ACROSS THE
SAN JUAN MOUNTAINS.

BY

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THIS LITTLE BOOK

IS

DEDICATED

BY

THE AUTHOR

TO

THE THREE COMPANIONS,

H. N. Tod,
Lionel Lindsay,
C. H. Wittenoom,

WHO SHARED THE INCIDENTS

AND EXPERIENCES HEREIN RELATED.
ACROSS THE
SAN JUAN MOUNTAINS.

On a superb morning in September, that month of many colors, four of us\(^1\) started on a ride among the mining districts of the San Juan, in southwestern Colorado. The starting point was Ouray, the picturesque little town named after the old chief, an Indian of renown, the friend of the white men who first explored the mountain fastnesses of the Uncompahgre. From Ouray we rode across the ranges to Telluride, Silverton, Lake City, Gunnison, and thence to Crested Butte and back, following a course which, on the map, looks like a figure 8, with Ouray at the base of the lower loop and Crested Butte at the top. See map. The distance was slightly over 400 miles; the country traversed is beautiful to the traveler and interesting to the mining engineer, so that the experience was sufficiently rich in incidents and information to warrant the account which it is my purpose to present.

We left Ouray early on the 5th of September, with the intention of visiting two mines in the vicinity—the American Nettie and the Bachelor. A mile below the town the trail ascends the precipitous sides of Gold Hill, and as our sure-footed mountain horses followed the zigzag through the pines we found that each turn of the trail brought a steadily expanding vista until, halting on a projecting rock, we could see far out toward the north to the table-lands behind Montrose, across the near valley to the terraced dip-slopes of Triassic sandstone, down upon

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\(^1\) The party consisted of Messrs. H. N. Tod, Lionel Lindsay, C. H. Wittenoom and the writer.
MAP OF SOUTHWESTERN COLORADO.
Ouray itself, cradled amid red rocks and golden aspens, and up beyond the town to the sentinel peak of Mt. Abram, which guards the sources of the swiftly flowing Uncompahgre.

On arrival at the American Nettie mine the superintendent, Mr. Kunz, permitted us to visit the underground workings. These have an aggregate length of 12 miles, and consist of a series of adits and drifts penetrating the top layers of the Dakota sandstone where it comes in contact with the overlying black shales of the Colorado series. Both formations are members of the Cretaceous, the Dakota being the basal member of that division. The ore is found in irregular masses occupying chambers in the sandstone and impregnating the rock along stringers or small veins which serve as a guide in prospecting. In the cavities the ore consists chiefly of a sintery mass of oxidized material interspersed with ochrous ironstone, but when the ore is found impregnating the body of the sandstone it appears in the form of sulphides—iron and copper pyrites, blende, galena and gray copper. The best ore seems to hug the contact with the overlying shales, in the manner illustrated in Fig. 1, where A and B are “pockets” of ore reaching downward from the shale-sandstone parting and connected by a seam X Y, which follows the line of division between the two rock formations. The pockets are full of crumbly oxidized ore intermixed with a little gypsum, while X Y also carries some gypsum and a thin layer of black crumbly lime-shale which
suggests that it originated from the dissolution of an impure gypsum. The country lies flat, with a slight dip to the northeast, and it is crossed by almost vertical dikes which have evidently been the immediate cause of such fracturing of the sandstone as was favorable to subsequent ore deposition. In prospecting, it is found best to follow stringers of pyrite or even mere “walls” (slight fractures devoid of ore) which are parallel to the course of the dikes.

These dikes are peculiar; they are not made up of volcanic rock; on the contrary, they consist of clastic material, that is, fragments of sedimentary rock, and in this case the fragments were recognizable as pieces of sandstone, probably derived from beds not far away. The dikes which we saw were 2 to 4 ft. in width, and were well defined by their distinct walls; the country near them was fractured and sheeted, a condition which is probably due to the disturbance brought about by the intrusions of volcanic rock, which are known to occur in certain parts of Gold Hill. Not that the clastic dikes are of direct volcanic origin—quite the contrary—they are built up entirely of sedimentary rock material which has been packed together and cemented by the water that has found its way into them; they occupy fractures which may have been, and probably were, the indirect result of an intrusion, through the neighboring formation, of true eruptive matter, such as has been referred to as actually occurring near-by. On the high ridge above the American Nettie mine there is a coarsely porphyritic diorite which suggests an agency capable of having brought about the fracturing which led, first, to the formation of the clastic dikes and, subsequently, to the circulation of the ore-depositing waters.

The American Nettie has a new tramway, whose catenary curve sweeps from the high cliffs of Gold Hill, and, with undeviating line, bridges the abyss of the valley. It is a picturesque bit of engineering. A descent of 1,820 ft. is made in 4,200 ft. The span which crosses the valley is

2 From the Greek, klastos, broken. It is employed to describe rocks made up of fragments, as distinguished from the crystalline.
2,100 ft. in length, and in that distance the drop is 915 ft. The Leschen Company built it and, owing to the very abrupt contour of the ground, they had to make especial provision for safety. The descending side has a cable 1½-inch diameter, while the cable upon which the empties return is 1 inch in diameter. The traction rope is ¾ inch. To the latter button-shaped clips are permanently attached,
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with intervening spaces, the length of which is regulated by the number of buckets in use. The buckets are automatically detached and attached to the rope, at the loading and terminal stations; at both terminals the buckets receive a retarding and accelerating movement, as they arrive and depart, respectively, in order to diminish the vibration attendant on the removal of the load from the line, and the return of it into service. The accompanying photograph illustrates one of the terminals.

On leaving the Nettie we followed the trail which took us around the northern ramparts of Gold Hill, downward into the valley, whence a road led to the Bachelor mine in Red Cañon. Two members of the party, who were unused to the mountain horse, marveled at his sure-footedness as we scrambled down talus slopes and threaded our way among loose blocks of fallen rock. It is my experience that a good "trail horse" will go almost anywhere that a man can go without using his hands, while the patient burro (donkey) will walk safely over ledges which bring a tremor to the hearts of those who are not mountaineers. All the exploratory work of the Rocky Mountain regions was done by "packing," that is, by the transport of supplies and machinery on the backs of animals. Both mules and donkeys are used in this service. When the former are employed they are strung out in a line and connected by rope. A man rides the leading mule and guides the whole cavalcade. Another man usually walks or rides in the rear. When burros (the word donkey being rarely heard in the mining regions) are engaged in packing they are not tied together, but each goes loose, and the owner drives them like a flock of sheep, differing only from the latter in that they have learned, from the narrowness of the trails, to walk in single file when that is required for safety. A mule will carry 250 pounds up grade and 350 pounds down, while a burro can manage to carry an average of 200 pounds. The mule requires to be fed, but the burro can eke out a precarious existence on the scant grass of the mountain slopes, and for this reason he has been most serviceable to the pioneer and
the prospector; if the camel be named "the ship of the
desert," then the patient long-eared friend of the miner
might well be christened "the porter of the hills."

