day conspicuous objects in the landscapes of the gold regions of California, where they cap hills called "table mountains," from their nearly level summits as seen against the sky, and their precipitous sides. In pl. 10, figs. 1, 2 and 3, the pipeclay is shown by *b* and the lava cap by *a*. With the formation of the lava cap the process of filling was completed. Pl. 10, fig. 1, shows the order of succession—bottom gravel, *g;* fine gravel and sand, *c;* pipeclay, *b;* lava, *a*. The dark shaded portion shows a cross section of a mountain with its ravines as they exist to-day. The dotted lines *m,m,* show the hills on either side of the valley as they existed during the process of filling, and the horizontal dotted lines *r,s,t,* the continuation of the beds *a,b,c,* before they were worn away.

Modern Forms.—The carving of the country to its present form then began. The river waters on resuming their sway were diverted into new channels, and in most cases two streams were formed out of the original one. When lava flows into a confined channel such as a valley, the surface and sides of the stream in contact with the rocks, and especially the thinner edges, cool more rapidly than the central core, which, remaining in a plastic condition, is liable from the pressure behind to break the upper crust. This is consequently piled up in the center of the flow in rugged masses with a higher elevation than the sides. In this way there is formed a depression on each side of the flow next to the valley walls, each of which becomes a watercourse, indicated by the arrows in fig. 1. Owing to the superior hardness of the lava the cutting away of the new channels took place largely at the expense of the rocks forming the walls of the valley. By degrees these were eaten away below the level of the under side of the lava, when the process went on more rapidly in the underlying clay and gravel, which on being undermined allowed the lava to break off in vertical faces forming the characteristic bluffs of the gold regions. While this process was going on large quantities of the finer gravel of the original deposits were carried down to lower regions, taking with it the finest of the gold, the coarse remaining behind, and new placers were forming. We have evidence that there were two outbursts of lava, producing similar results. In the lower valleys the lava caps are entirely basaltic, but in the higher regions the first eruptions were either trachytic or rhyolitic. Both eruptions are well shown in Plumas County, as in pl. 10, fig. 1. When, after the trachyte outburst, the cutting of the new valleys had proceeded to about half its ultimate extent, the basalt outbreak occurred and invaded some but not all of the streams. In this case the gravel contains pebbles of the lava covering the older channel, *a,b,c,g*, along with the quartz gravel which is characteristic of both, but the lava cap is an exceedingly hard, heavy, compact, black iron-like basalt, while the cap of the older channels is a light-colored gray or reddish trachyte, much lighter and coarser in grain than the basalt, and very harsh to the touch on a newly broken face. Being much softer than the basalt and less liable to take columnar forms, it seldom presents such conspicuous bluffs as the basalt. In some cases the basalt lies directly on the gravel; in others there is the usual bed of pipe-clay. If this is absent we may presume that the region was near the source of the lava flow, and that the material forming the clay bed had been washed down to the lower country or had not been ejected in large quantities. The clay beds under the basalt at Cherokee Flat in the foothills of the Sacramento valley are very thick, while in Onion valley, near the summit of the Sierra Nevada, at an altitude of 5,000 ft., they are either very thin or absent. That the eruption of the basalt was later than the formation of the older gravel beds is absolutely proved by the occurrence in the Laporte region, Plumas County, which is located on a trachyte-covered channel of great length and prominence, of a basalt cone overlying a bed of gravel, the pipe or neck of which was penetrated by one of the deep tunnels, and the gravel bed "drifted" all around it, some of the gravel being even surrounded by thin sheets of lava at the outer circumference of the neck which formed the vent. At this particular locality the trachyte cap had been eroded. The structure is shown in pl. 10, fig. 6, where *a* is the gravel and *b* the lava cone with its neck or pipe ascending through the bed-rock and gravel.

Since the basalt outburst, which was of enormous extent, covering hundreds or even thousands of square miles in California, Oregon and Washington, there seems to have been no serious volcanic disturbance, and the denudation went steadily on up to modern times, leaving a mountain range in the case of each flow, of which we have a plan in pl. 11, fig. 1, which represents two modern streams *R,R,* and the buried ancient river *SU,* with those portions of its lateral streams which have not been worn away in the general denudation. *L* represents the lava and pipeclay capping; *G* the gravel, and the heavy black lines that portion which is known as the bottom gravel and is suitable for drifting. As the denudation has not progressed evenly, it may happen that the gravel at some points has not been exposed, and the lava apparently lies on the bedrock, as at *U.*

"*Overflows.*"—In other places it may be exposed on one or both sides of the ridge, or the lava cap may have entirely disappeared, as at *G,* showing the gravel on the surface all the way across the dividing ridge. The richer bottom gravel found in the lateral branches of the stream will naturally be exposed as at *T,T.* A common term for these exposures is an "overflow," as though the gravel had been squeezed out of the hill, but that this expression is erroneous is shown from the fact that the grade or inclination of the bedrock dips into the hill, as shown in pl. 10, fig. 5, where *a* is the so-called overflow and *g* the main channel to which it leads. The only exception to this rule is where a remnant of the head of one of these lateral branches is left on the other side of the modern ravine, which has cut the lateral in two without removing the upper portion. Unless this lateral was a large stream, the gravel left will be only a small patch. If a large stream it may present all the features of the main channel if it happened to be covered with lava (which does not necessarily follow).

Laterals.—We also frequently hear miners speak of two or more channels in the hill. Such a condition of things is against all probability, the dividing of a stream into several branches being almost exclusively confined to those portions which have a flat grade, and does not occur where the grades are such as we find in mountain regions. What does occur is shown on the line *OP*, pl. 11, fig. 1, where if *OP* were a tunnel it would cut two bodies of gravel, but they would be only branches of the same stream, the first one encountered, if the tunnel started at *O*, having a steeper grade than the second, as lateral branches of a river have almost universally heavier grades than the main river. If there is a sudden expansion of the lava cap, and a more than ordinary width between the rims, such a proposition is almost sure to be found beneath the surface. Pl. 10, fig. 2, represents such a structure as would be found on the line *OP* of pl. 11, fig. 1, where we have two gravel banks *c*,*c*, under one lava cap *a*. Without going into further detail it may be said that all these features can be reproduced in a model, thus proving the general accuracy of the theory of origin.

Faulted Ancient Channels.—It is not to be expected in a country which has been the seat of such comparatively recent volcanic activity that there will be an absence of faults and dislocations in the channels. Unfortunately these are numerous and often interfere with the successful working of otherwise valuable property.

Three examples of such faulting are shown on pl. 11, in figs. 4, 5 and 6, all taken from the mining regions of Plumas and Sierra counties, Cal. Fig. 4 shows the situation at Grass Flat, near Laporte. Here the fault *AB* has cut the channel across its general direction, the left hand portion in the figure having been raised, or the right hand portion depressed, as shown. The bedrock at *e* consequently acted as a dam, and backed up the water flowing down the bedrock, till it formed an underground reservoir *P*, the drainage outlet of which near *A* was so near the surface that grassy meadows were formed at *C*, sustained by the perennial water in *P;* hence the name. It was impossible to work the submerged ground until a long and expensive drain tunnel had been run.

Fig. 5, same plate, shows a fault running lengthwise of the channel in the pit at Laporte, *ab* being the dislocation, *d* the bedrock, *c* the gravel, and *e* gravel from the later series of gravels previously described, barren and almost entirely devoid of quartz bowlders. Such a fault is not so detrimental to the working of the deposit, as it can be followed upstream without interference; but in such a case as in fig. 6, where the dikes *c,c,c,* have broken through and dislocated the gravel *g,* the drifting operations on the bottom gravels, shown in black, became so expensive that while the gravel was rich the expense involved in hunting the continuation of the channel beyond each dike consumed all the profits.

Folded Gravel Beds.—Instead of sharp faulting, gravel beds sometimes show evidence of disturbance in the shape of folds, either in smooth long sweeps or in a complication of smaller waves (pl. 12, figs. 1 and 2). Folds are, like faults, often accompaniments of volcanic eruptions, and the gravel may be dragged with the lava sheets.

HILLSIDE DEPOSITS.—These have the same origin as those just described, and are in fact in many cases, if not in all, only their lower portions, which, being at the time of the lava flows below the level of the sea or interior lakes, or for other causes, escaped the lava cap which buried the upper portions of the streams. As the land rose the streams began to cut down into these deposits, concentrating the contained gold on the bars and riffles along their sides, which sustain a constant renewal as the rainfall washes the hillsides down into the river bottoms.

There is one class of hillside deposits, of local origin, in which part of the gold has, in descending, been concentrated in pockets formed where favorable rock formations occur, as in the case of slates dipping into the hill. These pockets have since been covered over with soil and debris, and some of the gold may have been carried out of them and further down the hillside, spreading out in fanlike shape. In searching for such pockets the prospector pans out samples of dirt along the foot of the hill, noting where pay or at least some gold begins and ends; then runs a corresponding line of pan tests parallel and higher up, marking the limits of the pay. If this second line is, as is probable, shorter, it will indicate a triangle near the apex of which the pocket is sought for by trenching.

SEA BEACH DEPOSITS.—These are mainly derived from ancient gravel beds, which are reconcentrated by being broken down by the impact of the waves, and sorted by the waves and tides. As these deposits are in most cases the furthest removed from their original source, the contained gold is of the very finest character, and consequently the most difficult to save by mechanical appliances; these difficulties becoming steadily greater as the size of the particles of gold diminishes. If, however, the ocean were operating on solid rocks of any of the various kinds which contain gold, there is no reason why we should not find deposits of conglomerate with coarse gold, gradually fading out into finer and finer sediments with finer and finer gold, as the beds recede into deeper and deeper water, to which only the finer sediments would be carried by the reflux of the waves, or undertow. And further, if the coast line which is being destroyed be gradually sinking, as we know to be the case in many localities, just as it is rising in others, we should have such a bed of conglomerates, consisting of the larger waterworn fragments, extending over a large area, both in breadth and length, fading out on its upper surface into the finer and poorer material, and in some such way as this the beds of gold-bearing conglomerates may have been formed. The destruction of the shore line would be more rapid and the deposits more extensive than in those cases where the coast is gradually rising, as in this instance the same material would be longer exposed to the abrading action of the waves, the formation of conglomerates would be less, and of fine sediments more extensive, and the gold particles would suffer more abrasion and be reduced in size.

In searching for gold-bearing beach sands, these are naturally to be looked for under bluffs of gravel and conglomerate. A favorable time is after a strong wind blowing along the coast line, which makes cross waves, advantageous for concentration. The best spots will usually be those marked by lines and patches of black sand, which are almost always concentrated wherever any gold is.

Besides the beach sands proper, gold-bearing sands have been worked, off-shore, by dredging, on the coast of New Zealand.

GLACIAL DEPOSITS.—Under this head are included all those deposits in which ice has played a part in their formation, and we have consequently evidences of more complicated action. As in all other deposits there must be, to start with, a belt of gold-bearing rocks to be removed, or the resulting mass will be barren. Given such a belt of rocks there is no reason why glacial deposits should not contain gold, just as those which have been derived from aerial erosion, but we are likely to find a greater variety in the physical appearance of the gold, either smooth or angular, coarse or fine, because it has been released from the containing rocks by a variety of methods.

Glaciers transport to the lower valleys, first, the rocks or bowlders which are detached by frost from the exposed bluffs which form their boundary walls; and secondly, the rounded bowlders and sediment which are formed by their grinding action on the rocks over which they travel. If they cross a belt of gold-bearing rocks they must discharge into the valleys the contents of these rocks, along with the remains of the rocks themselves, either in the stream which issues from their "foot," or into the terminal moraine, if they terminate on land; or the contents may be widely dispersed by floating ice or icebergs if they terminate in the water.

While morainal deposits may be unsuited to mining ventures, the river deposits resulting from glaciation may be worked by machinery suitable to the retention of the excessively fine gold, which must necessarily be lost in the agitated waters of a sluice box.

GRAVEL MINING.

What Constitutes a Workable Gravel Proposition.—The elements which go to make a workable gravel mine are: 1, the amount of and distribution of the gold in the gravel; 2, the width, continuity, and extent of the deposit; 3, the character of the bedrock; 4, the depth of the bedrock in relation to the neighboring ravines; 5, the grade of the channel or bedrock and freedom from faults; 6, the available dumping ground for the waste material; 7, the character and amount of the water supply. While all these elements enter into every working proposition, they have widely varying values according to other conditions.

Placer Mining.—This term is sometimes used to include all methods of working placers or gravel deposits; it is here applied in the usual and more restricted sense, excluding hydraulic mining (which involves the use of water under pressure) and covering only those methods of gravel washing (mainly in recent placers) in which the water depends for its working qualities simply on its quantity and the grade of the sluice boxes in which it is used. The altitude of the source of supply cuts no figure, except as it affects the grades on which the gravel can be washed. As this condition involves the handling of every pound of gravel by manual labor, or practically so, it is only the richer and consequently the shallower deposits which are available, such as the beds of ravines, river-bars and the shallower adjacent deposits. When the former become too poor to work, the miner says he has lost the channel. It is not always meant that there is no longer indication of gold, but its concentration is not sufficient to warrant handling by such slow methods. For the "pan" and the "rocker" a very small quantity of water may be sufficient, and the amount of material handled daily is so comparatively small that the question of dumping ground does not trouble the miner, neither does the grade of the channel, nor disturbance by faults, because his appliances are movable on short notice; and the same may be said of the "long tom" or sluice box into which the gravel is shoveled when working on a somewhat larger scale; but the depth and character of the bedrock may be all important, as it is on the bedrock that the miner finds his chief reward. If he is unable to reach it on account of the influx of water, the cost of wing-damming the stream or pumping may eat up all the profits, and after all the bedrock may be such that it has not been able to retain the gold.

A perfectly smooth sluice box would permit all the gold to escape, and to avoid this the bottom is either provided with riffles in the shape of slats, or paved with bowlders and sometimes with wooden blocks cut across the grain. All of these methods provide crevices into which the gold drops as it is swept through the boxes by the force of the water, and is thus prevented from escaping. The bedrock in a stream acts in the same way. If perfectly smooth, as at *E*, pl. 12, fig. 3, it may be absolutely clean, there being no obstruction to give anything a retentive hold. A case of this kind occurred at Gibsonville, Cal., where a long tunnel was run to open a piece of ground lying between two mines which had paid handsomely, only to find on reaching the channel a perfectly smooth bedrock and almost perfectly barren. The most favorable condition is a bedrock pitching down stream as at *A*, in the same diagram, so that all the crevices are presented to the impact of the descending material. In such crevices the gold is literally jammed into the rock, and it will usually pay to mine from 6 in. to 1 ft. of its surface along with the gravel, especially if it be soft or, as the miners say, "cheesy." A similarly good bedrock is formed by the worn surfaces of limestone *B* and *C*, which being eaten out into irregular holes act as perfect riffles and give good results, as at Shaw's Flat and Columbia, Cal.; but less satisfactory returns are usually had from slaty rocks pitching up stream as at *D*, especially if the rocks be hard, as objects slip readily over such surfaces. The application of these principles will soon enable the prospector to work out the problems for himself and test his theoretical knowledge by experience. "Potholes," which are smooth round pits worn in the solid rock by the constant fall of water charged with sand, or the grinding action of an imprisoned bowlder, like a pestle in a mortar, are apt to be swept clean of any valuable contents. Bowlders in the bed of the stream of course act as riffles, but when large they add materially to the cost of mining, requiring derricks for their removal and much extra labor. If the gravel is cemented, as is not infrequently the case, it may be necessary to leave it exposed to the air to slack, if the cementing material (as clay) is such as will yield to such simple treatment; or it may be even necessary to pass it through a stamp mill; but deposits of this character are not likely to attract the placer miner, as they involve the outlay of considerable capital, which is only warranted by extensive explorations and the proof of extensive deposits.

Gold Pan.—Prospecting is usually done with a large shallow iron pan about 16 in. or more in diameter across the top, by 2¾ in. deep, with flaring sides, stamped out of a single piece of charcoal sheet iron, called and well known as a "gold pan." Such a pan filled with gravel and fairly heaped in the center will hold about 25 lb. and about 150 pans are usually considered equal to a cubic yard (the number varies with the size of the pan); values of gravel being estimated either by the pan or by the cubic yard and not by the ton. A cent is a piece of gold about $\frac{1}{32}$ in. square and half as thick as a $5 piece, as an approximation to give some comparative idea of size and value. With these figures the prospector can form some idea of what he may be able to do daily, as soon as he has found out how many pans of dirt he can wash daily or how many yards of gravel he can shovel into a sluice box, both of which will vary according to the locality, the character of the ground and the distance to water. Persistent panning is the only thing which will test a gulch. Just as one swallow does not make a summer, one pan of good dirt does not make a mine; nor does the failure to find gold in the first pan prove the locality to be barren. As a usual thing an abundance of quartz pebbles in the gravel is a good indication, and when these are accompanied with an abundance of black sand, minute garnets (transparent and red) and small rounded shot-like pebbles of chrome iron, it is not well to be easily discouraged. The signs of course may fail, but they are what the Mexicans term *pintas* or colors, and call for a thorough search. If the deposits are too poor to be worked by these primitive methods, but are shown to carry gold (as proved by extensive panning) over a large and well defined area, we may resort to the methods employed in *Hydraulic mining*, by which we can move and wash per man so vastly an increased quantity of gravel, that ground very poor in its average contents may prove remunerative; but we must remember that the hydraulic miner always calculates on a rich bottom streak which has to bear the loss, if any, involved in removing the top dirt, which may sometimes be a valueless clay; and generally stops work on the bank when the limits of this bottom streak are reached laterally

By hydraulic mining we understand the use of water under pressure; that is to say, at some suitable point the stream is turned into pipes which convey it to the ground to be worked; and by this means we take advantage of the weight of the water in the pipes to force large quantities through a nozzle, and secure a power to cut away the gravel bank without the aid of pick or shovel, and wash the material into suitable sluices. According to the pressure or head and the amount of water used, a miner's inch of water* will wash from 3 to 10 cu. yd. of gravel. The "head" is the difference in height between the point at which the water enters the pipe and that from which it is discharged; while the "pressure" is equal to the weight of a column of water of this height multiplied by the cross sectional area of the pipe, both in feet, by the weight of 1 cu. ft. of water, from which must be deducted the loss caused by friction (called the friction head) against the sides of the pipe, which will be governed by its length, size and condition of its interior as regards smoothness and cleanliness. This loss is greatest in small pipes.