When we reached the Bachelor mine the noon-day meal
was ready, so we accepted the invitation of Mr. George
Hurlbut, the principal owner of the mine, to take luncheon
before going underground. It will not be out of place
to refer to the food which miners get in localities like
these; it is surprisingly good, as a rule, even at proper-
ties which are a couple of miles above sea level and a cor-
responding distance from the main distributing points for
provisions. The companies usually charge one dollar per
day for board and lodging, where standard wages are
$3 per shift. The fare which the miner gets three times
a day is superior to that of the second-class hotel of the
neighboring mining towns and far better than that which
is the daily portion of workmen in other countries. There
is always one weak spot—the coffee; partly because it is
not prepared immediately before being served and partly
because it is made from adulterated mixtures, and largely
because the average mine cook does not know the taste of
real coffee—at all events, it is a concoction out of keeping
with the excellence of the remainder of the miner's fare
and much better adapted for staining floors or removing
boiler scale.

The Bachelor lode is closely associated with a clastic
dike of peculiar character; the same lode follows the dike
through the mines to the east, the Khedive, and to the
west, the Wedge. Light-colored sandstones and shales, be-
longing to the upper subdivision of the Triassic, constitute
the prevailing formation; their dip is slightly southeast-
ward and they are crossed almost at right angles by a dike,
which inclines a little to the north and follows a fault-
fissure of small displacement. In the Khedive the sedi-
mentaries form a low monoclinal fold broken by the dike-
fissure, with an amount of dislocation so slight as to be
difficult of measurement. The zinc-lead-silver lode of the
mine traverses both dike and country. When small it
usually follows one or other of the walls of the dike, and when enlarged it spreads out into both dike and country. The lode has a northing of 45 ft. in 480 ft., but this is due not so much to deviation from the perpendicular as it is the result of frequent offsets caused by slips along the bedding-planes of the country. These do not fault the ore, because they antedate it, but they cause the vein to diverge to one side in accordance with the course of the fracture along which the dike first, and the lode-forming solutions afterward, found a passage. The ore frequently spreads
out between the bedding-planes of the sandstone and shales; it is also found in seams following fractures in the outer country, which appear to be sympathetic to the main fissure occupied by the dike and the lode proper. The dike is usually about 2 ft. in width.

The dike, to be seen in the Bachelor workings, is called by the miners, of course, "porphyry," but it consists of fragments of quartz, from sub-angular pieces as large as a thumb-nail to grains of sand, and of flat pieces of black shale; the latter are very prominent, and give the dike-rock a distinctly mottled appearance, as the accompanying photograph⁴ shows. They vary in size from microscopic fragments to bits several inches long. Besides these the dike contains pieces of sandstone, often micaceous by reason of sericite. A characteristic of the dike-rock is the arrangement of the shale fragments with their longer axes parallel to the walls of the dike; this is more marked in some parts of the mine than in others, and it is usually most pronounced close to the walls. (See Figs. 2 and 3.) The latter form a distinct parting from the outer country, and sometimes are also accompanied by a selvage.

This, like the one we saw at the American Nettie mine, is a clastic dike and the origin of it affords good material for speculation. Mr. F. L. Ransome, of the United States Geological Survey, has contributed an interesting paper⁴ on the origin of this very dike, and he explains it thus:

"A fissure was formed, accompanied by some faulting, and was filled, chiefly from above, by fragments of the soft fissile black shale, which does not occur in the stratigraphically lower beds exposed in the immediate vicinity, and partly by material from the lower light-colored beds forming the present walls."⁵

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³ This photograph is taken from the Transactions American Institute Mining Engineers, Vol. XXX., p. 231.


That this pseudo-dike is built up of fragmentary sedimentary rock, that it occupies a fissure, and that it contains no lava or other volcanic matter as a cementing material—these data seem to be assured. The nice point about the problem is the mode of formation. Was it from above or below? Mr. Ransome accepts the first alternative, and in support of this view he is enabled to instance the sandstone dikes which Whitman Cross found in the granite near Divide, in Colorado; which, elsewhere, Darwin, Ussing, Irving and others have described, and ascribed to a filling from above. Hugh Miller found a pseudo-dike in Cromarty (Scotland) in which a mass of sandstone working in from above (probably) contained fossils. Diller wrote
a memoir on the sandstone dikes of California and concluded that they were injected from below.

In the Lipari Islands there occur masses of volcanic tuff, hard enough to be fractured, which exhibit cracks filled in with fallen dust and scoria. But this is an entirely different kind of occurrence, as also is that observed at Pontgibaud (France), where a silver-lead vein occurring in granulite is shattered, together with its encasing rock, and, for a length of 10 meters, at a depth of 50 meters, contains boulders of scoriaceous lava evidently derived from the alluvium which once covered the outcrop

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My authority is my friend Professor Judd, author of "Volcanoes" and Dean of the Royal School of Mines, London.
of the vein. It is obvious that occurrences of this kind, at surface or near it, are quite different in their origin from a clean-cut fracture many hundred feet underground, of great length and depth and persistent width. It is, however, worth while to emphasize the distinction.

As between filling from above by gravitation and filling from below through pressure, I am decidedly inclined to choose the latter. In the first place, no mining engineer familiar with the shifting of wall-rock would grant the idea of the maintenance underground of an open fissure, both large and crooked, in rocks so soft as these shales and sandstones, for a period long enough to permit of the complete filling up of the suppositions crevasse. The sandstones and their alternations of shale exhibit movement along the sloping bedding-planes, as might be expected, and in the mine care has to be exercised to prevent injury from the rock which breaks off along these partings. Next, the internal evidence of structure appears to be against such a view. Fig. 3 illustrates a noteworthy characteristic of the Bachelor dike, namely, the frequent tendency to bulges and to vein-like protrusions which extend from the body of the dike upward into the surrounding country; no downward filling would, so it seems to me, explain this condition of affairs.

The fragments of black shale are traced by Mr. Ransom to an overlying bed through which the dike does not penetrate. Because it does not pass through this shale bed it is inferred that the latter was the source of much of the shale scattered through the dike. But why should not a simpler explanation suffice? Namely, that the fissure occupied by the dike broke through the harder sandstone series and died out when it met the tenaceous, shifting and more flexible layers of shale, much in the manner observed in the Enterprise mine. (See Fig. 4.)

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FIG. 4.—DISAPPEARANCE OF A FAULT.
it is said that the black shale does not occur in the lower beds observable in the vicinity of the mine workings. I thought so, too, until, on the occasion of my second visit, I noticed an exposure of black shale near the roadside at a point a short distance below the Bachelor mill, and, presumably, not much deeper than the present workings of the mine. This points to the probability of there being other layers of black shale amid the sandstone series traversed by the dike and renders it unnecessary to go far afield for a possible source of the black slivers which are so characteristic of the clastic rock. May it not have happened, therefore, that the dike was formed by the crushing of sandstone and black shale along the line of a fissure which was filled with this material as the fissure was slowly formed, much as water rises into a crack in the overlying ice? The close packing of the material within the dike, as is indicated by the arrangement of fragments of shale parallel to the walls, is suggestive enough of subsequent pressure, and it is not without a further suggestion that greater pressure, but from below, may have originally pushed the clastic material upward into the fissure as it was formed. Water may have been present to give additional mobility to the broken matter, such water subsequently having been largely expelled by the squeezing in of the fissure-walls. Prof. Judd examined some specimens of the Bachelor dike which I sent to him, and he concluded that the consolidation of the fragments was due largely, if not entirely, to the later chemical action of percolating solutions. To this suggestion there is the confirmation afforded by the subsequent deposition of ore along the course of the dike.