It is evident that the grade of the gravel to be worked will depend on the number of yards which can be moved daily by a given quantity of water, and that this will depend on the pressure under which the water is used. To increase this pressure we have to gain altitude, and this forces the head of the water supply further and further back into the mountains; and as this supply must be constant during time of rain and drought alike, we are compelled to build reservoirs, into which the various minor sources of supply are collected and held in reserve. When we remember that mines such as those at North Bloomfield and Cherokee Flat, using 2,000 miner's inches or over, consume daily more than 33,000,000 gal., or water sufficient for a city

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*** 2,230 cu. ft.—a tank 12x12x15 ft. (See Chapter XVII. on Water.)**

of 350,000 inhabitants, it is not to be wondered at that there must sometimes be an expenditure of $400,000 or $500,000 on the water plant before a yard of gravel can be washed. With such a heavy preliminary expenditure on water, besides the cost of tunnels, sluices, buildings, etc., at the mine, annual repairs and working expenses, we must have correspondingly large deposits of gravel to justify the enterprise. The North Bloomfield Company in 1879 used 931,000 miner's inches of water (15,000,000,000 gal.), each inch of which moved on an average about 4 cu. yds. of gravel, or a total of about 3,724,000 cu. yds., equal to 2,310 acres 1 ft. thick, 231 acres 10 ft. thick or 23 acres 100 ft. thick. The actual area removed was probably about 7 acres some 300 ft. in depth. These are of course outside figures, but they emphasize very strongly the necessity of a thorough inspection of the water supply, and the facilities for disposing of or impounding the debris, before opening an extensive hydraulic proposition. It is time enough to test the quality of the bank when the water and debris questions are settled.

It would be beyond the proper scope and purpose of the present work to enter into the details of this highly developed method of mining. For such information the reader is referred to "A Practical Treatise on Hydraulic Mining in California," by Augustus J. Bowie, Jr.; "Practical Notes on Hydraulic Mining," by Geo. H. Evans; "Manual of Hydraulic Mining for the Use of the Practical Miner," by Theo. F. Van Wagenen, and other books and current literature.

Drift Mining.—There are, however, large bodies of gravel which cannot be handled by purely hydraulic methods for one or other of the following reasons: (1) The water supply may be totally inadequate, or the deposit may not justify the expense of bringing it on the ground; (2) the dumping ground also may be inadequate, or local interests may prevent it from being made available; (3) the top dirt may be so thick and worthless as not to warrant its removal; (4) the deposit may be entirely capped with lava, which cannot be economically removed; (5) the ravines on either side of the ridge containing the channel may not have been cut down deep enough to enable us to put in a tunnel on a hydraulic grade, or they may be too flat for suitable washing sluices; or (6) the ravines may be so high that their bottom is above that of the old channel, as in pl. 10, fig. 3, and we cannot gain access by a tunnel under any conditions.

In this last case it will be necessary to work the mine with pumping machinery through either shaft or incline, of which latter method the successful Damascus mine in California is a good example; but in this instance the incline followed the channel on its descending grade, and did not involve the dead work of shafting, the use of which cannot be said to have been more than partially successful. In all the other cases bedrock tunnels are resorted to, which are run through the rim on a water grade until the channel is reached, when the gravel is extracted and handled in cars very much in the same way as a coal mine is operated. Water can be accumulated until sufficient gravel is taken from the mine, and a clean up can be made daily, weekly or monthly as the case may be. Having to wash so small a quantity of gravel, comparatively speaking, the sluice boxes may be small, and but little water is required under very slight pressure or none at all, so that the plant is not necessarily costly. Given the gravel, the success of drift mining depends on the location of the tunnel with regard to the bottom of the channel, for many months of labor and many thousands of dollars may be expended on a tunnel which may be valueless if it should unluckily enter the gravel above the bottom of the channel, which it is unable to drain and render workable, as is the case with the lower tunnel in pl. 11, fig. 2. It is infinitely better to be too low than too high, but the location of these tunnels is a problem which will severely task the engineer and geologist combined.

The greater number of the drift mines are located well up in the mountains, on the steeper grades near the head of the old channels, and it is only here and there that the shape of the country has caused the removal of the lava cap and exposed the underlying gravel in such a shape that hydraulic work was possible, so that long stretches of the ancient river lie between these isolated spots where the altitude of the bedrock has been ascertained. In these unexplored sections it is only by inference that we know the channel to exist, and numberless abandoned tunnels show how little the miners were acquainted with its structure. To open a mine in such a situation is a delicate task and can only be safely done after boring across the general line of the old river, to ascertain the true position of its deepest portions, and its depth from the present surface. But before this can be done we must determine the course of the old stream so that we may be sure that the bore holes *are* located across, and do not follow it lengthwise. To make certain of this the rim of the channel on each side of the ridge must be carefully traced out and platted as in pl. 11, fig. 1, noting where the lava, pipeclay or gravel shows in contact with it; and the survey should be extended to include the bed of the ravines on each side of the ridge; levels should be run the entire length of the rim and the creek bottoms, with full notes of the rocks exposed in the latter, and these levels will disclose the exposed ends of the lateral streams *T, T,* which will outcrop in the lowest parts of the rim. When such a survey is platted we can approximately draw in the center line of the main channel, and of its branches, on the plan; which will cover only the main stream where its rims are approximately parallel, or the main stream and a lateral if there are wide expansions as at *OP,* and an exposure as at *I*. From these data we can draw an approximate cross section at any point, such as pl. 10, fig. 4, in which the rims are at the same altitude, making the unseen slopes of the old river *af* and *gf*, the same as those visible between the rim *a* and the bed of the creek *h*. It is evident that under such conditions the length of a horizontal tunnel to tap the bottom *f* would be equal to the width of the channel between the rims *a g*, as the triangles *dca*, *abf* and *fbg* are all similar. More difficulty will attend the determination of the length on such a line as *OP*, pl. 11, fig. 1, but the solution is practicable as an approximation. Of course this is not an absolute method, as it is based on the probability of the same rock taking the same or practically the same slopes when worn away under similar conditions, and this may not always be the case; but it will do to determine whether a tunnel is feasible, as, if the distance to the creek, as from *e* to *h*, is less than one-half the width between the rims, the probabilities are altogether in favor of the conditions shown in pl. 10, fig. 3. If the rims are of different altitudes, as in fig. 3, the center of the old channel will probably be located proportionately nearer the lower rim.

If this preliminary test prove satisfactory we can locate the borings with certainty, and they should be not less than three in number, probably five or upwards, as their respective depths may indicate. To ascertain the probable grades of the channel we must extend our investigations to the beds of the creeks on each side of the ridge, as it is important to know beforehand whether the country is faulted, whether the channel is choked by bowlders, and whether we are likely to encounter flat, moderate or steep grades in the ground when opened, as bad faulting might lead to failure, and might not be disclosed by the borings; bowlders are more difficult to handle even than in the open air; and the grades, as we have seen, largely influence the amount of gold in the bedrock gravel. There will probably be under any circumstances a slight flattening at the junction of each lateral branch with the main stream. By examining the modern ravines we may possibly find in each a band of rock as *F*, pl. 11, fig. 1, which is easily recognizable, and by using this as a common base, and following each ravine both up and down with a line of levels, we can arrive at a very fair idea of the probabilities where we cannot see the bed of the channel from what is visible in those of modern origin, especially if we find the rock strata occurring in orderly succession in each stream, on all points on which we desire information, whether it be faulting, dip of the rocks, accumulation of bowlders or grade. It would be possible to enlarge on this theme almost indefinitely, but enough has been said to furnish the key to the methods of exploration, which must be varied to suit each particular locality; and the miner, by the aid of this key, can study for himself the chances of success. The boring is not difficult or expensive, and will be nearly as satisfactory as an open shaft, which will cost more, take more time to sink, and might not after all be suitably located. The trachytic lavas seem to abound in choke-damp or carbonic acid gas, making good ventilation in the shafts imperative.

Machine Washing.—The operations just spoken of are based on the use of large quantities of water in open sluice boxes, in which there must inevitably be a loss of fine gold, as the records of the undercurrents show. Workings on a large scale have demonstrated the presence in gravel of gold so fine that it is not visible in the pan to the naked eye, just as reasoning demonstrated should be the case in gravels which owe their origin to glacial action, or which contain the products of the decomposition of pyrites. This very fine gold must certainly be swept away in the swirl of such streams as are used in either hydraulic or drift operations, as it takes a long time to settle even in still water. To save such gold it must be brought into contact with quicksilver in such a way that it cannot escape amalgamation. Such is the intention of all mechanical appliances which have been proposed. It is sufficient to say that by their means gold has been saved which is so infinitely fine that it can be applied as a paint on paper, producing a gilding smoother and thinner than gold leaf. Its presence having been demonstrated, the apparent absence of gold in the debris from localities where auriferous pyrites have been largely denuded is explained, and the metal is probably much more widely disseminated than has heretofore been supposed. The discovery of gold in this condition and the ability to save it may have far-reaching results in gold mining, especially as in talcose rocks and serpentines much fine gold occurs as films of infinitesimal thinness, which increase the value of the assays, but is exceedingly difficult to save in the mill. In a piece of solid rock we have the material controlled, no matter how fine it may be, and can detect its presence by assay of even small samples, but unfortunately we have no way of concentrating gravel so as to get suitable assay samples except by laborious processes, and may have to depend on working tests for the detection of such gold.

Test for Fine Gold in Gravel.—Probably the best experimental method would be to wash a large quantity of gravel, previously measured, in the same water, never allowing any of the latter to escape, but using it over and over again, retaining only the finest sands by a proper system of screens; and when a suitable quantity of sands had been accumulated they might be treated by the chlorination process, which dissolves every trace of fine gold in the mass and saves nearly all of it. The result obtained divided by the number of yards of gravel concentrated would give the average value per yard, and this might be greatly more than shown by test workings in the sluice box. The difference between the two results would be the invisible gold.

All machines suitable for this class of work use much less water per yard of gravel washed than is necessary in hydraulic operations, and this is a most important item if the deposits are so situated that pumping must be resorted to, as a good head of water (pumped) will cost from 15 to 30 cents per miner's inch according to the height to which it must be raised, and the length of the pipe through which it has to be forced, or the cost of labor and fuel.

Dry Washing.—The difficulties attending the separation of gold without the use of water, or as it is called rather curiously, "dry washing," are enormous, and it can only be attempted on the richest kind of material with even a shadow of success. The great mistake is made, as in so many other mining machines and processes, originated by persons who as a usual thing are totally ignorant of what has been attempted by others before they became inoculated with the idea, of supposing that the careful manipulation to which the inventor subjects the small quantity of material on which he operates can be repeated on a large scale in actual mining. For success it is absolutely necessary that the material should be absolutely dry and thoroughly pulverized, as any moisture, especially in clayey soils, will prevent the grains of gold from separating from the earthy matter.

Hydraulic Elevators.—Not a few localities in which gold is found abundantly present difficulties due to insufficient room below the deposit, on which we can construct sluices of sufficient length to properly wash the gravel, and in which we can deposit the debris after it is washed. In such cases we are compelled to resort to hydraulic elevators, by which the gravel is lifted from 30 to 50 ft. or over and there dumped into the sluice boxes, which can then be from one-eighth to a quarter of a mile longer than would otherwise be possible. The method is of course only available on moderately coarse material, as the diameter of the tube and the force of the lifting jet prevent the passage of very coarse material.

River Bars.—These usually form at the junction of two streams, or just below the point at which the current is deflected from one side of the river to another. If a stream is auriferous, these bars are often rich in gold, which is brought down in flood time from the upper country, often many miles. The Snake, Columbia and Fraser Rivers are good examples of such streams, in addition to the well known California localities. On the Fraser, at Yale, the amount of fine gold brought down by the stream, to localities not less than 50 miles from the source of supply, is so great that the surface of the pebbly bars, which act as riffles, pays to work over annually; and a panful of moss gathered from the bowlders exposed between high and low water mark, will show from fifty to several hundred colors. It can easily be understood from this that bars which have remained untouched for years may therefore be very rich; immensely so in some instances. Hill's bar, below Yale, must have yielded many dollars per cubic yard, when seven men with three rockers took out $90,000 in 90 days. These bars may be so near the level of the water, that it interferes materially with working them. In such cases *Wing dams* are resorted to. These structures consist of a wall of brush and bowlders, built out in the shallow water at some suitable point above the ground to be worked, to divert the current and inclose a block of desirable ground. The current is used to run water wheels which pump the inclosure dry or sufficiently so to enable the working of the gravel to be successfully carried on. Such structures are of course only available during a low stage of water, and any sudden flood is apt to wash them away, making the operation risky, as a whole season's work, as well as the money invested, may be lost in an hour. In some few cases it may be possible to divert the stream, which is a more satisfactory method if the ground rendered available is sufficiently extensive to justify the expense. Probably one of the most successful enterprises of this kind was on the Cape claim near Oroville, in California, the owners of which in early days turned the Feather River into a flume 40 ft. wide, and cleaned up from $600,000 to $700,000 in one summer's work, although they lost the flume during a sudden freshet before the job was completely finished.

Dredging the bed of the stream is sometimes resorted to, it being reasonable to suppose, from all we know of gravel mining, that if the bars in a river are worth working, the gravel beneath the surface, which we cannot see, must also contain gold in paying quantities. Such dredges are in successful operation in several localities, both in America and elsewhere. Some machines can handle as much as 150 tons of gravel an hour; but the quantity, as well as the success of the dredge, will depend largely on the character of the river bottom. If it is encumbered with large bowlders, it may be impossible to work it to advantage, and the best results will be obtained in moderately fine material of a uniform character.

Adjustment of Saving Appliances to the Size of the Gold.—In any appliance for working gravel by water, the measure of success will largely depend on the careful adjustment of the amount of water used, and the grade of the tables or sluice boxes, on or in which the gravel is washed, to the size of the particles of gold in the material under treatment; and the finer and finer these become the more accurate must be the adjustment. There are many localities where the entire bulk of the gold is so fine that we have to resort to the use of the principles involved in the undercurrent, or to the use of amalgamated plates, or to a lining in the sluice box, made of inch boards bored full of holes, or to blankets, burlaps, or rawhides with the hair pointing up stream, as in China; or to cocoanut matting laid over a coarse linen cloth, as in New Zealand. The localities where this kind of gold is chiefly found are along the banks of large rivers and sea beaches, and the gold is frequently accompanied by such large quantities of "black sand" (consisting of magnetic and titaniferous iron derived from the decay of granitic rocks) that these, in any stream weak enough to save the flaky gold, choke the saving appliances with a solid bed of iron sand, through which it is impossible for the gold to sink and reach the riffles or quicksilvered surface below, and it is consequently passed on through the sluices, on the top of the sand. The only method of improving this state of affairs is to first extract the iron sand, or that portion of it which is magnetic, from the material under treatment, so that the remainder may be finished in a much gentler current than would be necessary to carry off the iron sand, and yet sufficient for the task of separating the quartz sands from the gold. Various appliances have been designed to work these sands, but until recently they have met with but a very limited share of success. There appears, however, now to be a prospect, by the use of magneto-electrical appliances, of making more progress in the solution of the problem, which is a fascinating one on account of the abundance and widespread area of the material, and its constant restoration by the operations of nature.

In working this class of material, the aim should be to make the machinery as light and portable as possible, so that it may be readily moved to the material instead of hauling the material to the machine, as this rapidly becomes an expensive process, for while the material may be abundant it is usually of no great thickness at any one point. This is particularly the case in beach sands, which may be scattered by heavy storms and afterward reassorted by the gentler action of the waves in more moderate weather, which pan out the lighter particles of sand, leaving the gold and iron in a concentrated form.

Throughout this chapter especial attention has been paid to gold, but the same principles of prospecting and working are equally applicable to all minerals found in similar conditions, such as tin, platinum and its allies, and even native silver as at Planchas de Plata, in southern Arizona. These metals are, however, all worked in open air placers, and have not yet been found, so far as the writer is aware, in paying quantities in drift operations, though platinum and iridosmine are found in nearly all the gravel diggings of California, along with occasional diamonds.

CHAPTER XVII.

WATER AND ITS MEASUREMENT.

Water plays so important a part in all mining operations that the available supply becomes a vital question, whether for gold washing, for power or for milling and domestic use. The following simple rules for ascertaining the quantity and estimating the power which can be derived from it will be found useful in this connection.

Unit.—Water may be measured by the gallon, the cubic foot or the miner's inch, and the use of the special term depends somewhat on the purpose to which the water is to be applied; thus, city supplies are usually estimated in gallons; irrigation quantities in cubic feet or miner's inches, and for mining operations on a large scale almost universally in inches.

Weight.—A cubic foot of fresh water, with the barometer at 30 in., weighs, at 39° F., 62.423 lb.; 62.367 lb. at 60°; 62.218 lb. at 90°; and only 59.7 lb. at 212°, a fair average being 62.33 lb., but usually called 62.5 lb. for convenience. Below 39° the weight decreases, so that at 32°, or the freezing point, it is only 57.2 lb. and its specific gravity only 0.9195. Sea water weighs from 64.02 to 64.27 lb. per cu. ft.

Bulk.—A gallon of water U. S. standard contains 231 cu. in. This is equal to a cylinder 7 in. high by 6 in. in diameter, or to a cube 6.1358 in. on the edge, and is 0.13368 of 1 cu. ft., so that 1 cu. ft. contains 7.48 gal., or in general terms 7½ gal.

Miner's Inch.—This is the quantity of water which will flow through an orifice in a 1-in. board, 1 in. sq., in 24 hours. In selling water, however, the water companies sometimes make rates by the 10-hour and 12 hour in., users not requiring it for the full 24 hours. The inch varies according to the pressure under which it is discharged. The term arose in California in the early days of gold mining, but the customs of different camps varied, as the "head," by which is meant the distance from the top of the water to the center of the hole, ranged from 4 to 7, or sometimes as much as 8 in.. The 4-in. head is still used in the irrigation districts of southern California, but the 6-in. head has of late years been considered the standard in mining estimates. Under a 4-in. head, through an orifice 1 in. sq., the discharge is equal to 1,728 cu. ft. or 12,925 gal. in 24 hours. The 6-in. head discharges about 2,150 cu. ft., or 16,082 gal. in the same time. The North Bloomfield reports, as the results of experiments by Hamilton Smith, give 2,230 cu. ft. or 16.680 gal. The measurement is made by leading the water into a tank, provided at a height of 2 in. from the bottom with a horizontal slot of given dimensions, say 2 in., which can be closed by a moving bar, sliding in it. If it is desired to measure *all* the water, this bar is slid back until it allows the water to escape at such a rate that the surface stands constantly at the required head, and the size of the aperture can be read off immediately by graduations on the bar. If the slot is 2 in. high and the bar has been slid back 60 in. the flow will equal 2 × 60 = 120 in. If it is desired to measure off a definite quantity the slot or gate is properly adjusted, and the waste gate opened until the requisite head is obtained in the measuring tank.

Pressure.—Water exerts the same pressure in all directions. In pipes the pressure is equal to the area of the pipe in feet, multiplied by the vertical height of the pipe (not by its length), and the quantity thus ascertained by 62¼ lb. (the weight of 1 cu. ft. of water), or, if the area is calculated in inches, by 0.432292 of a pound (the weight of a column of water 1 in. sq. and 1 ft. high), and this by the height vertically of the pipe in feet, the result will be the pressure per inch in pounds. Moving water exerts less pressure than when it is stationary, but when cut off suddenly puts a greater strain on the pipe than the simple stationary load, to which the momentum of the moving column has been added.

The following table (condensed from Trautwine) gives the weight of water, at 62½ lb. per cu. ft., contained in 1 ft. of pipe of different diameters from 1 to 36 in. The fractions of inches are omitted, as seldom used in mining operations.

WEIGHT OF WATER IN 1 FT. OF PIPE.

Diam. in Inches.	Weight, Lb.	Diam. in Inches.	Weight, Lb.	Diam. in. Inches.	Weight, Lb.	Diam. in Inches.	Weight, Lb.
1	0.33952	10	33.952	19	122.56	28	266.18
2	1.3581	11	41.082	20	135.81	29	285.53
3	3.0557	12	48.891	21	149.73	30	305.57
4	5.4323	13	57.379	22	164.33	31	326.27
5	8.4880	14	66.545	23	179.60	32	347.66
6	12.223	15	76.392	24	195.56	33	369.74
7	16.636	16	86.916	25	212.20	34	392.48
8	21.729	17	98.121	26	229.51	35	415.90
9	27.501	18	110.000	27	247.51	36	440.00

The quantities increase as the squares of the diameter of the pipes. Thus a 36-in. pipe contains four times as much as one 18 in. in diameter—440 to 110.

Discharge Under Head.—The discharge of a pipe from the bottom of a reservoir is found by multiplying the area of the orifice by the velocity of the stream, which depends upon the head or pressure. If the opening is circular multiply the square of the diameter in feet or inches by 0.7854, and this will be the area in feet or inches. The velocity of discharge is ascertained by multiplying the square root of the head in feet by 8.03, and the result will be the velocity in feet per second. The following table (condensed from Trautwine) gives the velocity of discharge in feet per second for heads of from 50 to 500 ft. Intermediate heads can be made proportional to the nearest figures:

VELOCITY OF DISCHARGE UNDER DIFFERENT HEADS.

Head.	Velocity Per Second.	Head.	Velocity Per Second.
50	56.7	125	89.7
55	59.5	150	98.3
60	62.1	175	106.0
65	64.7	200	114.0
70	67.1	225	120.0
75	69.5	250	126.0
80	71.8	275	133.0
85	74.0	300	139.0
90	76.1	350	150.0
95	78.2	400	160.0
100	80.3	500	179.0

Power of Falling Water, (on the assumption that one horse power is equal to 33,000 lb. raised 1 ft. per minute).—Multiply together the number of cubic feet of water which fall per minute; the vertical height of the fall or head in feet; and the number 62.3 (the weight of 1 cu. ft. of water in pounds); and divide the result by 33,000. Thus 800 cu. ft. of water falling 16 ft. would give a theoretical horse power of 24.17. But water wheels do not realize all this power. Undershot wheels only realize from one-quarter to one-third; breast wheels about one-half; overshots, from two-thirds to three-quarters; turbines and wheels of the Pelton type from three-quarters to 85%. In general terms large quantities of water under small heads are best utilized by turbines; but above 20-ft. heads the impact wheel will be found satisfactory even up to pressures of 2,000 ft. The makers of the Pelton wheel issue a circular giving useful data in relation to the measurement and use of water, and from it the following tables are extracted. The first gives the h. p. of

1 in. of water under heads from 1 up to 1,100 ft. This inch equals 1½ cu. ft. per minute. The table assumes 85% efficiency.

TABLE FOR CALCULATING HORSE POWER.

Heads in Ft.	Horse Power.	Heads in Ft.	Horse Power.	Heads in Ft.	Horse Power.	Heads in Ft.	Horse Power.
1	0.0024147	320	0.772704	170	0.410499	480	1.159056
20	0.0482294	330	0.796851	180	0.434646	490	1.183206
30	0.072441	340	0.820998	190	0.458793	500	1.207350
40	0.096588	350	0.845145	200	0.482940	520	1.255644
50	0.120735	360	0.869292	210	0.507087	540	1.303938
60	0.144882	370	0.893439	220	0.531234	560	1.352232
70	0.169029	380	0.917586	230	0.555381	580	1.400526
80	0.193176	390	0.941733	240	0.579528	600	1.448820
90	0.217323	400	0.965880	250	0.603675	650	1.569555
100	0.241470	410	0.990027	260	0.627822	700	1.690290
110	0.265617	420	1.014174	270	0.651969	750	1.811025
120	0.289764	430	1.038321	280	0.676116	800	1.931760
130	0.313911	440	1.062468	290	0.700263	900	2.173230
140	0.338058	450	1.086615	300	0.724410	1000	2.414700
150	0.362205	460	1.110762	310	0.748557	1100	2.656170
160	0.386352	470	1.134909				

Measurement by Weirs.—In general terms a weir is any obstruction across a stream, as a dam, over which all the water in the stream is compelled to flow, or so much of it as may be desired, which can be regulated by suitable waste gates, which will maintain a constant depth on the weir. Select a place in the stream, where on being dammed a pond will be formed of sufficient length to check the velocity of the stream. Across the lower end of this spot place a board or plank, in which a square notch has been previously cut through which the water must flow. The length of the notch in the dam should be from two to four times its depth for small quantities of water, and longer for large quantities. The edges of the notch should be beveled toward the intake or upper side, and the clear fall below the notch should be not less than twice the depth, that is 12 in. if the notch is 6 in. deep, and so on, to prevent loss by back water. In the pond, from 3 to 6 ft. above the dam, according as the stream is small or large, drive a stake, and then obstruct the water until it rises precisely to the bottom of the notch (which must be level) and mark the stake at this level. Then complete the dam so as to cause all the water to flow through the notch, and after allowing time for the water to settle, mark the stake again for this new level. If preferred the stake can be driven with its top precisely level with the bottom of the notch and the depth of water be measured with a rule after the water is flowing freely through the notch, but the marks are preferable in most cases. The distance between the marks is the theoretical depth of flow corresponding to the depth in the table, where an example is given of the method of making the calculation. The quantity thus obtained can be converted into gallons or miner's inches as desired.

The following table will save trouble in making computations from weir measurements:

TABLE FOR WEIR MEASUREMENT.

Giving cubic feet of water per minute that will flow over a weir 1 in. wide and from ⅛ to 20⅞ in. deep.

Inches.		⅛	¼	⅜	½	⅝	¾	⅞
0........	.00	.01	.05	.09	.14	.19	.26	.32
1........	.40	.47	.55	.64	.73	.82	.92	1.02
2........	1.13	1.23	1.35	1.46	1.58	1.70	1.82	1.95
3........	2.07	2.21	2.34	2.48	2.61	2.76	2.90	3.05
4........	3.20	3.35	3.50	3.66	3.81	3.97	4.14	4.30
5........	4.47	4.64	4.81	4.98	5.15	5.33	5.51	5.69
6........	5.87	6.06	6.25	6.44	6.62	6.82	7.01	7.21
7........	7.40	7.60	7.80	8.01	8.21	8.42	8.63	8.83
8........	9.05	9.26	9.47	9.69	9.91	10.13	10.35	10.57
9........	10.80	11.02	11.25	11.48	11.71	11.94	12.17	12.41
10........	12.64	12.88	13.12	13.36	13.60	13.85	14.09	14.34
11........	14.59	14.84	15.09	15.34	15.59	15.85	16.11	16.36
12........	16.62	16.83	17.15	17.41	17.67	17.94	18.21	18.47
13........	18.74	19.01	19.29	19.56	19.84	20.11	20.39	20.67
14........	20.95	21.23	21.51	21.80	22.08	22.37	22.65	22.94
15........	23.23	23.52	23.82	24.11	24.40	24.70	25.00	25.30
16........	25.60	25.90	26.20	26.50	26.80	27.11	27.42	27.72
17........	28.03	28.34	28.65	28.97	29.28	29.59	29.91	30.22
18........	30.54	30.86	31.18	31.50	31.82	32.15	32.47	32.80
19........	33.12	33.45	33.78	34.11	34.44	34.77	35.10	35.44
20........	35.77	36.11	36.45	36.78	37.12	37.46	37.80	38.15

Suppose the weir to be 66 in. long, and the depth of water on it to be 11⅝ in. Follow down the left hand column of the figures in the table until you come to 11 in. Then run across the table on a line with the 11, until under ⅝ on top line and you will find 15.85. This multiplied by 66, the length of weir, gives 1046.10, the number of cubic feet of water passing per minute.

Measurement in an Open Stream by Velocity and Cross Section.—Measure the depth of the water at from 6 to 12 points across the stream at equal distances between. Add all the depths in feet together and divide by the number of measurements made; this will be the average depth of the stream, which multiplied by its width will give its area or cross section. Multiply this by the velocity of the stream in feet per minute, and you will have the cubic feet per minute of the stream.

The velocity of the stream can be found by laying off 100 ft. on the bank and throwing a float into it at the middle, noting the time passing over the 100 ft. Do this a number of times and take the average. Then dividing this distance by the time gives the velocity in feet per minute at the surface. As the top of the stream flows faster than the bottom or sides—the difference being about 8%—it is better to measure a distance of 120 ft. for float and reckon it as 100.

This method can also be applied to measurements of water in flumes. The error will tend toward excess, if the friction along the sides and bottom is not allowed for.

TABLE FOR MEASURING WATER BY MINER'S INCHES.

Length of Opening in Inches.	Openings 2 Inches High.			Openings 4 Inches High.		
	Head to Center 5 in.	Head to Center 6 in.	Head to Center 7 in.	Head to Center 5 in.	Head to Center 6 in.	Head to Center 7 in.
	Cu. Ft.	Cu. Ft.	Cu. Ft.	Cu. Ft.	Cu. Ft.	Cu. Ft.
4	1.348	1.473	1.589	1.320	1.450	1.570
6	1.355	1.480	1.596	1.336	1.470	1.595
8	1.359	1.484	1.600	1.344	1.481	1.608
10	1.361	1.485	1.602	1.349	1.487	1.615
12	1.363	1.487	1.604	1.352	1.491	1.620
14	1.364	1.488	1.604	1.354	1.494	1.623
16	1.365	1.489	1.605	1.356	1.496	1.626
18	1.365	1.489	1.606	1.357	1.498	1.628
20	1.365	1.490	1.606	1.359	1.499	1.630
22	1.366	1.490	1.607	1.359	1.500	1.631
24	1.366	1.490	1.607	1.360	1.501	1.632
26	1.366	1.490	1.607	1.361	1.502	1.633
28	1.367	1.491	1.607	1.361	1.503	1.634
30	1.367	1.491	1.608	1.362	1.503	1.635
40	1.367	1.492	1.608	1.363	1.505	1.637
50	1.368	1.493	1.609	1.364	1.507	1.639
60	1.368	1.493	1.609	1.365	1.508	1.640
70	1.368	1.493	1.609	1.365	1.508	1.641
80	1.368	1.493	1.609	1.366	1.509	1.641
90	1.369	1.493	1.610	1.366	1.509	1.641
100	1.369	1.494	1.610	1.366	1.509	1.642

CHAPTER XVIII.

ARTESIAN WELLS.

Definition.—Strictly speaking, an artesian well should flow naturally over the top of the pipe without pumping. The name is very frequently but erroneously applied to any bored well, but such wells merely differ from any ordinary well in the size of the hole and the method of lining it.

Theory.—Artesian wells depend for their success on the property of water finding its own level, or the tendency to stand at the same height in both the legs of a tube bent into the shape of a U. We must therefore have for the source of water a region higher than the one where the well is to be sunk, and even then, owing to the friction in the ground and tube, the water will not rise quite to this level.

Basin Wells.—To secure the best results we must have a saucer-shaped basin of strata all dipping toward the center, and no part of the rim of the basin must be lower than the point at which the well is sunk (except as hereafter explained); and this basin must be filled with alternating layers or strata of material which will allow the ready flow of water, such as gravel; and others, such as clay, which will not permit its passage. Such a condition of the strata is shown in pl. 14, fig. 8. To make it more intelligible the vertical heights are made out of proportion to the horizontal, but this does not affect the principle.

We have here three beds of clay, *c*,*b*,*d*, and two beds of gravel *g* and *e*, with surface dirt *a*. Now if a well be sunk at the center of the basin, as at *w*, it would penetrate all these beds. The upper bed of clay *c* would hold water, and if the well did not go through it we should have only an ordinary well. But as the stratum of clay *c* would prevent any water which fell on the surface exposure of the gravel *g* from reaching the surface again, this bed would form a reservoir in which the permanent water level would be the height of its lower outlet If then we extend the well into the gravel *g* we should make a lower opening and the pressure in the underground reservoir would force the water up the well, and perhaps over the top. But if we extend the well through *g* and the clay *b* into the gravel *e* we shall have tapped a larger reservoir, the gravel being thicker, with a larger surface exposure at a greater height, and the increased pressure will cause the water to rise above the top of the well, giving a permanent flow without pumping. This is a true artesian well.

It might however happen, as in pl. 14, fig. 9, that a portion of the strata had been cut away and subsequently overlaid by horizontal deposits as at *c*, but if these should be a retentive clay, the result would be the same, as the lower edges of the gravel *g* lying between the beds of clay *a,b,* would be hermetically sealed by the clay *c*, and the well *w* would still be artesian on account of the pressure resulting from the altitude of *a* and *b*.

From the foregoing it will be seen that the best results will be obtained in those wells which are nearest the center of the basin. These will be under greater pressure than those nearer the rim of the basin, and the flow will gradually diminish as it is approached, until those nearest to it, penetrating the retaining clay higher than the natural outlet, will have no overflow and become pumping wells. The central wells will, however, be more expensive to put down.

Exceptional Cases.—Other causes, however, than the occurrence of saucer-shaped basins may give rise to favorable conditions for artesian wells, as in the case of San Bernardino in Southern California, which lies a few miles north of Colton. All the wells in the latter town are supplied with windmills, while in San Bernardino there are upward of 800 artesian wells, furnishing an immense flow of water. The quantity is so great that large irrigating ditches are supplied from this source. The boundary line between the two regions is a nearly straight line running west of north. Along this line there has been an immense fault across the wide valley of the San Gabriel River, with its alternating beds of clay and gravel, which has raised the solid rock on the west, until it acts as a retaining dam, converting the valley to the eastward into a huge underground reservoir, very much as in pl. 11, fig. 4, where *AB* may represent the fault, forming the reservoir *P*, so that while wells to the left of *A* would require windmills those at *C* might be artesian. (The illustration is drawn for a different purpose, but the relative position of the rocks and gravel beds is the same.) Here the water finds its way into the upturned edges of the strata, bounded by the two walls of the valley, and not being able to pass the barrier of rock at the western end of the valley is forced to the surface through any opening piercing the retaining clays. That this is the case is proved by the wells being deep close up to the break or fault instead of encountering the retentive clays at gradually diminishing depths going westward.

Requisite Conditions.—In the case just cited, the fault having become impermeable, or not affording an outlet for the water, an artesian basin was formed where none would otherwise have been possible, but it does not always follow that because we have the proper shaped basin it will furnish an artesian flow. If the beds of clay are thin, very slight earthquake disturbances may have broken them, so that they no longer act as retaining walls, but allow the escape of the water to other lower strata where it may be lost; or the gravel beds may not be continuous over large areas, but contained instead between two layers of clay united all round like the crust of a pie over the fruit, in which case there would be no pressure; and sometimes, when the flow is small, a deeper sinking in search of a greater supply may allow the water to escape into a lower stratum having a natural outlet, and the flow be lost altogether. So many contingencies surround the successful sinking of artesian wells that only actual trial can determine the probability of success, except in cases where obviously there can be no extensive basin, as in broken mountain countries.