In Figs. 2 and 3 the Bachelor dike is illustrated. Fig. 2 exhibits the relation of the vein to the dike. A B is quartz, carrying streaks of galena and gray copper (tetrahedrite). There is also some blende present. Inclusions of country (sandstone) give the vein a mottled look along its outer edge, between D and E. The clastic dike B C contains several large pieces of shale, and a few signs of
MOUNTAIN ROAD BETWEEN OURAY AND RED MOUNTAIN.
ore. The fractures alongside the dike, at X, X, appear as dark threads of sulphides. In Fig. 3, taken at the east breast of the main drift in the adjoining Khedive mine, the clastic material is 17 inches wide, and exhibits one of those vein-like branches or off-shoots which are occasionally to be seen. In this regard the clastic material behaves just like a lava. The set-off at the top of the section is also a common feature. Sympathetic fractures occur in the encasing rock. In this instance the vein had merged into the dike and could only be seen vaguely in the form of patches of ore within the body of the dike.

The whole occurrence is one of great interest. If these clastic dikes are studied with reference to true lava dikes on the one hand and veins of asphaltum and gilsonite on the other hand, it should be possible to arrive at a clearer idea concerning the general question of the manner in which rocks undergo that fracturing which precedes ore deposition.

The next day, September 6, our cavalcade clattered up the main street of Ouray en route to Telluride by way of the Mt. Sneffels range. Cloudless weather, not unusual after the rains of late August, made the ride up Cañon creek to the Camp Bird mill a stimulating pleasure. Much of this road is cut out of the solid rock, in many respects it is a fine example of mountain engineering, and it is kept in good order because it serves as the avenue of traffic for two of the largest mines in Colorado—the Revenue and the Camp Bird. This part of Colorado owes much to an energetic little man who began by being an Indian interpreter, became a road-builder and, finally developed into a successful railroad organizer. Mr. Otto Mears is called the "Pathfinder of the San Juan"; he has left a monument as enduring as Thorwaldsen's lion of Lucerne, which lies sculptured in the rock above the Swiss lake—and much more useful—for the roads which Otto Mears built into the sides of the cliffs that look down upon the Uncompahgre and its tributaries have contributed in a
large degree to the successful development of some of the best mines in North America.

Mountain roads for heavy traffic should have a grade not to exceed 12 per cent and a width of about 15 ft. On the typical American high-road of to-day the cost of freighting by wagon averages 25 cents per ton per mile; this rate is always exceeded when the grade is above 12 per cent; in the mountains the rate is often ten times as much, because the loads pulled up the weary zig-zags are small compared to the horse-power employed. Thus, with four animals, averaging 1,250 pounds apiece, a load of 6,000 pounds, distributed between the wagon and its contents, can be handled along an average mountain road at the rate of 1 1/2 miles per hour. When the gradient exceeds 12 per cent it is more economical to pack, that is, to transport material by loading it upon mules or burros. The average cost of this method of transport is from 75 cents to $1 per ton-mile when there is no return load.

We overtook a train of burros with a miscellaneous freight of planks, groceries and boxes of dynamite destined for a small mine on Mt. Potosi; these, with bulky packages that hid their ears and left only a view of active extremities, looked at a distance for all the world like a migrating colony of Brobdingnagian ants.

Advancing carefully along the inside of the road, whose outer parapet stood sheer over a precipitous cliff, we hurried our horses past the burro train and soon covered the six miles between Ouray and the Camp Bird mill, where Mr. W. J. Cox, the manager, gave us every facility for inspection. The mill contains 60 stamps, weighing 850 pounds, with a drop of 6 to 8 inches, made 100 times per minute, and a resulting crushing capacity of 180 to 190 tons per day. The pulp passes through cloth screens of 26-mesh and No. 29 wire. It is then discharged upon silver-plated copper tables, which are the full width of

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19 Mr. Jas. W. Abbott tells me that on European roads the cost ranges from 6 to 13c. per ton-mile, with an average of about 10c.
the mortar, 54 inches, and have a length of 16 ft. The pulp then proceeds through classifiers, which distribute it among the concentrators—Wilfley tables and Frue vanners. The coarse material goes to vanners which have corrugated belts, the finer pulp goes to the plain belted vanners, and the slimes pass on to the Wilfley tables. Experiments were being made in the use of a 5-ft. Huntington mill for re-grinding the coarser sands. This is likely to prove suggestive. The tailings are delivered to the cyanide plant, and are pumped into vats, having a capacity of 275 tons apiece,

where they undergo solution for nine days. Tests were being made by Mr. Godfrey Doveton, who had charge of the cyanidation, with a view to determining whether the Johnson filter-press cannot be advantageously employed in the treatment of the slimes which overflow from the tanks; at present the press is only used in connection with the precipitate from the zinc-boxes. In Western Australia the large filter-presses have a capacity up to 6 tons apiece, with a tendency to increase. They were found to expedite the treatment of slimes and to economize water. All experi-
ments made in this direction should be useful because they point to a great economy of time and labor.

The Camp Bird ore is one of the most docile. The total extraction of gold is fully, sometimes more than, 90 per cent of the assay-returns from the crude ore. The latter carried about two ounces in gold at the time of our visit; the concentrates represent about 10 per cent in weight and 20 per cent of the value of the original ore, they contain 9 to 12 per cent lead, 12 to 15 per cent zinc, 14 to 16 per cent iron and 20 to 22 per cent silica (as quartz). They also carry from 2½ to 4 oz. of gold and from 11 to 15 oz. of silver per ton. They are sacked and sent on mule-back to Ouray, the charge for transport being $2.50 per ton—for the six miles of down grade. Coal is brought up as return freight at a cost of $4 per ton. The concentrates are then sent over the range, via Marshall Pass, to the Denver smelters, 388 miles distant, at a cost, for transport, of $7.50 per ton and a charge, for treatment, of $7 to $8 per ton. The bullion, resulting from amalgamation and cyanidation, is sent under escort every day.
to Ouray, whence it is sent through an express company to the mint at Denver.\textsuperscript{11}

After partaking of Mr. Cox's hospitality we mounted again and began the ascent to the Camp Bird mine in Imogene basin. As we surmounted the first rise we found ourselves in a wide amphitheater of serrated ridges with a broad gap in the direction whence we had come. Looking backward down Cañon creek, one could not fail to observe the fact of a succession of geological formations on account of the variations in the color of the rocks. The road from Ouray first cuts through a gray ridge of Silurian limestone, then passes over reddish beds of Upper Carboniferous lime and shale which, in turn, are unconformably overlaid by a Tertiary conglomerate whose nearly horizontal beds have a wide extent throughout the adjoining mining district of Telluride. This San Miguel conglomerate, as it is called, has a particular interest because it lies at the base of a great series of fragmental volcanic rocks (chiefly andesite-brecia) and lava-flows which inclose the majority of the important mines of the region. This series is called the San Juan formation. The road intersects the base of the series a short distance below the Camp Bird mill at about 9,100 ft. above sea level, as is shown by the accompanying photograph, where \( A \) \( B \) marks the line of separation between the two formations. Our trail continued to pass over successive layers of the breccia and its intercalated flows of lava until we reached the summit of the range, at 13,800 ft. When a mine is situated in this country of andesitic breccia the distance separating the deepest workings from the sedimentary rocks at the base of the San Juan formation becomes a matter of practical importance, because experience warrants the expectation that an impoverishment will be encountered when the vein passes out of the volcanic series. The Camp Bird

\textsuperscript{11} Since the date referred to, an excellent account of the Camp Bird mill and mine has been prepared by Messrs. Purington, Doveton and Woods. See Transactions American Institute of Mining Engineers, 1902.
A BIT OF GEOLOGICAL EVIDENCE ON THE ROADSIDE.
lower tunnel, for example, is about 2,100 ft. above the San Miguel conglomerate, so that there is plenty of room for further downward development. A generalized section of the geology and topography is given in the accompanying sketch, which I have borrowed from Mr. H. A. Titcomb's article in the Columbia School of Mines Quarterly, of November, 1902.

The Virginius, a neighboring mine, has an adit—the Revenue tunnel—which strikes the vein at a point 2,400 ft. below the outcrop and 10,800 ft. above sea level. The conglomerate is supposed to be about 1,000 ft. deeper. A shaft has proved the vein for 900 ft. below the adit, so that the total exploration on the vein extends for a vertical height of 3,300 ft., which is the deepest development attained by any mine in Colorado. The Virginius vein is remarkable in other respects also. It has been worked for more than 20 years. For the first 400 ft. in depth the vein was stoped continuously, although its width only ranged between a finger and a hand’s breadth. The ore was chiefly gray copper—argentiferous fahlerz—and aver-
REVENUE MILLS, MT. SNEFFELS, COLORADO.
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aged 400 to 600 oz. silver per ton. At about 1,200 ft. down the shaft, which followed the vein, entered a poor zone, which extended for 300 ft. further. At the level of the Revenue adit another poor zone, about 150 ft. thick, was encountered. The new vertical shaft, sunk from the adit, has found good ore, 30 inches wide, at 550 ft. The Virginius, by the way, has a large electric installation which operates both mine and mill. The electric cars used for underground traction are remarkable in taking the high pressure of 800 to 900 volts from a bare wire placed about the height of a man’s head. The power is generated from a succession of Pelton wheels, which use the water of Canon creek. They present an interesting feature in the fact that the nozzles are worn out in ten days by the action of sand at high velocity, which is the consequence of using a stream charged with tailings from a mill.

On arrival at the Camp Bird the superintendent, Mr. William Beaton, piloted our party through a portion of the workings. Both Mr. F. L. Ransome and Mr. C. W. Purington have recently described this lode in detail. A production, up to date, of about $7,500,000 places the Camp Bird among the great mines of Colorado. It is also interesting as having been until lately the property of the man who opened it up, Mr. Thomas F. Walsh.

The history of the discovery of this celebrated mine is curious. The only outcrop on the vein for several thousand feet is in a small gully right at the head of Imogene basin. A claim was located on this outcrop in 1877, but nothing further was done because no ore of any value was exposed at this point. William Weston and George Barber, who were the owners, made a

12 It is a pity that the word “tunnel” is so often misapplied. In the above case, and ordinarily in mining, the word “adit” should be used. A tunnel is a gallery or working which reaches from daylight to daylight, like a railroad tunnel. A main cross-cut or level which connects a mine with daylight is an adit. 13 Bulletin No. 182. United States Geological Survey, pp. 89-90 and 200-204, and Transactions American Institute of Mining Engineers, May, 1902. Also Engineering and Mining Journal, May 30, 1903.
proposal to H. W. Reed and Caleb Reed that if they would run a cross-cut tunnel, which would cut the vein at about a depth of 150 ft., they could have the option of locating a new claim on whichever side of the cross-cut they chose. The cross-cut was run, and in due course intersected the vein. The Reed brothers drifted 50 ft. to the west and took up a claim on that side. This was then patented under the name of the Una claim. On the eastern side the Gertrude claim was pegged out by Weston and Barber, who, later on, sold it to the Allied Mines Company. This was in 1878. Subsequently the company extended a drift for 40 ft. into the Gertrude ground, but found no ore of any value; later still, another 10 ft. was driven, so as to make the distance 50 ft., and thus qualify for patent. This was in 1884. The ore in the last 10 ft. was not assayed because the work was only done to fulfill legal requirements and the first 40 ft. of the drift had carried no pay ore. But as a matter of fact the drift had, in the last two or three feet, broken into rich ore; it remained there undetected until 1896, when Walsh broke some samples and had them assayed, thereby taking the decisive step toward becoming a millionaire. Moral: Never fail to test the ore of a drift which is penetrating into new ground, and never assume that ore is poor because it looks like ore you know to be poor.

The rest of the story is well known. Walsh was an experienced miner who had met with some success both at Leadville and Rico. In 1896 he was manager of the pyritic smelter erected at Silverton for the treatment of the ores sent down from Red Mountain by the Yankee Girl and Guston mines. Walsh had, in 1894, organized the company which put up this plant. In the search for silicious ores he investigated the mines of the surrounding country, not only those in operation, but also the abandoned prospects. He acquired the Hidden Treasure mine, in Imogene basin—this was a low-grade silver-lead property, which has never done much. In July, 1896, he went to see how work was going on at the Hidden Treasure,
and incidentally he noticed some pieces of pink spar amid the débris scattered at the foot of the cliffs, which form the upper limits of Imogene basin. This pink spar he took to be fluorite, and because it reminded him of Cripple Creek, where also he had mined with some success, he made a mental note of the occurrence. In the following September he revisited the locality and climbed up into the old Gertrude adit, from which he inferred the pink spar to have come. It was rhodochrosite; but no matter. It led him to take samples at the breast of the east drift. They were sent at once to Ouray to be assayed. The returns gave several ounces of gold per ton. More samples were taken and sent to Leadville for assay. The results were confirmatory, so he went to work quietly and began the steady consolidation of the adjoining property. Mr. Walsh's success was the reward following many years of most energetic search, a search backed by unusual experience in mining and extending over a large area which contained a great number of deserted old workings likely to prove remunerative under new economic conditions.