The writer sunk 500 ft. in the San Joaquin Valley, Cal., but never found water which came nearer the top of the well than 12 ft., while further north, in what would have been deemed a less favorable locality, 18 out of 19 wells were successful and the deepest was less than 200 ft.

While gravel has been spoken of as the source of water in the foregoing pages, it may be found in any other porous rock which will easily permit its flow, such as sand, sandstone, conglomerate, shale, chalk or even limestone, the essential point being that whatever its nature it must lie between two non-permeable strata of clay or rock. The retaining strata, instead of clay, as assumed above, may be of any compact rocks such as hard and unbroken slates, quartzite, etc. Without these there can be no artesian well. When such a bed is found in sinking, the operator may expect satisfactory results, not otherwise; and if water is found beneath it in reasonable quantity care should be taken not to break the underlying one, for the reasons already given.

If successful, artesian wells are invaluable for the water supply of cities and irrigation, as, though in some cases their first cost may be large, it is not invariably so, but on the contrary often quite moderate, and the annual repairs are nominal.

Permanence of Supply.—The well at Aire in Artois, France, has given a stream rising 11 ft. above the surface for the last 100 years, but in some cases where the success of the experiment has induced the sinking of a large number of wells in the same basin, the consequent increase in the size of the outlet, combined with excessive demands on the reservoir, has diminished the pressure and reduced the flow, as in the London basin in England. Aside from such causes there is little to fear except from destructive earthquakes which may rupture the strata, but fortunately these are rare.

Examples.—The following table of a few wells will give some idea of the depths which have been attained and show that there is no relationship between the depth of the well and the quantity of water obtained. In "Physical Data and Statistics of Calfornia," by W. H. Hall, there are minute details of many hundreds of wells varying in depth from 90 to over 1,000 ft., and with bores ranging from 2 in. to 7 in. As is the case elsewhere, many of the wells proved valueless for either drinking purposes or for irrigation on account of the large amount of mineral matter (chiefly the salts of sea water) which the water contains, the amount running up to as much as 231 grains of solid matter per gallon; but the general results have been very satisfactory. The deepest bore reached a depth of 2,160 ft. without finding artesian water.

SPECIMEN ARTESIAN WELLS AND BOREHOLES.

Locality.	Depth. Ft.	Diameter Inches.	Flow in Gal. 24 Hours.	Height. Ft.	Temperature.
Grenelle, France	1798	....	864,000	....	82°
Passy, France	1923	28	5,582,000	54	82°
Paris Basin, France	300 to 400	2-8	....	....	....
London Basin	300 to 900	....	....	4	....
Chicago	700 to 1000	5	800,000	....	....
Sperenberg Germany	4194	13	....	....	....
Louisville	2086	3	800,000	....	76½°
Bourne, England	95	....	500,000	40	....
Philadelphia	200	8	50,000	....	....
California	72	4	271,000	2	67°
California	85	3	139,000	2	68°
California	90	4	239,000	3	....
California	95	7	465,000	1½	68°
California	100	3	224,000	2½	....
California	106	6	315,000	1	65½°
California	123	3	164,000	2	65½°
California	123	7	1,011,000	....	....
California	140	3	173 000	2	....
California	205	7	926,000	....	....
California	300	7	388,000	7	64°

USEFUL TABLES.

ELEMENTS (CLARKE).

Name.	Symbol.	Atomicity.	Atomic Weight.		Sp. Gr.
			H=1.	O=16.	
Aluminum.........	Al	IV.	26.91	27.11	2.50—2.81
Antimony(stibni'm)	Sb	V	119.52	120.43	6.62—6.86 5.74—5.83 amorphous
Argon	(?)	(?)	(?)	(?)	(?)
Arsenic.	As	V	74.44	75.01	5.63—5.96 3.70—4.72 allotropic
Barium.............	Ba	II	136.39	137.43	3.75—4
Bismuth	Bi	V	206.54	208.11	9.67—10
Boron	B	III	10.86	10.95	2.53—2.68
Bromine	Br	I	79.34	79.95	2.95—3.19
Cadmium..........	Cd	II	111.10	111.95	7.99—8.69
Cæsium............	Cs	I	131.89	132.89	1.87—1.89
Calcium	Ca	II	39.76	40.07	1.55—1.80
Carbon	C	IV	11.91	12.00	3.33—3.55 diamond 1.84—2.5 graphite 1.76—2.10 charcoal 1.72—1.78 lampblack
Cerium	Ce	III	138.30	139.35	6.63—6.73
Chlorine............	Cl	I	35.18	35.45	1.33 liquefied
Chromium.........	Cr	VI	51.74	52.14	6.20—7.3
Cobalt..............	Co	IV	58.55	58.99	7.72—8.95
Columbium (niobium).	CborNb	V	93.02	93.73	6—7.37
Copper (cuprum) ..	Cu	II	63.12	63.60	8.39—8.96 8—8.2 allotropic 7.27—8.22 molten
Erbium....	Er	(?)	165.06	166.32	....
Fluorine	F	I	18.91	19.06	....
Gadolinium	Gd	(?)	155.57	156.76	....
Gallium............	Ga	(?)	69.38	69.91	5.93—5.96
Germanium........	Ge	(?)	71.93	72.48	5.469
Glucinum (beryllium).............	Be or Gl	II	9.01	9.08	1.64—2.01
Gold (aurum)......	Au	III	195.74	197.23	19.2—19.47
Helium	He	(?)	(?)	(?)	(?)
Hydrogen..........	H	I	1.000	1.008	.025—.033 liquefied .620—.628 occluded
Indium	In	III	112.99	113.85	7.11—7.42
Iodine......	I	I	125.89	126.85	4.82—5.02 solid 3.79—4 molten

ELEMENTS (CLARKE).—*Continued.*

Name.	Symbol.	Atomicity.	Atomic Weight.		Sp. Gr.
			H=1.	O=16.	
Iridium	Ir	IV	191.66	193.12	18.61—22.42
Iron (ferrum)	Fe	VI	55.60	56.02	7.48—7.87 bar 7.13 reduced by C 8.12 electrolytic 6.88 molten 8.05 molten steel
Lanthanum	La	III	137.59	138.64	6.05—6.16
Lead (plumbum)	Pb	IV	205.36	206.92	11.16—11.50 10.37—10.95 molten
Lithium	Li	I	6.97	7.03	5.78—5.89
Magnesium	Mg	II	24.10	24.28	1.69—2.24
Manganese	Mn	VI	54.57	54.99	6.86—8.03
Mercury (hydrargyrum)	Hg	II	198.49	200.00	14.—15.19 solid 12.57—13.61 liquid
Molybdenum	Mo	VI	95.26	95.99	8.49—8.64
Neodymium	Nd	(?)	139.70	140.80	....
Nickel	Ni	IV	58.24	58.69	7,81—9.26
Nitrogen	N	V	13.93	14.04	0.37—0.90 liquefied
Osmium	Os	VI	189.55	190.99	21.4—22.477
Oxygen	O	II	15.88	16.00	0.58—1.24 liquefied
Palladium	Pd	IV	105.56	106.36	10.8—12.15
Phosphorus	Ph	V	30.79	31.02	1.48—2.34
Platinum	Pt	IV	193.41	194.89	19.5—21.8 15.79—21.15 spongy 20.98—22.89 precip. black
Potassium (kalium)	K	I	38.82	39.11	.84—.87
Praseodymium	Pr	(?)	142.50	143.60	....
Rhodium	Rh	IV	102.23	103.01	11—12.1
Rubidium	Rb	I	84.78	85.43	1.52
Ruthenium	Ru	VI	100.91	101.68	11—12.26
Samarium	Sm	(?)	149.13	150.26	....
Scandium	Sc	III	43.78	44.12	....
Selenium	Se	VI	78.42	79.02	4.2—4.86
Silicon	Si	IV	28.18	28.40	2—2.49
Silver (argentum)	Ag	I	107.11	107.92	9.55—10.62 9.12—10 molten
Sodium (natrium)	Na	I	22.88	23.05	93—.98
Strontium	Sr	II	86.95	87.61	2.40—2.58
Sulphur	S	VI	31.83	32.07	1.46—2.09
Tantalum	Ta	V	181.45	182.84	10.08—10.78
Tellurium	Te	VI	126.52	127.49	6.11—6.34
Terbium	Tr	(?)	158.80	160.00	....
Thallium	Tl	III	202.61	204.15	11.78—11.91
Thorium	Th	IV	230.87	232.63	10.97—11.23
Thulium	Tu	(?)	169.40	170.70	....
Tin (stannum)	Sn	IV	118.15	119.05	7.14—7.60 5.80—6.02 allotropic
Titanium	Ti	IV	47.79	48.15	
Tungsten (wolfram)	W	VI	183.43	184.83	16.6—19.26
Uranium	U	VI	237.77	239.59	18.23—18.68
Vanadium	V	V	50.99	51.38	5.5—5.87
Ytterbium	Yt	III	171.88	173.19	....
Yttrium	Y	III	88.35	89.02	....
Zinc	Zn	II	64.91	65.41	6.48—7.21
Zirconium	Zr	IV	89.72	90.40	4.15

The atomic weights here given have been compiled by Prof. F. W. Clarke from the most recent and reliable determinations and are adopted as standard by the American Chemical Society.

In addition to the foregoing there are a number of supposed elements—actinium, holmium, idunium, ilmenium, mosandrium, neptunium, phillippium and decipium, not accepted as valid by all chemists. Argon and helium, however, are placed in the list, though little is known about them.

The wide range in specific gravity is due to impurity of samples in some cases; temperature when tested; with metals whether cast, rolled, hammered, etc.; and to the fact that the determinations were made by different chemists using different methods.

In the older chemical nomenclature oxygen was assumed as 16 to 1 of hydrogen. Later determinations give 15.88 to 1. Consequently the values of atomic weights are calculated on two scales, on one of which hydrogen is taken as 1, and on the other, oxygen as 16. The differences are only fractional.

GENERAL CLASSIFICATION OF MINERALS (BRUSH).

I. MINERALS WITH METALLIC OR SUB-METALLIC LUSTER.

NOTE.—Minerals having metallic luster are opaque. and do not transmit light even through their thinnest edges. The color of their powder, or their streak, is therefore dark, though not necessarily black. The minerals with sub-metallic luster which are included in this section all give dark-colored streaks. Many dark-colored minerals whose luster is doubtful have been placed here, and also in Section II.

A.—FUSIBLE FROM 1 TO 5 OR EASILY VOLATILE.

1. *Arsenic Compounds.*—B. B. on charcoal give a volatile coating of arsenious oxide.
2. *Selenium Compounds.*—B. B on charcoal give a characteristic radish-like odor and impart an azure-blue color to the reducing flame.
3. *Tellurium Compounds.*—When treated in a test-tube with 5 cc. of concentrated H_2SO_4 and gently heated, the acid assumes a reddish-violet color.
4. *Antimony Compounds.*—B. B. on charcoal give a dense white coating of oxide of antimony.
5. *Sulphides.*—When roasted in the open tube or on charcoal give the odor of sulphurous anhydride, but do not give the reactions of the preceding divisions.
6. Not belonging to the foregoing divisions.

B.—INFUSIBLE, OR FUSIBLE ABOVE 5, AND NON-VOLATILE.

1. *Iron Compounds.*—Become magnetic after heating B. B. in the reducing flame.
2. *Manganese Compounds.*—Impart to the borax bead in O. F. a reddish-violet color.
3. Not belonging to the foregoing divisions.

II. MINERALS WITHOUT METALLIC LUSTER.

NOTE.—Minerals without metallic luster are transparent, although they may have such an intense color that they transmit light only through very thin edges. The color of their powder, or their streak is generally white or light-colored, never black.

A.—EASILY VOLATILE OR COMBUSTIBLE.

Rapidly disappear when heated B. B. on charcoal.

B.—FUSIBLE FROM 1 TO 5, AND NON-VOLATILE, OR ONLY SLOWLY OR PARTIALLY VOLATILE.

PART I.—Give a *Metallic Globule* when fused with sodium carbonate on charcoal.

1. *Silver Compounds.*—B. B. with sodium carbonate on charcoal give a globule of silver.
2. *Lead Compounds.*—B. B. with sodium carbonate on charcoal give a globule of lead.
3. *Bismuth Compounds.*—B. B. with sodium carbonate on charcoal give a globule of bismuth.
4. *Antimony Compounds.*—B. B. with sodium carbonate on charcoal give a globule of antimony.
5. *Copper Compounds.*—B. B. with sodium carbonate on charcoal give a globule of copper. The powdered mineral on charcoal, after moistening with hydrochloric acid, imparts an azure-blue color to the blowpipe flame.

PART II. *Iron Compounds.*—Become magnetic after heating before the blowpipe in the reducing flame.

1. *Sulphates, Arsenides, and Phosphates*, chiefly.—Soluble in hydrochloric or nitric acid without a perceptible residue, and without yielding gelatinous silica upon evaporation.
2. *Silicates.*—Soluble in hydrochloric or nitric acid, and yield gelatinous silica upon evaporation, or decomposed with the separation of silica.
3. Not belonging to the foregoing divisions.—Insoluble in hydrochloric acid.

PART III. When fused with sodium carbonate on charcoal do *not* give a metallic globule, and when fused alone in the reducing flame do *not* become magnetic.

1. *Salts of the Alkali and Alkali-Earth Metals.*—After intense ignition before the blowpipe, either in the forceps or on charcoal, the ignited material gives an alkaline reaction when placed on moistened turmeric paper.
   - a) Easily and completely soluble in water.
   - b) Insoluble in water, or difficultly or only partially soluble.
2. *Arsenates, Phosphates and Borates*, chiefly.—Soluble in hydrochloric acid, but do not yield a jelly or a residue of silica upon evaporation.
3. *Silcates.*—Soluble in hydrochloric acid, and yield gelatinous silica upon evaporation.
   - a) In the closed tube give water.
   - b) In the closed tube give little or no water.
4. *Silcates.*—Decomposed by hydrochloric acid with the separation of silica, but without the formation of a jelly.
   - a) In the closed tube give water.
   - b) In the closed tube give little or no water.
5. Not belonging to the foregoing divisions. Insoluble in hydrochloric acid.

C.—INFUSIBLE, OR FUSIBLE ABOVE 5.

1. *Salts of the Alkali-Earth Metals.*—After intense ignition before the blowpipe, either in the forceps or on charcoal, the ignited material gives an alkaline reaction when placed on moistened turmeric paper.
2. *Carbonates, Sulphates, Oxides, Hydroxides and Phosphates*, chiefly.—Soluble in hydrochloric acid, but do not yield a jelly or residue of silica upon evaporation.
3. *Silicates.*—Soluble in hydrochloric acid, and yield gelatinous silica upon evaporation.
4. *Silicates.*—Decomposed by hydrochloric acid with the separation of silica, but without the formation of a jelly.

5. Not belonging to the foregoing divisions. Insoluble in hydrochloric acid.
    - a) Hardness less than that of glass or a good quality of steel. Can be scratched by a knife.
    - b) Hardness equal to or greater than that of glass. Cannot be scratched by a knife.

CHARACTERS OF MINERALS (DANA).

1. Name, synonyms.
2. Crystalline, form and structure.
    System of crystallization.
    Axial ratio and angular elements.
    Twinning
    General structure, amorphous varieties, initiative forms, etc.
3. Physical characters:
    Cohesion, Cleavage, Fracture, Hardness.
4. Characters relating to
    Heat,
    Electricity,
    Magnetism.
5. Taste and odor.
6. Chemical composition.
7. Pyrognostic qualities (blowpipe).

SYSTEMS OF CRYSTALLIZATION (DANA).

I. Isometric—3 equal axes, at right angles to each other. (Ex.—cube, octahedron, dodecahedron = pyrite).

II. Tetragonal—3 axes. The 2 lateral axes equal, the vertical axis longer or shorter; all at right angles to each other.

III. Hexagonal and Rhombohedral, 4 axes; 3 lateral axes in same plane at 60° from each other and a fourth vertical axis at right angles to them and either longer or shorter.

In the Hexagonal system proper there are 4 principal planes of symmetry; 3 equal planes intersecting at 60°, and a fourth unequal, normal to them; also 3 auxiliary planes diagonal to the first set (example, apatite group).

The Rhombohedral system includes forms with only 3 planes of symmetry intersecting at 120° in the vertical axis. (Ex. rhombohedron—many forms of calcite and tourmaline).

IV. Orthorhombic—3 unequal axes at right angles to each other; 3 planes of symmetry, which intersect in these axes but are all different.

V. Monoclinic—3 unequal axes, of which one lateral axis is inclined to the vertical axis, the other angles right angles; 1 plane of symmetry.

VI. Triclinic—3 unequal axes, and their intersections are all oblique.

MINERAL CHARACTERS DEPENDING UPON LIGHT (DANA).

Kinds of Luster:

1. Metallic; sub-metallic.
2. Adamantine (like diamond).
3. Vitreous (like broken glass).
4. Resinous (like yellow resin).
5. Greasy (like elæolite).
6. Pearly.
7. Silky (the result of a fibrous structure).

Degrees of Intensity:

1. Splendent.
2. Shining.
3. Glistening.
4. Glimmering.

INDIVIDUALIZATION OF CRYSTALS (CROSBY).