The main level of the Camp Bird is now over a mile in length, so that when we emerged from underground it became necessary to make haste in order to cross the range before dark. Ouray is 7,806 feet above sea level, the No. 2 level of the Camp Bird is at 11,510 feet, and the place where the trail crosses the divide is at an altitude of about 13,800 feet. The trail is a good one in summer, so that we did not require to lead our horses save in the steepest portions of the rise and in the abrupt descent on the other side. When we attained the summit a halt was called in order that we might take in the splendid panorama of mountains which lay outspread on either hand. Looking back over the course we had traveled we could see the shadows hastening to cover the valley of Canyon creek and the sheltered corner among the hills where Ouray lay concealed; in the far northeast the dark mass of the Uncompahgre plateau loomed purple in the fading light. Looking the other way the grim desola-
tion of time-worn summits and crumbling crags reached down into the gloomy gorge of the San Miguel, which suddenly broadened into the sunlit valley of Telluride, checkered with cultivation and bright with the gleam of blue water. Beyond were green foothills, out of which arose the sculptured mass of Mt. Wilson, silhouetted against the setting sun, and further still, northwestward, rim upon rim of far-off hills fading into the bourne of distant Utah.

The descent to Telluride was tedious, for it meant leading our horses most of the way—and some horses are particularly slow to be led, however willing to be ridden; besides, the drop from the top of the range to the valley is just five thousand feet in the course of five miles. All the way down one passes mines and mills; of the latter, the new Tomboy mill in Savage basin loomed conspicuous through the dusk.

At first sight it seems curious to build a large mill at an altitude of nearly 12,000 feet, instead of choosing a site in the valley and transporting the product of the mine over an aërial tramway. This is a much-mooted question. As a rule the valley site is preferable, because of the availability of a water supply, the greater cheapness of fuel for power and heating purposes, the nearness to a base of supplies, the facility which the tramway itself gives for transmitting materials up to the mine, the more kindly conditions of living for workmen, etc. If water can be secured at the mine, the erection of a mill close-by saves the cost of a tramway, that is, an amount ranging, say, from $20,000 to $50,000; but the water-supply of the high altitudes is so closely dependent upon melting snows as to be uncertain, unless a reservoir or natural lake affords a chance for storage. Of course, if the mill is at the mine, the concentrates have to meet the cost of carriage to the valley and this can be, in part, set off as against the expense of tramming the ore itself to the mill, if situated at a lower level. The Tomboy pays $2.75 per ton for packing concentrates from the mill to the head of
the valley, at Pandora, and as the ore yields from 8 to 12 per cent of concentrates this cost represents about 25c. per ton of crude ore. The item of fuel for motive power is eliminated by the electric transmission of power. Blacksmith coal is carried by the pack train to the Tomboy at a cost of $8 per ton, an amount one-half of which represents the expense of transport. The mill and other buildings are heated by steam; in some cases by low-pressure boilers, in others by high-pressure boilers with reducing valve. In summer 40 tons of coal are consumed per month; in winter, 200 tons are consumed per month. Coal costs an average of $10 per ton, delivered at the mine. Water for milling purposes is obtained from Lake Ptarmigan, by a pipe-line one and three-quarter miles long.\textsuperscript{14} The lake is just over the range and only 350 feet below the crest, so that the light pumps are sufficient. These are operated by electricity, which is bought from a large power company in the valley, at the rate of $80 per h.p. per annum. The Smuggler Union mine, which has its own generating plant, pays only $35 to $40 per h.p. per annum, but as against this, of course, is offset the interest and redemption of the capital used for an expensive installation. On the whole, therefore, it may be said that the comparison of conditions affecting the operation of a mill in the valley and that of a mill at the mine is without decisive result and depends entirely upon local factors. One of these is the ability to secure a good mill-site at a reasonable price. Another possible factor is the snowslide. To a stranger the interruption and damage from this source would seem to present a very serious obstacle to the use of a tramway. It does, but to the same extent it affects all the operations in a precipitous snowy mountain region. Last spring\textsuperscript{15} the Smuggler-Union tramway was

\textsuperscript{14} The line starts with a 5-in. pipe, which is reduced to 4 inches at the summit; from the summit to the mill it is reduced gradually, to 2\frac{1}{2} inches. For these and other data I am indebted to Mr. John Herron, the manager of the Tomboy mine.

\textsuperscript{15} The writer refers to 1902.
stopped for several weeks as a consequence of the damage done by a slide, and during the same season the Liberty Bell mine-buildings were swept away, so that the mill was idle for four months. In the latter case eighteen lives were lost, and the majority of these belonged to rescue parties who set out to the aid of those who were caught by the first slide. Successive avalanches entombed the rescuers.

As a rule, it is possible to predict the track of snowslides, because they commonly follow the line of destruction marked out by them in previous years, but as a matter of fact, the great injury to life and property due to snowslides is just the one which is caused by the unexpected slide which takes an entirely unsuspected line of descent. Such was the cause of the Liberty Bell catastrophe, for, of course, the buildings were erected at a spot confidently believed to be immune from such a danger.

The destructiveness of a snowslide must be seen to be appreciated; buildings and tramways are as toys before its fierce oncoming and men in the path of its descent are as straws in a whirlwind. In fact, much of the damage is due to the vacuum caused by the rapid motion of a mass of snow and the cyclonic disturbance which follows in its wake. I have often watched them descending a neighboring ravine, when myself out of all chance of danger. The thunder of its tempestuous descent first calls one’s attention, and then one sees the mass of snow gathering underlying rocks, uprooting trees, amid a quickly gathering mist of snow particles driven fiercely by the whirlwind in the rear. The rushing mass will not stop at the bottom of the slope, but its momentum will carry it some distance up the opposite declivity, while all the forest trembles and the air is darkened with a snow mist.

The stretch of country covered by Marshall and Savage basins, and thence to the valley at Pandora, has seen many a snowslide. A long tale of woeful fatalities and romantic heroism could be told concerning these three or four miles of mountain land.
In the cemetery at Telluride there are many large graves inclosing the remains of groups of unfortunate miners who were swept into eternity by the fateful avalanche. Their resting places are unadorned by showy tombstone or grandiose epitaph, but close-by a new white marble monument attracts the passer-by to read the inscription upon its face. It tells a startling story to those who can read between the lines. In July, 1901, the management of the Smuggler Union mine introduced the system of working by contract, a system which results in paying a workman according to his work, and which, therefore, is directly opposed to the underlying principle of unionism, which demands an equal wage for the idle and the energetic, the capable and the incapable. There was a strike, the members of the union, for the most part, refused to work, while a large proportion of experienced miners accepted the contract system and remained at the mine. On the 3rd of July, the eve of the Declaration of Independence, a body of strikers attacked the mine, shot indiscriminately into the bunkhouses, offices, and other buildings, succeeding in killing eight non-union men and in driving the remainder over the range. In this cowardly assault one striker was shot. It is his tombstone that so conspicuously adorns the Telluride cemetery; upon it there is this inscription: "Erected by the 16-to-1 Miners' Union in memory of (then follows the man's name). Born in Koojoki Wora, Finland. Died at Smuggler, Colo., July 3, 1901, aged 27 years." Then follow these noble lines of Longfellow:

"In the world's broad field of battle,  
In the bivouac of life.  
Be not like dumb driven cattle—  
Be a hero in the strife."