I. Distinct, separate and so nearly perfect minerals that their proper forms may be clearly recognized=crystallized.
II. Confused mass showing crystal faces or planes and cleavage planes, but no perfect crystals (rock salt and white marble)=crystalline or massive.
III. Crystalline form and cleavage both entirely wanting to the unaided eye, but the specimen shows double refraction when a thin section is viewed by polarized light (chalcedony)=cryptocrystalline or compact.
IV. Entirely devoid of crystallization (opal and obsidian)=amorphous.
Implanted crystals=crystals of uniform size thickly set on a surface.
Drusy=very small implanted crystals.

INTERNAL STRUCTURE OF MINERALS (CROSBY).

Granular—Fine to coarse=in grains.
Compact or impalpable=when the grains are invisible to the naked eye.
Glassy or vitreous=no trace of granular structure even under microscope; may be crystalline (like vitreous quartz) or amorphous (like obsidian).
Lammellar=lamination independent of crystallization, or dependent. In the first case called banded; in the second, foliated.
Fibrous=if coarse, ealled columnar or baaded.

EXTERNAL FORMS OF MINERALS (CROSBY).

Botryoidal=rounded, grapelike.
Mammillary=larger rounded prominences.
Stalactitic=deposited from solution by dripping water from overhanging rock.
Stalagmitic=Deposited from solution by dripping water on floor of caves, etc.
Tufaceous=porous deposits formed when reeds, grasses, moss, etc., are incrusted by mineral solutions.
Concretionary=rounded mass or nodule produced by aggregations of mineral matter in the body of a rock.
Pisolitic=if the concretions are small (about size of peas).
Oölitic=if very small (fish roe or mustard seed).
Geodes=hollow concretions.
Amydaloids=almond shaped, deposited in the vesicles or steamholes of lava
Dendritic, arborescent, mossy=(stains of iron and manganese, native copper, etc.), resembling vegetation.
Reticulated.=net-like.
Plumose=feather-like.
Filiform=wire or thread-like.
Acicular=like needles.

FRACTURE (CROSBY).

Conchoidal=shelly.
Even.
Uneven.
Earthy (like clay or chalk).
Hackly.
Splintery.

SCALE OF FUSIBILITY OF MINERALS (VON KOBELL).

1. Stibnite (antimony glance), large fragments are fusible in the ordinary flame of a candle.
2. Natrolite; fine needles are fusible in the flame of a candle; large fragments fuse to a globule B.B.
3. Almandite (alumina-iron garnet); infusible in the flame of a candle; can be fused to a globule B.B. if in small fragments.
4. Actinolite (var. amphibolite); fusible to a globule in fine splinters B.B.
5. Orthoclase; in very fine splinters is still fusible to an irregular globule; if in larger fragments only the edges are rounded B.B.
6. Bronzite (diallage); only the finest edges or points can be rounded B.B.

To these Crosby adds:

7. Quartz; infusible alone, B.B.

THE GEOLOGIC SERIES, ACCORDING TO LE CONTE.

Eras.	Ages.	Periods.	Epochs.
5. Psychozoic..	7. Age of Man.	Human. 23.	**Recent.**
4. Cenozoic...	6. Age of Mammals..	Quaternary........22	**Terrace. Champlain. Glacial.**
		Tertiary............21	**Pliocene. Miocene. Eocene.**
3. Mesozoic...	5. Age of Reptiles....	Cretaceous.........20 Jurassic............19 Triassic 18	
Upper. 2. Palæozoic...	CARBONIFEROUS 4. Age of Acrogens and Amphibians.	Permian...........17 Carboniferous 16 Sub-carboniferous.15	
	DEVONIAN. 3. Age of Fishes.....	Chemung ....14 Hamilton..........13 Corniferous ....12 Oriskany 11	
Lower.	SILURIAN. 2. Age of Invertebrates	Helderberg ....10 Salina.............. 9 Niagara .... 8 Trenton............ 7 Canadian........... 6	
	CAMBRIAN.	Dikelocephal's zone 5 Paradoxides zone.. 4 Olenellus zone..... 3	
1. Archæan or Archæzoic.....	1. Archæan...........	Huronian.......... 2 Laurentian......... 1	

THE GEOLOGIC SERIES, ACCORDING TO DANA.

[See also p. 68 for the system adopted by the U. S. Geological Survey.]

Age of Man, or Quaternary.		
Mammalian Age.		Tertiary Period.
Reptilian Age.	Cretaceous.	
	Jurassic.	Wealden (epoch).
		Oŏlitic (epoch).
		Liassic (epoch).
	Triassic.	
Carboniferous Age.		Permian.
		Carboniferous.
		Sub-carboniferous.
Devonian Age, or Age of Fishes.		Catskill.
		Chemung.
		Hamilton.
		Corniferous.
Silurian Age, or Age of Invertebrates.	Upper Silurian.	Oriskany.
		Lower Helderberg.
		Salina.
		Niagara.
	Lower Silurian.	Trenton.
		Canadian.
		Primordial, or Cambrian.

Below the Lower Silurian come the azoic schists and granite.

CLASSIFICATION OF ROCKS

A. Igneous Rocks. B. Aqueous and

ACIDIC.——— IGNEOUS

Glassy.	**Acid Glasses. Obsidian, Perlite, Pumice, Pitchstone.**				
	Chief Feldspar Orthoclsae.			**Chief Feldspar**	
	Biotite (or) (and) Hornblende (or) (and) Auglite.			**Biotite (or) (and) Hornblende.**	
	+Quartz.	—Quartz.	Nepheline or Leucite.	+Quartz.	—Quartz.
Felsitic and Porphyritic.	TRACHYTE GROUP.			ANDESITE GROUP.	
	Rhyolite. (Quartz Porphyry.) (Quartz Felsite.)	Trachyte. (Prophyry.) (Felsite.)	Phonolite (rare). Leucite Phonolite (very rare).	Dacite. (Porphyrite.)	Andesite. (Porphyrite.)
Fragmental.	Rhyolite Tuff and Breccia.	Trachyte Tuff and Breccia.	Phonolite Tuff and Breccia.	Andesitic Tuff and Breccia.	
Granitoid.	GRANITE GROUP.			DIORITE GROUP.	
	Granite (Pegmatite)	Syenite (rare).	Nepheline-Syenite (rare). Leucite-Syenite (very rare).	Quartz-Diorite (Tonalite).	Diorite.
SiO_2.	80.65%	65.55%	60.50%	70.60%	65.05%

ACCORDING TO PROF. J. F. KEMP.
Æolian Rocks. C. Metamorphic Rocks.
ROCKS).

————BASIC.

Andesite Obsidian.		Basic Glasses, Scorias, Tachylite, Basic Obsidian.			
Plagioclase.		Nepheline, Leucite.	No Feldspar.		
Pyroxenes.		A Series of Rare Basaltic Rocks.	Augite (or) (and) Hornblende (or) (and) Biotite.		Ultra-basic Rocks.
—Olivine.	+Olivine.		—Olivine.	+Olivine.	
BASALT.		GROUP.			
Augite-Andesite.	Basalt.	With Nepheline, Leucite (seldom Mellite) one or all.	Augitite.	Limburgite	Basic Segregations in normal Magmas.
Olivine-free Basalt.	Dolerite.	Not readily distinguishable from Basalt without the microscope. Extremely rare in America.	Not readily distinguishable from Basalt. Extremely rare in America.		
(Diabase.)	(Olivine-Diabase.)				
Basaltic Tuffs and Breccias.					Meteorites. Water.
GABBRO		GROUP.			
Diabase. Gabbro. Anorthosite. Norite.	Olivine-Diabase. Olivine-Gabbro. Olivine-Norite.	Theralite (extremely rare).	Pyroxenite.	Peridotite.	Ice.
55.45%		45.38%	55.400%	45.300%	30.00%

THE PRINCIPAL

Grand Divisions.	Origin.	Structure.	Material.	Incoherent State.
Stratified.	Aqueous and Æolian (the latter only slightly stratified, of fine materials usually not compacted).	More or less earthy.	Arenaceous or sandy.	Sand. Gravel. Shingle. Rubble. Volcanic fragments. Volcanic ash.
			Argillaceous or clayey.	Mud. Clay.
			Calcareous or limey.	Ooze. Chalk. Chemical precipitate.
Metamorphic or Transition.	Aqueous, with subsequent heat, pressure and chemical agencies.	Roughly stratified; in part crystalline; usually fissile.		

ROCKS (LE CONTE).

Compacted State.	Essential Components.	Remarks.
Sandstone.	Silica, often with iron oxide.	
Grit.	Small pebbles (mostly quartz) cemented with silica and iron oxide.	
Conglomerate.	Large pebbles and bowlders similarly cemented.	
Breccia.	Angular fragments (usually volcanic) of various rocks, cemented with silica and iron oxide.	
Tufa.	Fine volcanic dust compacted under water.	
Shale.	Indurated particles of clay, usually with some quartz grains and iron oxide.	
Limestone.	Calcite, amorphous or partly crystalline.	
Magnesian limestone, dolomite.	Dolomite and calcite.	
Magnesite.	Magnesite.	
Gneiss.	Mica, quartz, feldspar.	
Mica schist.	Mica, quartz, feldspar.	
Chlorite schist.	Chlorite, quartz, feldspar.	
Talcose schist.	Talc, quartz, feldspar.	
Hornblende schist.	Hornblende, quartz, feldspar.	
Garnet schist.	Garnet, quartz, feldspar.	
Slate.	Hardened shale, cleavage across stratification planes.	
Quartzite.	Altered sandstone.	
Marble.	Altered limestone, calcite.	
Serpentine.	Altered magnesian minerals.	

THE PRINCIPAL

Grand Divisions.	Origin.	Structure.	Material.	Occurrence.
Unstratified.	Igneous.	Crystalline.	Plutonic or massive.	Occurring massive.
				Occurring in intrusions.
			Volcanic or true eruptives.	Occurring in overflows.

Besides the essential components there are many minor "accidental" morphic—such as magnetite, pyrite, olivine, etc., but these usually occur in

ROCKS (LE CONTE).—(*Continued.*)

Compacted State.	Essential Components.	Remarks.
ACIDIC—		Entirely crystalline (holocrystalline); usually coarse grained (microcrystalline).
Pegmatite (graphic granite).	Large plates of mica imbedded in feldspar.	
Granite.	Quartz, orthoclase feldspar, mica.	
Eurite or granulite.	A fine-grained granite.	
Syenite.	Orthoclase feldspar, hornblende.	
Quartz syenite.	Quartz, orthoclase feldspar, hornblende.	
Porphyritic granite	Large crystals of feldspar in a finer groundmass.	
BASIC—		
Diorite.	Plagioclase feldspar, hornblende.	
Quartz diorite.	Plagioclase feldspar, hornblende, quartz.	
Gabbro.	Plagioclase feldspar, augite, olivine (granitoid variety of diabase).	
ACIDIC—		Microcrystalline groundmass, with or without larger crystals imbedded.
Quartz porphyry.	Microcrystalline groundmass, with larger crystals of orthoclase and quartz.	
Felsite.	Microcrystals of orthoclase and quartz.	
BASIC—		
Diorite.	Plagioclase and hornblende (microcrystalline).	
Diabase.	Augite and hornblende (microcrystalline).	
ACIDIC—		Glassy groundmass, with fine to coarse crystals imbedded, or wholly vitreous. Usually fine-grained (microcrystalline) or imperfectly crystalline (cryptocrystalline). The following exist in the stony condition: rhyolite, liparite, trachyte, phonolite, basalt, dolerite and andesite. The following are glassy: Scoriæ, pumice, obsidian, and tachylite.
Rhyolite.	Vitreous groundmass, with crystals of quartz and orthoclase (sanidin).	
Trachyte.	Vitreous groundmass, with crystals of orthoclase (sanidin).	
Phonolite.	Vitreous groundmass, with crystals of sanidin and nepheline.	
Light colored scoriæ.		
Pumice.		
Obsidian.		
BASIC—		
Andesite.	Vitreous groundmass, with crystals of plagioclase, augite or hornblende.	
Basalt.	Vitreous groundmass, with crystals of plagioclase, augite and olivine.	
Black scoriæ.		
Tachylite.		

or accessory minerals in most rocks, especially in the igneous and meta-
small proportions.

CLEAVAGE (CROSBY).

Kinds:
In the isometric (I.) system.................... } Cubic, octahedral dodecahedral, etc.
—tetragonal (II.) system .... }
—hexagonal and rhombrohedral (III.) system }
—orthorhombic (IV.) system. } } prismatic, basal and pyramidal.
—monoclinic (V.) system..... } pinacoidal.... }
—triclinic (VI.) system....... } }

Degrees:
Perfect or eminent (like mica).
Distinct.
Indistinct or imperfect.
In traces.
Difficult.

MINERALS DISTINGUISHED ACCORDING TO TOUCH OR FEEL (CROSBY).

Meager (like chalk, clay, etc).
Harsh.
Rough.
Smooth.
Unctuous.
Greasy.

MINERALS DISTINGUISHED ACCORDING TO TASTE (CROSBY).

Astringent.
Cooling.
Sour.
Bitter.
Saline.
Alkaline.
Adhesive.

MINERALS DISTINGUISHED ACCORDING TO ODOR (CROSBY).

Sulphurous.
Arsenical (like garlic).
Horseradish (selenium).
Argillaceous (like clay).
Fetid (like some limestones).

SCALE OF HARDNESS (MOHS).

1. Talc (foliated), very soft.
2. Gypsum (compact alabaster), can be scratched by the finger nail.
3. Calcite, can be crushed between the teeth.
4. Fluorite, easily scratched by knife steel.
5. Apatite, about the hardness of knife steel.
6. Feldspar (orthoclase), easily scratched by quartz.
7. Quartz (crystalline), scratches ordinary glass.
8. Topaz, easily scratches quartz.
9. Corundum, scratched only by diamond.
10. Diamond, the hardest mineral known.

Dr. F. M. Endlich says: "In testing the hardness of a mineral by this scale, care should be taken that the pure mineral, not a mixture, is obtained. If a mineral scratches calcite, but is scratched by fluorite, to about the same degree, its hardness lies nearly midway between 3 and 4, and is expressed by 3.5. If it barely scratches calcite, but is decidedly scratched by fluorite, the hardness is 3—3.5; if nearer to fluorite in hardness, but still scratched by it, the hardness is 3.5—4."

VALUES OF METALS, ORES, MINERALS, ETC.

[Quotations are those ruling in the United States January 1, 1899. The selling point, when not otherwise stated, is assumed to be New York City.]

Substance.	Unit.	Price.	Remarks.
NON-METALLIC.			
Abrasives:			
Corundum	Lb.	4.5-10c.	
Diatomaceous or infusorial earth	Long ton.	$20.00-40.00	Best ground
Emery	Long ton.	18.50-32.00	Crude Naxos.
Garnet	Short ton.	38.00-57.00	
Grindstones	Short ton.	10.50	
Pumice	Lb.	4-40c.	Lump.
Quartz	Short ton.	$3.00	Lump.
Rottenstone	Lb.	6-18c.	Lump.
Rouge	Lb.	17-30c.	
Tripoli	Short ton.	$12.00	
Alum	100 lb.	1.65	Lump.
Aluminum sulphate	100 lb.	1.25-1.75	
Asbestos	Short ton.	19.50	
Asphaltum	Short ton.	40.00	Best Cuban.
		18.00	Lower grade.
		30.00	Trinidad.
		40.00-60.00	Utah gilsonite.
Asphaltic limestone	Short ton.	12.12	
Barytes	Short ton.	7.75	Crude.
		10.00	Best.
Bauxite	Long ton.	3.00-4.50	
Bitumen	Lb.	3½-5c.	
Bituminous sandstone	Short ton.	$2.81	
Borax	Lb.	6¾-7¼c.	Crystal and Powder
Bromine	Lb.	45c.	
Cement, natural hydraulic	Bbl.	65c.75	Barrels of 300 lbs.
Cement, Portland	Bbl.	$1.75@2.50	Barrels of 400 lbs.
Cement, slag	Bbl.	1.65	Barrels of 350 lbs.
Chalk	Short ton,	2.00-2.10	Commercial lump.
Chrome ore	Long ton.	$20.25	
Clay, china	Short ton.	7.50-9.50	Domestic f. o. b at works.
Clay, fire	Short ton.	4.00-5.00	Best
Coal, anthracite, stove	Long ton.	2.00	Scranton, Pa.
Coal, bituminous	Short ton.	40-70c.	Pittsburg.
Coal, cannel	Short ton.	$2.95	
Coal, lignite	Short ton.	1.25	Denver.
Coke, Connellsville	Short ton.	1.84	Pittsburg.
Coke, Trinidad	Short ton.	1.25	Denver.
Cobalt oxide	Lb.	$1.76—1.85	
Copperas	100 lbs.	57½c.65c	
Copper sulphate	Lb.	3¾c. 4c	Best grade.
Cryolite	Lb.	8½c.	From Greenland.
Feldspar	Short ton.	$7.00-7.75.	Ground.
Flint, silica	Short ton.	2.50-4.00	Lump.
Fluorspar	Short ton.	6.00	Crushed.
Fuller's earth	100 lb.	75c.85c	Lump.

VALUES OF METALS, ORES, MINERALS, ETC.—*Continued.*

Substance.	Unit.	Price.	Remarks.
Grahamite	Short ton.	$33.00	
Graphite (plumbago)	Lb.	1¼-4½c.	Ceylon, crude.
Gypsum	Long ton.	$4.00	Rock.
Iodine	100 lb.	2.55	Crude.
Iron ore, hematite	Long ton.	3.25-3.65	Cleveland, bessemer.
Iron ore, limonite	Long ton.	2.10-3.25	Cleveland, non-bessemer.
Iron ore, magnetite	Long ton.	3.25-3.65	Cleveland bessemer.
		2.55-3.25	" Non-bessemer.
Lime	Bbl.	75c.-$1.00	Barrels of 250 lbs.
Litharge	Short ton.	$91.50	
Magnesite	Short ton.	7.00-8.00	Crude lump.
Manganese ore	Long ton.	2.05	50%.
Marble, flour	Short ton.	8.00	
Mica, ground	Lb.	4-6c.	
Mica, sheets	....	....	According to size and quality.
Mineral wool	100 lb.	$1.00-4.00	Slag.
Monazite	Short ton.	140.00	92%.
Ozokerite	Lb.	6-8c.	Imported.
Paints, ocher	Short ton.	$8.00-15.00	American.
Paints, red led	Lb.	5¾-6c.	American.
Paints, vermilion	Lb.	14-16c.	American lead.
		90c.	Chinese quicksilver.
		90c.	English quicksilver.
Paints, white lead	Lb.	4½-5c.	American, dry.
Paints, zinc white	Lb.	3¾-4½c.	American, extra dry.
Petroleum	Bbl.	$8.50	Bbl. of 42 gal., crude.
Phosphate rock	P. unit.	7-10c.	
Pitch, coal tar	Gal.	8c.	
Pyrites	Long ton.	$3.25-5.00	American lump ore.
Salt, ground	Bbl.	3.50-6.00	Barrels of 280 lbs.
Saltpeter	Lb.	3-3¾c.	Crude.
Slate, ground	Short ton.	$4.00-6.00	
Slate, roofing	Square.	2.25-10.50	"Square" = 100 sq. ft. as laid on roof.
Soapstone	Short ton.	11.00	
Sodium nitrate	100 lb.	1.50-1.60	
Strontium carb. prec.	Lb.	13-14c.	
Sulphur	Long ton.	$19.00-21.50	Lump, Sicilian.
Talc, common	Short ton.	10.00-15.50	Southern.
Talc, fibrous	Short ton.	8.00-9.00	New York.
Uranium oxide	Lb.	2.00-3.00	
METALS.			
Aluminum	Lb.	30-34c.	98%.
		30-43c.	90%.
		38c.	Sheets.
		33-39c.	Nickel alloy.
Antimony	Lb.	9¼c.	Cookson's.
		8¾-8⅞c.	Other.
Copper	Lb.	12¾c.	Lake.
Ferromanganese	Long ton.	$50.00	Pittsburg.
Gold	Troy oz.	20.67	
Iron, No 2 foundry	Long ton.	11.25 11.50	At furnace.

VALUES OF METALS, ORES, MINERALS, ETC.—*Continued.*

Substance.	Unit.	Price.	Remarks.
Iridium	Gram.	$1.19	Price in Germany.
Lead	100 lbs.	3.75	New York.
Nickel	Lb.	33-36c.	Accord'g to quantity.
Platinum	Troy oz.	$14.50-16.00	
Quicksilver	Flask.	41.00	New York; flask of 76½ lbs.
Silver	Troy oz.	59½-60c.	Com'l value.
Spiegeleisen	Long ton.	$23.00	Pittsburg.
Zinc	100 lb.	5.00	New York.
Rare Elements. [Prices given are at makers' works in Germany, unless otherwise noted.]			
Barium—Amalgam	Gram.	$1.19	
Electrol	Gram.	5.71	
Beryllium—Powder	Gram.	5.95	
Crystals	Gram.	9.04	
Nitrate	Oz.	2.50	New York.
Boron—			
Amorphous, pure	Gram.	19c.	
Crystals, pure	Gram.	$1.43	
Nitrate	Lb.	1.50	New York.
Calcium—Electrol.	Lb.	4.28	
Cerium—Fused	Gram.	2.02	
Nitrate	Lb.	28.00	New York.
Chromium—Fused	Kg.	5.95	
Pure, powder	Kg.	1.79	
Chem. pure cryst	Gram.	19c.	
Cobalt—(98@99%)	Kg.	$5.35-5.71	
Pure	Kg.	30.94	
Didymium—Powder	Gram.	3.81	
Nitrate	Oz.	4.00	New York.
Erbium	Gram.	3.09	
Nitrate	Oz.	3.00	New York.
Gallium	Grain.	9.52	
Germanium—Powder	Gram.	33.32	
Fused	Gram.	35.70	
Glucinum—Powder	Gram.	5.95	
Crystals	Gram.	9.04	
Nitrate	Lb.	2.50	New York.
Indium	Gram.	4.05	
Lanthanum—Powder	Gram.	4.28	
Electrol, in balls	Gram.	9.04	
Nitrate	Oz.	3.50	New York.
Lithium	Gram.	2.38	
Nitrate	Oz.	60c.	New York.
Molybdenum—Powder	Kg.	$2.62	
Fused, electrol	100 grams.	15.47	
Niobium	Gram.	3.81	
Osmium	Gram.	95c.	
Palladium—Sponge	Gram.	95c.	
Sheet and wire	Gram.	$1.70	

VALUES OF METALS, ORES, MINERALS, ETC.—*Continued.*

Substance.	Unit.	Price.	Remarks.
Rhodium...............	Gram.	$2.87	
Rubidium—Pure........	Gram.	4.76	
Ruthenium—Pure......	Gram.	1.55	
Selenium—Com'l pwd'r	Kg.	26.18	
Sublimed powder....	Kg.	35.70	
Sticks.................	Kg.	28.56	
Silicium—Amorphous..	100 grams.	2.87	
Crystals, pure.......	100 grams.	7.14	
Strontium—Electrol....	Gram.	6.19	
Tantalum—Pure	Gram.	3.57	
Tellurium C. p. sticks	100 grams.	11.90	
Powder...............	100 grams.	9.52	
Thallium...............	Kg.	23.80	
Thorium—	Gram.	7.85	
Nitrate, 45@50%......	Lb.	7.50-8.00	New York.
Titanium...............	Gram.	71c.	
Uranium................	Gram.	48c.	
Nitrate	Oz.	25c.	New York.
Vanadium—Fused.....	Gram.	$1.19	
Wolfram—Fused	100 grams.	23.80	
Powder, 95@98%.....	Kg.	2.38	
Chem. pure..........	Kg.	7.14	
Ore...................	Kg.	47.60	Lump.
Yttrium................	Gram.	3.33	
Nitrate...............	Oz.	4.00	New York.
Zirconium—Com'l......	Kg.	119.00	
Pure..................	Gram.	71c.	
Nitrate................	Oz.	$1.00	New York.

CONVERTING UNITED STATES WEIGHTS AND MEASURES TO METRIC.

LINEAR.					CAPACITY.							
Inches to Millimeters.	Feet to Meters.	Yards to Meters.	Miles to Kilometers.		Drams to Cubic Centimeters.	Ounces to Milliliters	Quarts to Liters.	Gallons to Liters.	Cub. In. to Cubic Centimeters	Cubic ft. to Cubic Meters.	Cub. Yds. to Cubic Meters.	Bushels to Hectoliters.
25.4000	0.304801	0.914402	1.60935	= 1 =	3.70	29.57	0.94636	3.78544	16.387	0.02832	0.765	0.35242
50.8001	0.609601	1.828804	3.21869	= 2 =	7.39	59.15	1.89272	7.57088	32.774	0.05663	1.529	0.70485
76.2001	0.914402	2.743205	4.82804	= 3 =	11.09	88.72	2.83908	11.35632	49.161	0.08495	2.294	1.05727
101.6002	1.219202	3.657607	6.43739	= 4 =	14.79	118.30	3.78544	15.14176	65.549	0.11327	3.058	1.40969
127.0002	1.524003	4.572009	8.04674	= 5 =	18.48	147.87	4.73180	18.92720	81.936	0.14158	3.823	1.76211
152.4003	1.828804	5.486411	9.65608	= 6 =	22.18	177.44	5.67816	22.71264	98.323	0.16990	4.587	2.11454
177.8003	2.133604	6.400813	11.26543	= 7 =	25.88	207.02	6.62452	26.49808	114.710	0.19822	5.352	2.46696
203.2004	2.438405	7.815215	12.87478	= 8 =	29.57	236.59	7.57088	30.28352	131.097	0.22654	6.116	2.81938
228.6004	2.743205	8.229616	14.48412	= 9 =	33.28	266.16	8.51724	34.06896	147.484	0.25485	6.881	3.17181

SQUARE.					WEIGHT.			
Sq. Inches to Square Centimeters.	Square Feet to Square Decimeters.	Square Yards to Square Meters.	Acres to Hectares.		Grains to Milligrams.	Avoirdupois Ounces to Grams.	Avoirdupois Pounds to Kilograms.	Troy Ounces to Grams.
6.452	9.290	0.836	0.4047	= 1 =	64.7989	28.3495	0.45359	31.10348
12.903	18.581	1.672	0.8094	= 2 =	129.5978	56.6991	0.90719	62.20096
19.355	27.871	2.508	1.2141	= 3 =	194.3968	85.0486	1.36078	93.31044
25.807	37.161	3.344	1.6187	= 4 =	259.1957	113.3981	1.81437	124.41392
32.258	46.452	4.181	2.0234	= 5 =	323.9946	141.7476	2.26796	155.51740
38.710	55.742	5.017	2.4281	= 6 =	388.7935	170.0972	2.72156	186.62089
45.161	65.032	5.853	2.8328	= 7 =	453.5924	198.4467	3.17515	217.72437
51.613	74.323	6.689	3.2375	= 8 =	518.3914	226.7962	3.62874	248.82785
58.065	83.613	7.525	3.6422	= 9 =	583.1903	255.1457	4.08233	279.93133

1 chain = 20.1169 meters.
1 square mile = 259 hectares.
1 fathom = 1.829 meters.
1 nautical mile = 1853.27 meters.
1 foot=0.304801 meter, 9.4840158 log.
1 avoir. pound = 453.5924277 gram.
15432.35639 grains = 1 kilogram.

CONVERTING METRIC TO UNITED STATES WEIGHTS AND MEASURES.

LINEAR.					CAPACITY.							
Meters to Inches.	Meters to Feet.	Meters to Yards.	Kilometers. to Miles.		Milliliters or Cubic Centi-liters to Fluid Drams.	Centiliters to Fluid Ounces.	Liters to Quarts.	Dekaliters to Gallons.	Hektoliters to Bushels.	Cubic Centi-meters to Cubic Inches.	Cubic Meters to Cubic Feet.	Cubic Meters to Cubic Yds.
39.3700	3.28083	1.093611	0.62137	= 1 =	0.27	0.338	1.0567	2.6417	2.8375	0.0610	35.314	1.308
78.7400	6.56167	2.187222	1.24274	= 2 =	0.54	0.676	2.1134	5.2834	5.6750	0.1220	70.629	2.616
118.1100	9.84250	3.280833	1.86411	= 3 =	0.81	1.014	3.1700	7.9251	8.5125	0.1831	105.943	3.924
157.4800	13.12333	4.374444	2.48548	= 4 =	1.08	1.352	4.2267	10.5668	11.3500	0.2441	141.258	5.232
196.8500	16.40417	5.468056	3.10685	= 5 =	1.35	1.691	5.2834	13.2085	14.1875	0.3051	176.572	6.540
236.2200	19.68500	6.561667	3.72822	= 6 =	1.62	2.029	6.3401	15.8502	17.0250	0.3661	211.887	7.848
275.5900	22.96583	7.655278	4.34959	= 7 =	1.89	2.368	7.3968	18.4919	19.8625	0.4272	247.201	9.156
314.9600	26.24667	8.748889	4.97096	= 8 =	2.16	2.706	8.4534	21.1336	22.7000	0.4882	282.516	10.464
354.3300	29.52750	9.842500	5.59233	= 9 =	2.43	3.043	9.5101	23.7753	25.5375	0.5492	317.830	11.771

SQUARE.					WEIGHT.			
Square Centi-meters to Square Inches.	Square Meters to Square Feet.	Square Meters to Square Yards.	Hectares to Acres.		Kilo-grams to Grains.	Hecto-grams to Ounces Avoirdu-pois.	Kilo-grams to Pounds Avoirdu-pois.	Grams to Ounces Troy.
0.1550	10.764	1.196	2.471	= 1 =	15432.36	3.5274	2.20462	0.03215
0.3100	21.528	2.392	4.942	= 2 =	30864.71	7.0548	4.40924	0.06430
0.4650	32.292	3.588	7.413	= 3 =	46297.07	10.5822	6.61386	0.09645
0.6200	43.055	4.784	9.884	= 4 =	61729.43	14.1096	8.81849	0.12860
0.7750	53.819	5.980	12.355	= 5 =	77161.78	17.6370	11.02311	0.16075
0.9350	64.583	7.176	14.826	= 6 =	92594.14	21.1644	13.22773	0.19290
1.0850	75.347	8.372	17.297	= 7 =	108026.49	24.6918	15.43235	0.22505
1.2400	86.111	9.568	19.768	= 8 =	123458.85	28.2192	17.63697	0.25721
1.3950	96.874	10.764	22.2	= 9 =	138891.21	31.7466	19.84159	0.28936

The only material standard of customary length authorized by the U. S. Government is the Troughton scale, whose length at 59°.62 Fahr. conforms to the British standard. The yard in use in the United States is therefore equal to the British yard.

The only authorized material standard of customary weight is the Troy pound of the Mint. It is of brass of unknown density, and therefore not suitable for a standard of mass. It was derived from the British standard Troy pound of 1758 by direct comparison. The British avoirdupois pound was also derived from the latter, and contains 7000 grains Troy.

The grain Troy is therefore the same as the grain avoirdupois, and the pound avoirdupois in use in the United States is equal to the British pound avoirdupois.

The British gallon = 4.54346 liters.

The British bushel = 36.3477 liters.

By the concurrent action of the principal Governments of the world an International Bureau of Weights and Measures has been established near Paris. Under the direction of the International Committee, two ingots were cast of pure platinum-iridium in the proportion of 9 parts of the former to 1 of the latter metal. From one of these a certain number of kilograms were prepared, from the other a definite number of meter bars. These standards of weight and length were intercompared, without preference, and certain ones were selected as International prototype standards. The others were distributed by lot to the different Governments and are called National prototype standards.

The metric system was legalized in the United States in 1866.

The International Standard Meter is derived from Mètre des Archives, and its length is defined by the distance between two lines at 0° Centigrade, on a platinum-iridium bar deposited at the International Bureau of Weights and Measures.

The International Standard Kilogram is a mass of platinum iridium deposited at the same place, and its weight *in vacuo* is the same as that of the Kilogramme des Archives.

The liter is equal to a cubic decimeter of water, and it is measured by the quantity of distilled water which, at its maximum density, will counterpoise the standard kilogram in a vacuum, the volume of such a quantity of water being, as nearly as has been ascertained, equal to a cubic decimeter.

Long ton: 2240 lb. avoirdupois	=	1016	kilogram.			
Short ton: 2000 " "	=	907.2	"			
Pound avoirdupois	=	453.6	grams.			
Flask of mercury=76½ lb. avoir.	=	34.700	kilogram.			
Troy ounce	=	31.104	grams.			
Gallon	=	3.785	liters.			
Barrel of petroleum	=	42	gal.	=	1.59	hectoliter.
" " salt	=	280	lb.		127	kilogram.
" " lime	=	200	"		90.720	"
" " natural cement	=	300	"		136.080	"
" " Portland cement	=	400	"		181.440	"
Gold coining value per oz. Troy	=	$20.6718		=	$0.6646	per gram.
Silver " " " " Troy	=	$1.2929		=	$0.04157	" "

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PLATE 1.

Fig. 1.—Idealized step faults.

Fig. 2.—Actual fault in the Leadville district, Colo.

Fig. 3.—Simple fissure without displacement.

Fig. 4.—Idealized fault, hanging wall depressed.

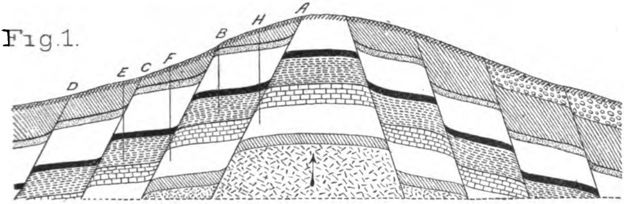
Fig. 5.—Idealized fault, reversed, foot wall depressed.

Figs. 6, 7.—Actual condition of examples 4 and 5, showing bent edges of the strata.

Fig. 8.—Contact vein, due to movement of strata.

Plate 1

Fig. 1.



2. Cross Section of Leadville District

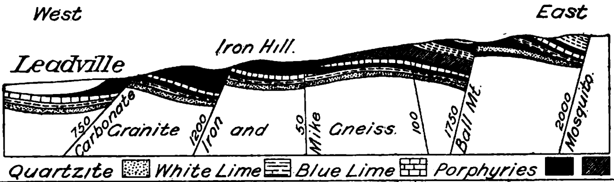
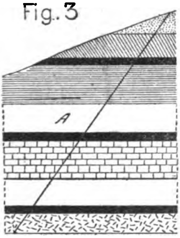


Fig. 3



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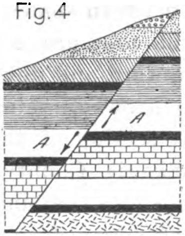

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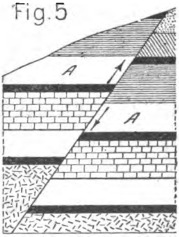

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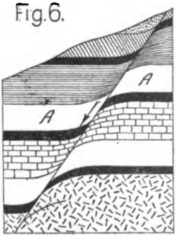

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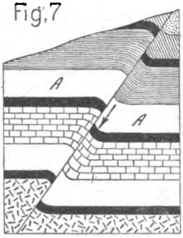

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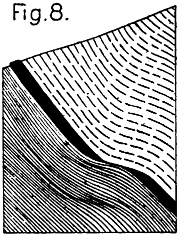


A.H.S. DELT.