This—this is the prostitution of poetry! Remember, too, that no one has ever been punished for the murdering of the eight miners killed on that same day, while the one murderer, killed in the act, is commemorated in marble and in poem!
This intolerable outrage emphasizes the conditions of affairs in this district. There has been a manly effort made by three or four of the mine managers to protect the rights of property and good citizenship, but it has been handicapped by the interference of political considerations. Mr. A. L. Collins, the manager of the Smuggler Union mine, told me of the receipt by him, from the secretary of the union, of a list of "seabs," namely, men who refused to accept the edicts of the union—16-to-1 union, if you please!—and this list was interesting because the names upon it could be pronounced!—that is, they belonged to men of American and English descent, as against the bulk of the miners in the district who are Austrians, Italians, Slavs, etc. Mr. Collins inserted a paid advertisement in each of the local papers promising work at the mines under his charge to any man on that list.

The above lines had just been written, on November 19, 1902, when the news of the assassination of Arthur Collins shocked the whole profession of which he was so honorable a member. I have elsewhere expressed my feeling concerning this tragedy. It is a bitter price to pay for frontier lawlessness and that political expediency which holds the law bound in its slimy coils.

The mine which was the scene of these unhappy doings is one of the largest in Colorado; it was discovered in 1875, when one of the claims, the Sheridan, was first located. A stray occurrence of the mineral sylvanite, the telluride of gold and silver, was the cause of the naming of the mining camp. The lode proved remarkably persistent in richness through the Mendota, Sheridan, Smuggler and Union claims, and beyond them into other mines; it has been traced for over four miles on its strike and it has been continuously stoped along one portion for a length of 5,000 feet. The Smuggler lode has yielded altogether about $12,000,000. It cuts through the crest of the range at 13,200 feet, where it is encased in rhyolite; at 12,450

16 The editorial on the "Tragedy at Telluride" in the Engineering and Mining Journal of November 29, 1902.
feet it passes into a sheet of augite-andesite which is 550 feet thick, and below this it goes through the great series of andesitic breccias which reach down to the San Miguel conglomerate, at an altitude of 10,000 feet. The variation in geological environment has not been without its effect upon the character of the vein. Mr. Collins informed me that the payable part of the vein reaches up to the rhyolite cap, the limit of productiveness coinciding to a remarkable degree with the base of the rhyolite, where the vein becomes pinched,—a mere persistent parting easily discernible even at a distance on account of the discoloration of the encasing rock. In the rhyolite, the vein is accompanied by a little mud or selvage and some silver ore, in patches, but no cellular quartz such as can be seen lower down. This bit of evidence does not favor the idea of a secondary enrichment of the lower ore-bodies by means of the removal of values in the uppermost portions of the vein. In the augite-andesite the bonanza ore-bodies occur, the richest masses of silver ore coinciding roughly in their distribution with certain harder, almost horizontal, layers of this andesite. Similarly, in the underlying breccia, which is fine-grained, the pinches in the vein occur along nearly level lines coinciding with the bedding-planes of the country. Good ore makes in zones, but oxidation reaches downward irregularly, and does not coincide with enrichment.

The Smuggler vein, as the drawings will show, is notably banded; the hanging wall is usually well-defined and carries a casing, immediately underneath which a persistent quartz-leader is generally to be seen. This leader is the first part of the vein to show oxidation. The footwall is "frozen" with quartz stringers, which merge into the country. The general structure of the vein suggests multiple fracturing with but slight actual displacement, and a shat-

17 Mr. John B. Farish has since informed me that in the adjoining ground, of the Humboldt mine, he found that these patches of ore in the rhyolite indicated ore-bodies in the underlying andesite.
tering of the rock without much actual crushing. Vugs, or crystal-lined cavities, are frequent; they are due to crustification, or crystal-lined growth, around the sides of spaces separating pieces of broken rock.

The accompanying drawings were made underground during a visit in 1901; Fig. 6 represents the back of a stope at the ninth level. On the hanging there is a quartz seam, A A. This is usually the rich streak; if any free gold is to be found in the lode, it will be found there. The quartz is white and rather massive, with crystalline vugs which are frequent. The next band, B B, is a strip of hard country, included in the vein; the part E to D is also breccia, with some quartz; the footwall country, D F, is
full of quartz stringers which drop into the vein; the outer country contains vugs and some quartz. On the hanging there is a soft shaly band, about 3 feet wide, which is used by the miners as a "shooting course," that is, it is recognized as an easy line of fracture and separation between the ore and the rock.

Fig. 7, obtained in a neighboring stope, suggests the arrangement of ore in relation to the bedding of the breccia. The hanging-wall leader is represented by the stringer B B. A B is a casing of soft shaly country corresponding to the shooting course described in connection with Fig. 6. D D are seams of white quartz carrying iron-stained vugs. E E is a quartzose band. The included country in the middle of the vein, from B to E, is mottled by brecciation and does not contain as much quartz as is usual. The footwall is hard.

The lode yields a wonderful array of fine crystals of quartz, siderite, calcite, argentite, rhodochrosite, gold and silver. The transparency of most of these, especially the quartz and the siderite, suggests an extremely slow process of crystallization. Siderite, the carbonate of iron, occurs in handsome yellow crystals encrusting both quartz and calcite. Calcite was the last mineral to be precipitated, and it is found lying upon the quartz which lines the geodes or vugs. Rhodonite, the silicate of manganese, occurs in irregular bands, usually on the footwall or else in the main body of the pay-ore. Rhodochrosite, the carbonate of manganese, is occasionally seen in rose-red crystals. Gold is found in crystalline aggregates forming specimens of great beauty. Wire gold also occurs. Both the wire and the crystalline gold have the composition of the true alloy, Au Ag.18 In the upper workings the native gold is purer.

While the lodes of the vicinity, as a rule, have the general structure of sheeted bands of country rather than that of large fault-fractures, it is a fact that several of the

18 A fact determined by the late Arthur L. Collins, who gave me many of the data contained in this description of the Smuggler-Union.
SMUGGLER LODE.
FIG. 7.
poorer veins follow pronounced lines of faulting. I measured the vertical dislocations, which coincide with the Contention and the Allegheny veins; in the first case the displacement is 58 ft. and in the second it is 21 ft. The Pandora faults the Smuggler about 50 ft.\footnote{John A. Porter. "The Smuggler-Union Mines, Telluride, Colorado." \textit{Transactions} American Institute of Mining Engineers. Vol. XXVI., p. 452.} The Vir-ginian vein is faulted twenty feet by a crossvein.\footnote{C. W. Purington. "Preliminary Report on the Mining Industries of the Telluride Quadrangle, Colorado," p. 837.} In these cases it is the poor vein which follows the fault.