PLATE 2.

Fig. 1.—Illustrating terms used in describing rocks. *A*, conformable series; *B*, unconformable with *A*; *C*, *D*, *E*, unconformable with *A* and *B*, but conformable among themselves.

Fig. 2.—Generalized structure of the Comstock lode.

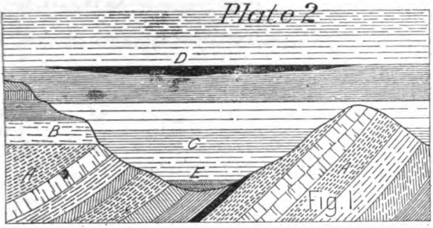
Fig. 3.—Difference between shales (*a*) and schists (*b*).

Figs. 4, 5.—Effect of pressure on the earth's crust, both upward and downward.

Fig. 6.—Faults and throws in veins.

Figs. 7, 8, 9.—Cross section of the Cumberland coal mine, Skagit County, Wash., showing parallelism of coal and iron ore beds.

Plate 2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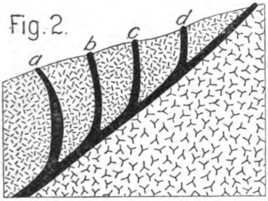
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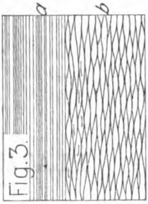
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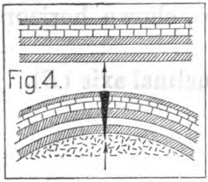
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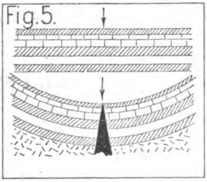
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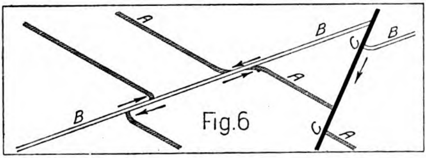
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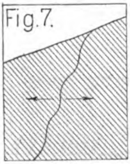
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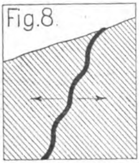
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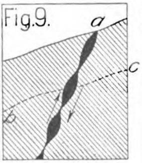
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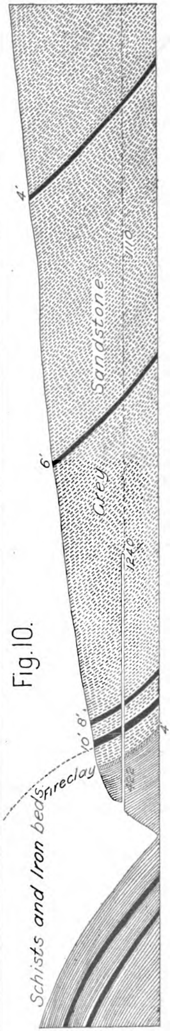


Fig. 10.

R.H.S. DELT.

PLATE 3.

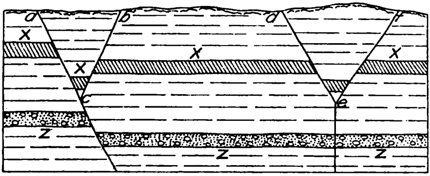
Figs. 1, 2, 3.—Illustrations of trough faults.

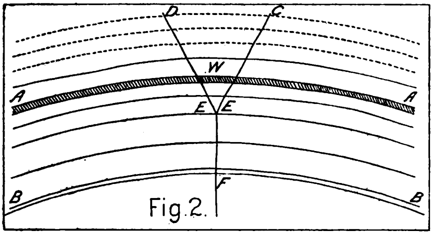
Fig. 4.—Different forms of fissures, shown horizontally.

Fig. 5.—Anticlinal axis (*A*) and synclinal axis (*B*).

Plate 3

Fig. 1.





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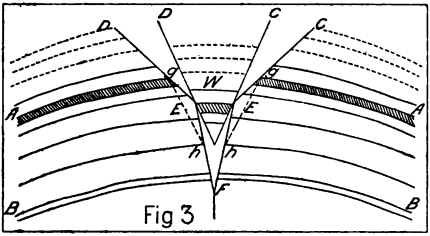
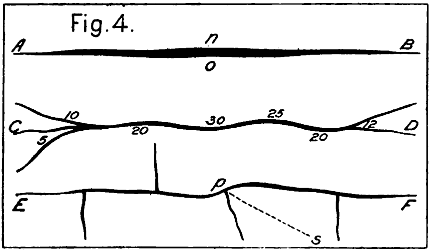


Fig 3

Fig. 4.



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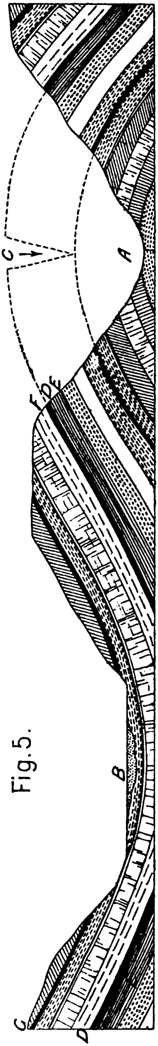


Fig. 5.

PLATE 4.

Fig. 1.—Folding of rocks; horizontal plan (after Geikie).

Figs. 2, 3.—Cross section of the same rocks (after Geikie).

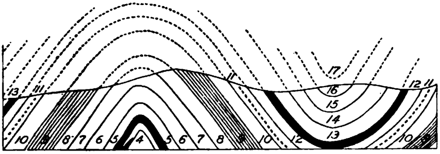
Fig. 4.—Value of rock exposures to the prospector; showing utility of surface croppings, as compared with underground workings.

Fig. 5.—Trough faults in coal seam (after Jukes).

Fig. 6.—Extreme folding of strata by lateral pressure.

Plate 4

Fig. 2.



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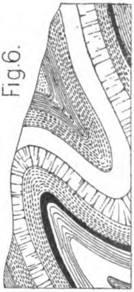
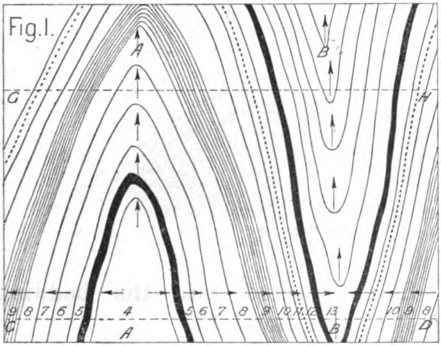


Fig. 1.



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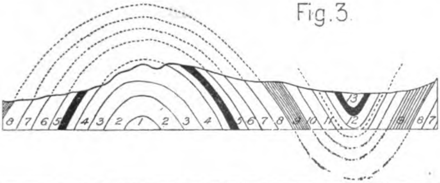

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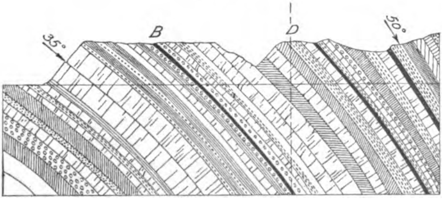

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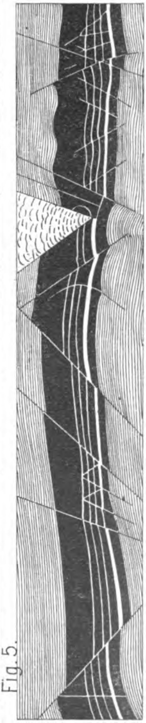


R. H. S. DELT.

PLATE 5.

Figs. 1, 2, 3, 4.—Lavas injected into the bedding of rocks (after Geikie).

Fig. 5.—Granite intruded into metamorphic schists.

Fig. 6.—Basalt intruded into coal seam.

Plate 5

Fig. 1

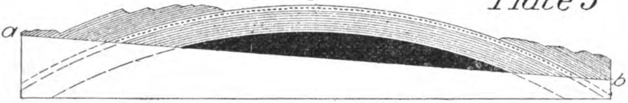
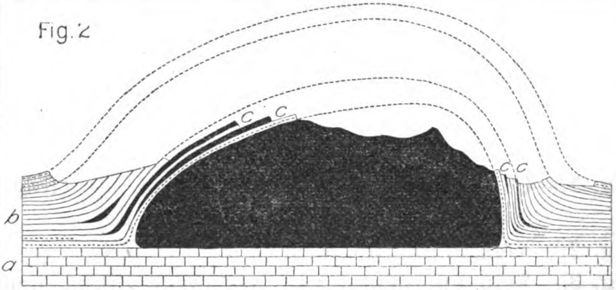


Fig. 2



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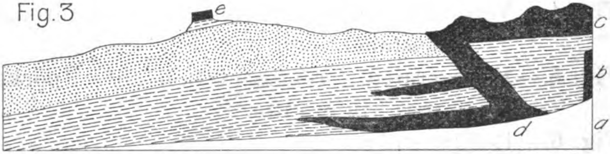

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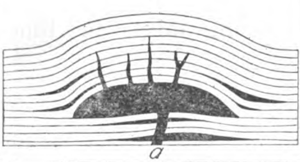


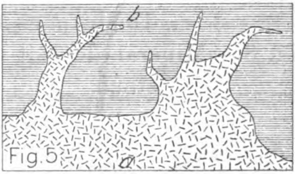
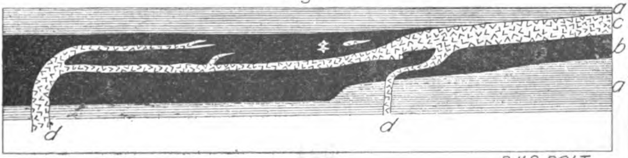


Fig. 5

Fig. 6



R. H. S. Delt.

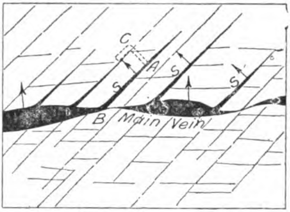
PLATE 6.

Fig. 1.—Compression veins in slates or shales (Keystone mine, Amador County, Cal.).
Fig. 2.—Vein in granite, with spurs.
Fig. 3.—Vein on contact of porphyry dike; one wall "frozen."
Fig. 4.—Vein on contact of porphyry dike, through limestone.
Fig. 5.—Exaggerated representation of "pocket mines" in granite.
Fig. 6.—Refilling of a lode.
Fig. 7.—Fissure veins, with associated beds, at Tombstone, Ariz.
Fig. 8.—Mineral deposit following joints in limestone.

Plate 6

Fig. 1.

Fig. 2.



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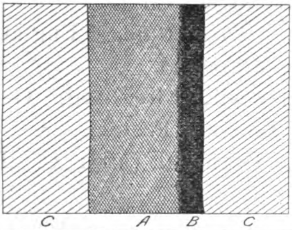

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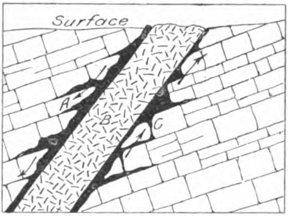

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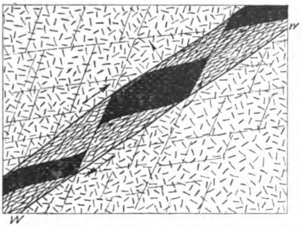

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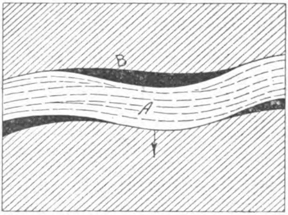

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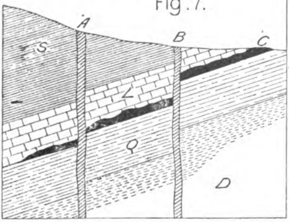

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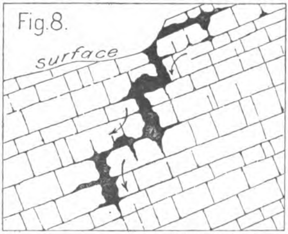

R.H.S. DELT.

PLATE 7.

Fig. 1.—Cross section of the Wheal Dolcoath, Cornwall (after C. Le Neve Foster).

Fig. 2.—Hematite deposit, Ulverstone, England (after C. Le Neve Foster).

Fig. 3.—Zinc (calamine) deposit, Altenberg, Germany (after C. Le Neve Foster).

Fig. 4.—Wheal Mary Ann, Cornwall (after C. Le Neve Foster).

Fig. 5.—Great Flat lode (England), segregated deposit (after C. Le Neve Foster).

Fig. 6.—Cross section of Mother lode in Mariposa County, Cal.

Fig. 7.—Bedded porphyry and quartz veins.

Fig. 8.—Veins of satin spar in conglomerates, Death Valley, Cal.

Fig. 9.—Veins of quartz in conglomerates, Death Valley, Cal.

Figs. 10, 11.—Bedded veins, cropping around hill.

Plate 7

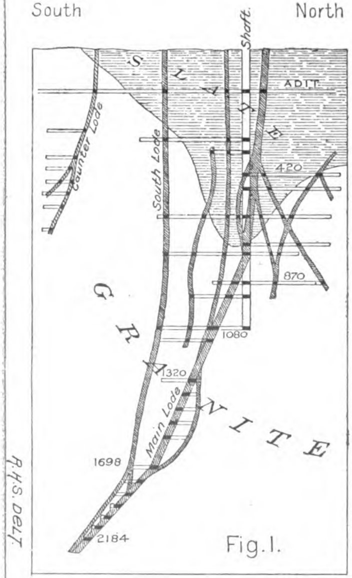

Fig. 1.

Cross Section of Dolcoath Mine.

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Fig. 2.

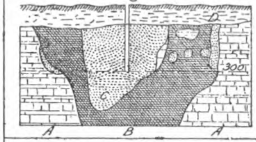


Fig. 3.

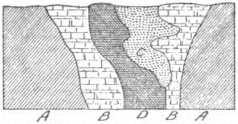
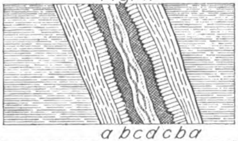


Fig. 4.



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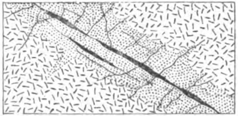

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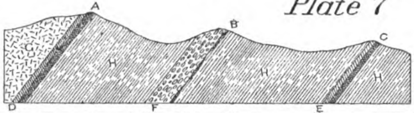

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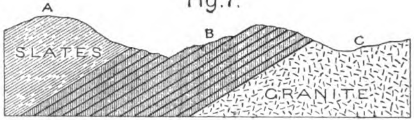
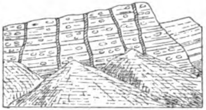
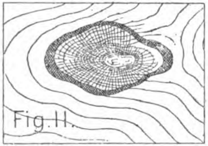


Fig. 8.

Fig. 9.





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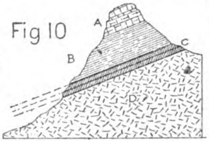
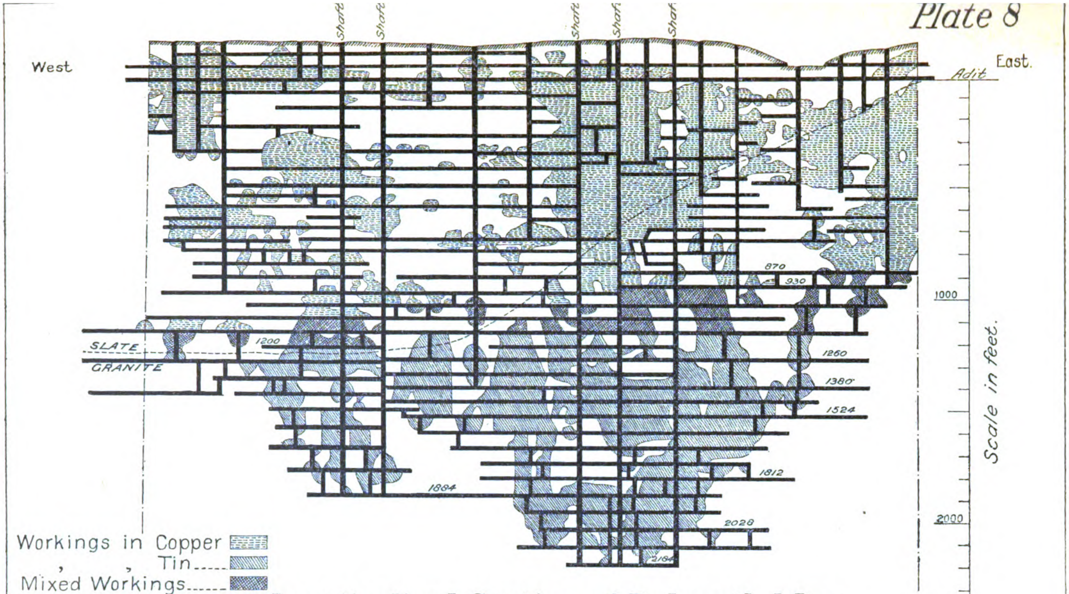


Fig 10

PLATE 8.

Longitudinal section of Wheal Dolcoath tin mine, Cornwall (after C. Le Neve Foster).

Plate 8



Longitudinal Section of Dolcoath Mine

R.H.S. DELT.

PLATE 9.

Fig. 1.—Dip of veins.

Figs. 2, 4.—Locating working shafts on a lode.

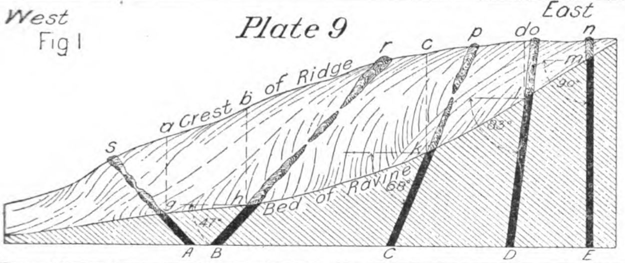
Figs. 3, 5.—Illustrating course of an outcrop in a hilly country.

Fig. 6.—Ravine formed on lode, when the ore consists of soft material.

Fig. 7.—Rake of ore shoots, and formation of ravines across a lode of hard quartz.

Plate 9

Fig 1



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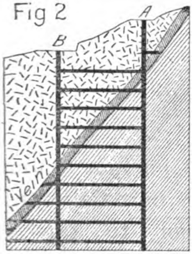


Fig. 3.

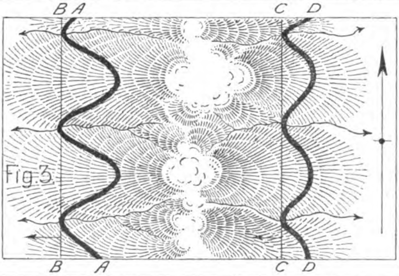


Fig. 4.

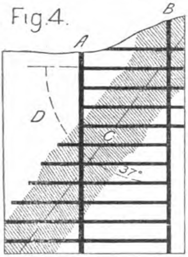


Fig. 5

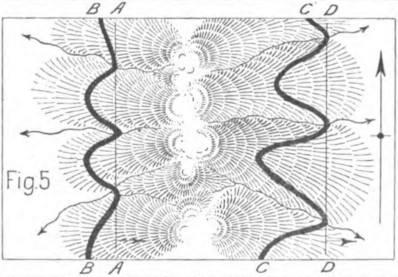
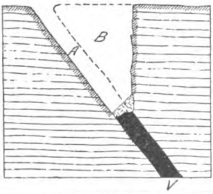


Fig 6.



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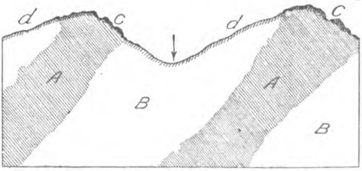

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PLATE 10.

Figs. 1, 2, 3.—Formation of the ancient buried gold-bearing river deposits in California.

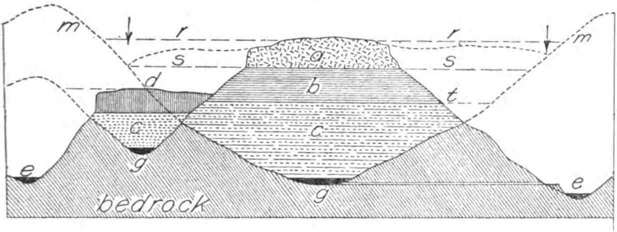
Fig. 4.—Probable length of tunnel to tap the "channel."

Fig. 5.—Side ravine or so-called "overflow" of gold-bearing gravel.

Fig. 6.—Basalt cone (*b*), through gravel bed (*a*), at Laporte, Cal.

Plate 10

Fig. 1.



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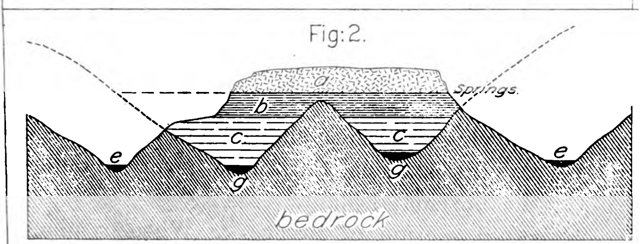

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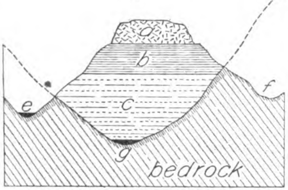

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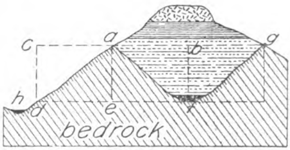

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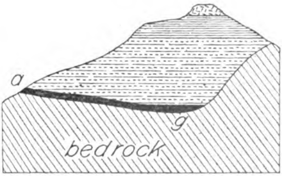

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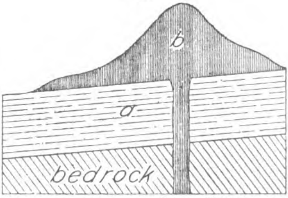

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Fig. 1.—Showing present shape and condition of the ancient California river channels; horizontal plan.

Fig. 2.—Cross section of Breece & Wheeler placer mine, California.

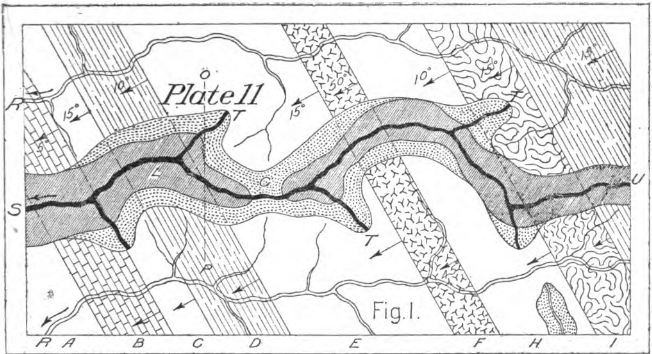
Fig. 3.—Petrified tree, coated with iron pyrite, Sailor Flat, Cal.

Fig. 4.—Fault in placer beds, Grass Flat, Cal.

Fig. 5.—Reverse throw of placer beds, Laporte, Cal.

Fig. 6.—Faults in gravel bed, caused by dikes.

Plate 11



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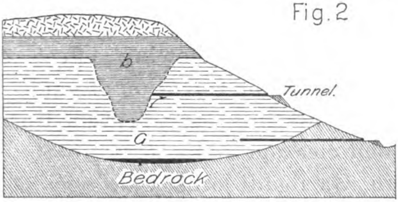

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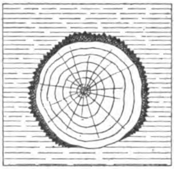

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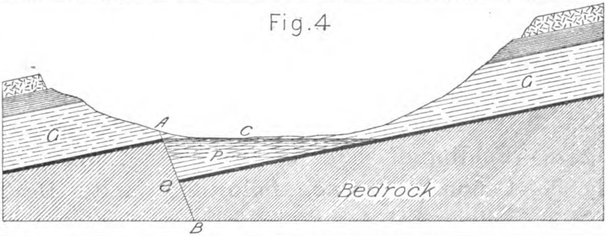

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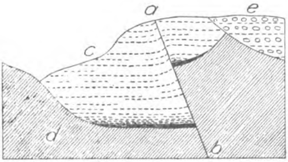

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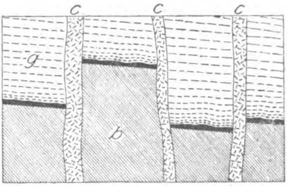

Fig. 6

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Fig. 3.—Section of river bed, showing effect of the bed rock on the retention of gold.

Fig. 4.—Slate quarry, showing stratification lines, *B*, *B*, and cleavage lines, *L*, *L*.

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Fig. 6.—Unconformable gravel beds, divided by a bed of sinter.

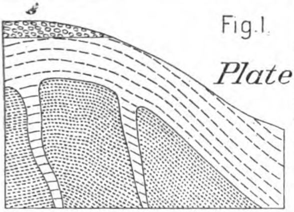
Fig. 7.—Changes of currents of water in a gravel deposit, with petrified trees, Sailor Flat mine, Cal.

Fig. 8.—Folding of slates by pressure of dike (*D*).

Fig. 9.—Cañon or ravine, following fault, Death Valley, Cal.

Plate 12

Fig. 1.



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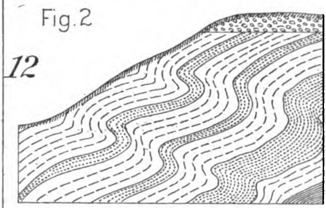

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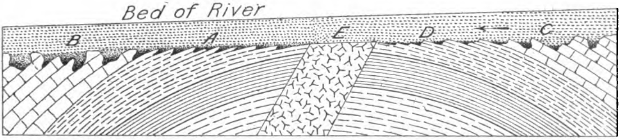

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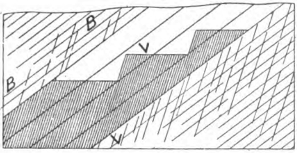

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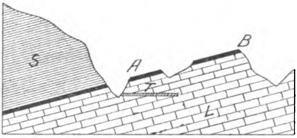

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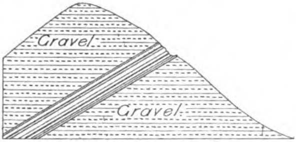

Fig. 7

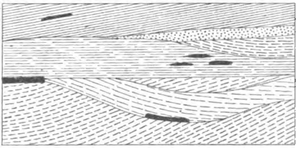

Fig. 8

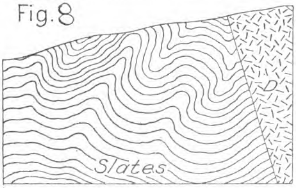

Fig. 9

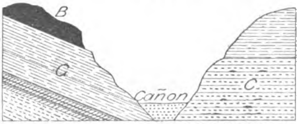

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PLATE 13.

Figs. 1, 2, 3, 4, 5, 6, 7.—Data for estimating quantity of ore in a mine.
Fig. 8.—Miner's horn spoon.
Fig. 9.—Development of mines.
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Fig. 14.—Mica crystal.
Fig. 15.—Hornblende crystal.
Fig. 16.—Augite crystal.

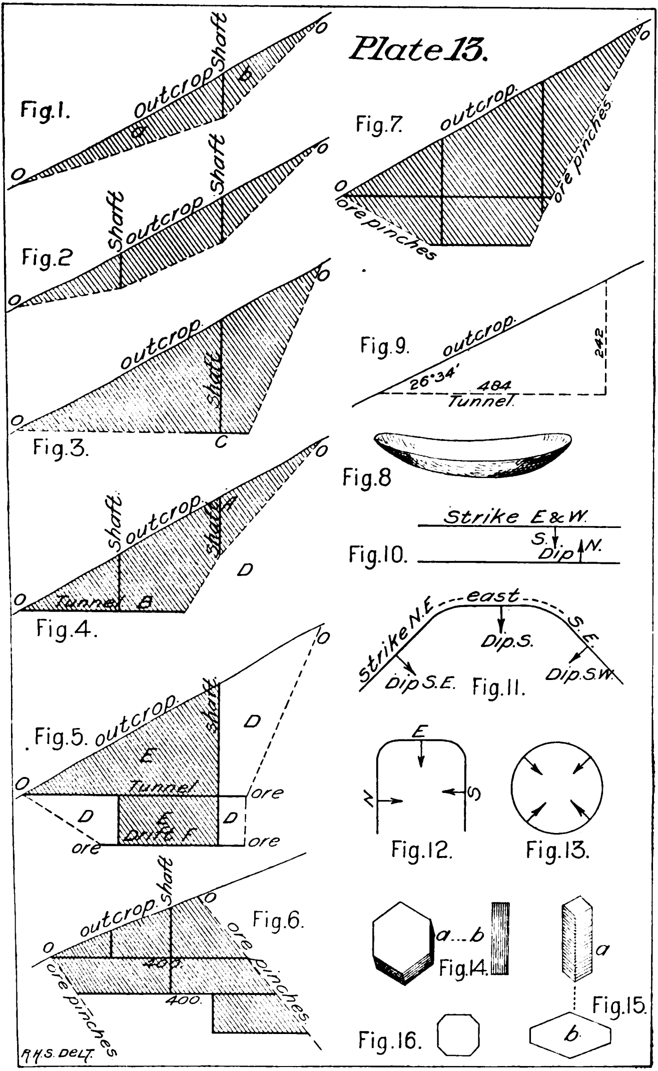


Plate 13.

Fig.1.
outcrop
Shaft
a
b
o
o
Fig.2
Shaft
outcrop
Shaft
o
o
outcrop
Shaft
o
o
C
Fig.3.
shaft
outcrop
Shaft
A
D
o
o
Tunnel
B
Fig.4.
Fig.5.
outcrop
shaft
D
E
O
o
Tunnel
ore
D
E
D
Drift
F
ore
ore
outcrop
shaft
o
o
Fig.6.
ore
pinches
200
400
ore pinches
R.H.S. DELT.
Fig.7.
outcrop
ore pinches
o
o
ore pinches
Fig.9.
outcrop
242
26°34'
484
Tunnel.
Fig.8
Strike E & W.
S.
Dip
N.
Fig.10.
strike N.E
east
S.E.
Dip.S.
Dip S.E.
Fig.11.
Dip.S.W.
E
N
S
Fig.12.
Fig.13.
a...b
Fig.14.
a
Fig.15.
b
Fig.16.

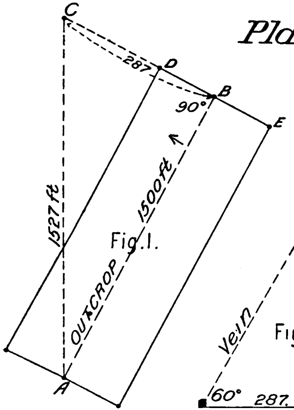
PLATE 14.

Figs. 1, 2, 3, 4, 5, 6, 7.—Showing method of making locations, good and bad.

Fig. 8.—Artesian well in basin with continuous rim higher than pipe outlet; *c*, *b*, *d*, clay beds; *g* and *e*, gravel beds; *a*, surface dirt; *w*, well.

Fig. 9.—Artesian well in basin with rim defective on one side; but which flows because the basin is sealed by the water-tight clay bed *c*; *g*, gravel bed; *a* and *b*, clay seams; *w*, well.

Plate 14.



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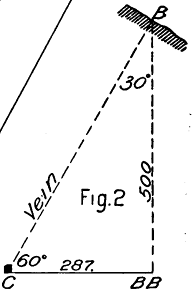

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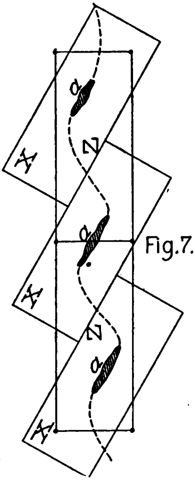

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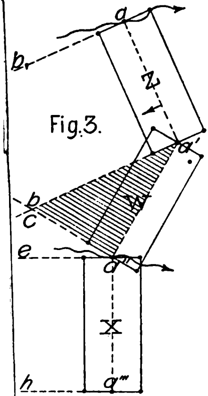

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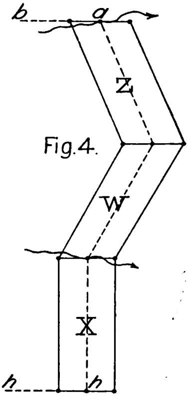

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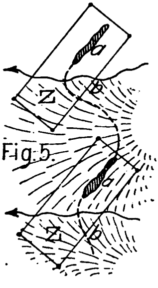

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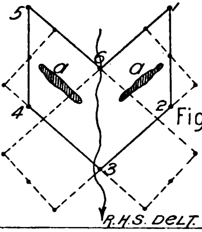

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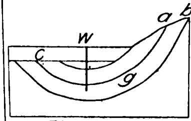

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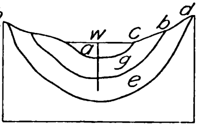

Fig. 8.

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PLATE 15.

Figs. 1, 2.—Correct form of blaze on trees as witness marks. Fig. 1, front view; fig. 2, side view.

Figs. 3, 4.—Good (3) and bad (4) stone-and-stake monuments.

Fig. 5.—Posting location notice in tin can.

Figs. 6–12.—Making locations (see Chap. X.),

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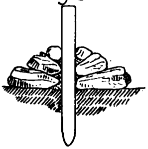

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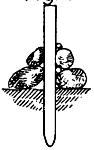

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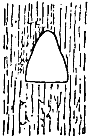

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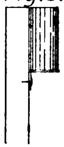

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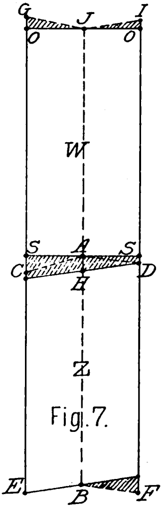
Fig.6.



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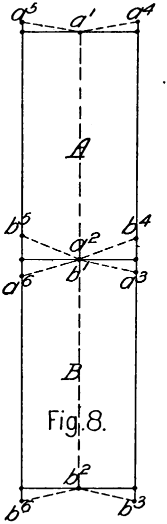

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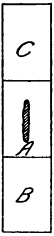

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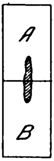
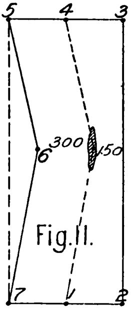


Fig.9.

Plate 15.



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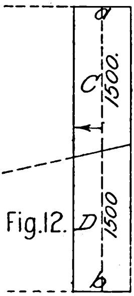

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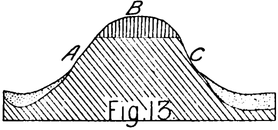

Fig.13.

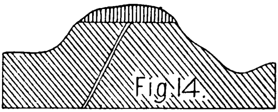

Fig.14.

R.H.S. Delt.

INDEX.

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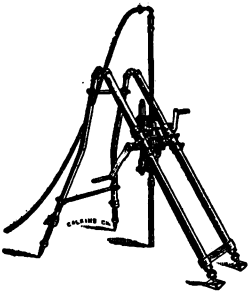
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