We spent a couple of days at Telluride, visiting the mines in the vicinity. Two of our party went up to the Contention mine, and avoided a long ride over road and trail by getting into one of the buckets of the tramway which makes a bee line up the mountain side. The aerial voyage was made speedily and safely, if not very comfortably. In winter the managers of many of the properties find it expedient to make their trips to the mines over the tram route and in spring, when the deadly snowslide may launch itself down the mountain at any time, it is much safer to travel on the tramway, not because it is always immune from this peril, but because of the shorter time to which one is exposed to danger in making the journey on the tramway, as compared to floundering painfully on horseback or toiling patiently uphill on snowshoes. The Contention is an interesting lode because it is productive of gold ore in a Tertiary conglomerate, not in the form of a bed of conglomerate impregnated with gold,\footnote{Such as the conglomerate beds of the Witwatersrand, for example.} but a nearly vertical vein-fracture cutting through a nearly horizontal formation and passing above this conglomerate into the andesite-brecia series and below the conglomerate into sandstones of the Jurassic. This is an example of the great diversity of geological environment which distinguishes the Telluride district; within a small area productive gold and silver veins have been worked not only in the Tertiary volcanics
and the Tertiary conglomerate underneath them, but also in Jurassic limestone (the Sawpit mines) and in Triassic sandstone (the Allegheny). This, however, is a subject too wide for more than incidental reference.\(^{22}\)

The big mines of the Telluride district afford examples of good management and the close economy which goes with such management. During the past fiscal year the Tomboy treated 85,726 tons of ore, the average yield of which was $9.98 and the average cost per ton, $5.85. With the help of the new mill, the costs are expected to be brought down to $5.50. The Liberty Bell mine, for the year ending September 30, 1902, despite snowslides and other unforeseen delays, handled 67,439 tons for a yield of $7.15 per ton, at a total working cost of $5.53 per ton; while the Smuggler-Union, on a larger tonnage, has brought the total expenses to just under $4 per ton. In 1902 the average mining costs were $2.90 and milling expenses $0.90 for 92,917 tons. Summer costs were better than those in winter; for instance in April, 1902, the mining cost was $2.81 and the milling $0.74, for 12,-979 tons. The figures for mining include expenses of ore up to delivery at dump.

In referring to good management it will not be out of place to mention the action of the manager of the Tomboy mine, who, when the old mine had evidently become exhausted, was enterprising enough to secure options on adjoining ground, at that time giving promise of a good thing. Mr. Herron bought the Argentine for his company and thereby put the Tomboy on its feet again. In his negotiations he was supported by his directors, and the result is the possession of a mine which has made the shares of the company more valuable than they were at the time of its organization. Mr. Herron acted for the directors, the directors acted for the shareholders, and although

\(^{22}\) An excellent geological report on this district has been published. "Preliminary Report on the Mining Industries of the Telluride Quadrangle, Colorado," by Chester W. Purington, United States Geological Survey.
the transaction was a large one the shareholders were debited only with a bonus of $10,000, which was given by the company to the mine manager in recognition of his services. It is an incident worthy of record and does honor to all concerned. If managers and directors of mining companies always took such a proper view of their duties, the industry of mining would gain hugely.

On the 8th of September we started for Silverton. We took the recurrent zig-zag of the Bridal Veil trail, and in an hour reached the top of the waterfall, whose filmy traceries had originated the name. The beauty of the waterfall is gone, a sacrifice to utilitarian engineering. which has taken the water to supply power to the Smuggler-Union mill. The pipe-line climbs to the place where once the waterfall flung itself into space, and the penstock stands where it paused for breath before its leap into the sunlit ravine. As we halted at the head of the trail, the San Miguel valley lay outspread with panoramic spaciousness.

Nearly horizontal lines of differently colored rocks in ordered succession gave the suggestion of long-continued natural forces building up the superstructure out of which the sculpturing hand of Time had chiseled the great array of mountain peaks which rose against the cloudless skies. Emerson has said somewhere that we ought to "respect the naturlangsamkeit which hardens the ruby in a million years, and works in durations in which Alps and Andes come and go as rainbows." It is restful to contemplate this patient operation of natural forces in contrast to the unresting eagerness of man—a nervous energy nowhere more marked than among the mines and mills which lie under the shadows of these very mountains. Such contemplation should conduce to equanimity. I think it does. The records of the geological societies show that geologists, as a rule, live long.

Above the valley rise the short slopes of red sandstones of the Trias, surmounted by the white line of the La Plata sandstone at the base of the Jurassic, and above this distinct stratum, marked by a medial layer of dark limestone,
there succeed the variegated shales and sandstones of the McElmo formation at the top of the Jurassic; these, being fairly soft, have a gentle slope, partially covered by vegetation, and are topped with the gray band of the Dakota sandstone, at the base of the Cretaceous. All these rocks dip down the valley westward, so that the horizontal bedding of the overlying San Miguel conglomerate brings out the unconformity very clearly. This Tertiary conglomerate has a dark-red color, as seen from a distance, and it belts the base of the steep cliffs above the valley with persistent conspicuousness. It is about 400 feet thick just below Pandora, and is covered by the vast succession of volcanic ejectamenta, which rise tier upon tier for a height of 3,500 feet, culminating in serrated peaks which soar far above the uppermost limits of vegetation.

In leaving this wonderful geological section it will not be unfitting to suggest that instructors of geology in our schools of mines will find nowhere on the globe a better locality wherein to bring home to the student the relation between geology and mining, nor will they find, with convenience, a district which illustrates so well the working and the results of natural erosion, the operation of which Hutton and Lyell emphasized as fundamental among the processes of geological action.

When we resumed our ride, we found ourselves on a trail threading a pine forest. In sheltered spots the wild flowers of summer still lingered, and the trail crossed busy rivulets, whose voice was the only sound disturbing the quiet of regions strangely devoid of life. Emerging from the pines, we found ourselves on the treeless waste above 'timber line,' and followed an easy ascent along the bare, rounded slopes at the head of an amphitheatre of ridges. It was a lifeless desolation, bleak and still, until suddenly a series of salutes rang out, to be echoed grandly from peak to peak. These were the blasts from mine-workings which we had not seen; they marked the noon hour. It was time for "croust" (literally crust), as the Cornish miners call the meal which divides their working time; so we off-
saddled beside the first stream and ate our luncheon while the horses nibbled the scant, dry grass. It seemed good to be there under that serenely blue sky and amid an air that made "the world seem young and life an epic." Those who do not know the exhilaration of these high altitudes have not realized what perfect vitality means. On resuming the ascent, we were soon amid loose slopes of débris, over which the horses went with no more difficulty than ourselves, although the increased rarity of the air told on them very obviously. The trail was lost, and on choosing the lowest ridge to the south, we found ourselves eventually where we did not expect to be; that is, overlooking the little mining town of Ophir, which I knew to be out of our course to Silverton. We looked from a razor-back ridge far down a precipitously steep slope into a distant little green valley; a white road marked the center of it, and a cluster of dwellings, like match-boxes, seen so far, marked the settlement of Ophir. This is not Solomon's treasure-house, but as the slanting sunlight touched the clusters of yellow aspens upon the lower slopes of the valley we found reason enough for the fitness of the name.

Retracing our steps into the basin from which the ridge arose, we crossed to the eastern side, and finding a trail, ascended a crumbling ridge, from which we could see the whole complex of mountains stretching from Red Mountain to Silverton and far beyond. We were 13,200 feet above sea level. It did not take long to regain our wind, and shortly the four of us were picking a way down the further side, winding in and out of those semi-circular basins which are so characteristic of the high country just above the timber line. It was wearisome pulling unwilling horses over talus slopes, so we soon halted for a breathing space and took in the view. An amphitheater of rugged peaks formed our background; tiers built up of successive extrusions of andesite looked out upon a vast lifeless desolation of gray summits and dun-colored ranges, from which rose three flaming peaks, red as torches to anarchy. These, the Red Mountains, are a landmark
throughout the region. Their color is due to the solfataric action of thermal waters upon the iron sulphides disseminated through andesitic rock. At the foot of these iron-stained ridges are situated the famous Guston and Yankee Girl mines, which were so prolific about fifteen years ago. The origin of the lodes is connected with that of the peculiar red summits, in that both are traceable to the activity of acid waters which have precipitated rich silver minerals on the one hand, and, on the other hand, have removed the more soluble portions of the andesite, depositing additional silica, so that the resulting quartzose country has withstood erosion sufficiently to survive in the form of red summits, which now serve as beacons to the prospector.

We reached Silverton before dark.

Silverton exhibited a condition of bustling activity; the country tributary to it, up and down the Animas and along its numerous tributary streams, has recently undergone a good deal of that new development which is essential to the maintenance of production in a mining district. In fact, by reason of the energetic development, particularly of gold mines, which has been going on ever since the fall in the price of silver in 1893, the surrounding region is to-day one of the most prosperous mining tracts within the Rocky Mountain area.

The mountains around Silverton were first invaded by the pioneers in 1871, when the Little Giant vein was discovered by Miles T. Johnson. In 1872 an arrastra was put up, not far from the present site of the large modern plant of the Silver Lake mine. At that time the nearest trading station was at Conejos, in the San Luis valley. Until 1873 the Indians had legal control over the region, but this was ended peaceably by the Brunot treaty.


Early on the morning of September 9 our party of four rode down the wide main street en route for the Golden Fleece mine, near Lake City, about 40 miles distant. Just outside the town one passes the entrance to Cement creek. Here there is a new pyritic smelter which is close to the site of the old Green smelter, erected by Judge Green, of Cedar Rapids, Iowa, in 1874. The machinery for that early metallurgical establishment came on burroback from Colorado Springs, over 300 miles, Colorado Springs being at that time the terminus of the railway. The first furnace was made of sandstone without any lining, and Mr. John A. Porter has told me of the advantages and disadvantages of this method of construction. It had one advantage: when the silicious portion of the charge was insufficient for a good mixture the side of the furnace contributed the silica which was wanting! In 1876 the first water-jacket used in Colorado was put into service at the Green smelter; it was a round jacket three feet in diameter and was made by Fraser & Chalmers, at Chicago. The year before, 1875, Mr. Porter had put in a siphon-tap, suggested by his experience at Eureka, Nevada, from which place he had come to Silverton. This was the second siphon-tap employed in Colorado; the first was put in at the Swansea works, near Denver, by Ahrents. Nothing remains of the old Green smelter save a cabin with a brick chimney, which used to be the assay-office of the establishment. This plant was the parent of the San Juan Smelting Works at Durango, erected in 1880, and contributed an important share to the early development of the surrounding region.

Local smelters such as these have helped the exploration of the mountains. In riding across country, as we were doing, one would occasionally see, in contrast to the bright coloring of the aspens, a black patch of ground, suggestive of the gloomy gulf down which Pluto snatched the fair Persephone. These dark patches are old slag-dumps, which have crumbled to dust, and serve as reminders of the little smelters which preceded the large centralized establishments erected in later years at Pueblo and Denver.
THE SMUGGLER UNION TRAMWAY.
The memory of these early efforts has crumbled away, like their slags, but they are interesting not only as small beginnings of a great industry but on account of their human associations. They served to train many of our best men. John A. Porter has been mentioned in connection with the Green smelter; at the Rico works, first built under the name of the Grand View smelter, in 1879, such men as F. M. Endlich, Hofman and Arnold successively got experience and, in much later years, W. C. Brace, E. J. Wilson and L. D. Godshall. The early seventies in Colorado saw the beginning of many reputations which are now well established. Dr. Edward D. Peters is said to have been a great champion of the reverberatory in those days; he built a smelter at Dudley, at the foot of Mt. Bross, in 1872. The ores were rich in silver and copper, but loaded with heavy spar, so that although he began with only a calcining and stone blast-furnace, 36 by 42 inches in section, with water-cooled tuyeres, he subsequently added a reverberatory furnace, having a 9½ by 15 ft. hearth, which was fired with spruce wood. The ores were unfit for smelting by themselves, but the smelter was operated with moderate success for two years. At that time West was in difficulties with a matte blast-furnace at Black Hawk, and Collom was bucking against the impossible zinc-silver ores of Georgetown at a little smelter just below Empire, near the forks of Clear creek.

Col. William L. Chandler was at Saints John, in Summit county, just over the continental divide, where the ore from a mine at Keystone was made into a silicate of lead in the fusion-hearth of a roasting reverberatory furnace. This was called "matte" and was treated in a low shaft furnace; the height from the tuyeres to the charging door being 5 ft. This stuff was sent to Empire, where John Collom was running the small shaft-furnace already mentioned. The treatment was a failure until H. A. Vezin took charge of the works and produced good silver-lead. This was early in 1872 and was the first lead produced on a commercial scale on the Atlantic slope of
Colorado. In 1875 Anton Eilers took charge at Saints John, but left in a short time in order to join Billings at the Germania works at Sandy, near Salt Lake City. He was succeeded at Saints John by Franz Fohr, who, in later years, was manager of the Harrison Reduction Works at Leadville.

In 1874 Mather & Geist established their works at Pueblo with two furnaces. This was the beginning of the Pueblo Smelting & Refining Company. A certain Prof. Cheney at Animas Forks and a Prof. Durier at Animas City started smelting furnaces in localities as ill situated for fuel as for ore—doomed, therefore, to point a moral and adorn a melancholy tale.

Richard Pearce had his first experience, in Colorado, in 1873, at an unsuccessful smelter erected near Empire, on the site of Collom's old works. At the end of 1873 this ill-fated establishment closed and Mr. Pearce moved to Black Hawk, where Prof. N. P. Hill, not long arrived from Brown University, was in trouble with the pyritic ores of Gilpin county. Pearce and Hill joined forces and, under the advice of the former, an addition was made to the plant, whereby it became possible to treat the matte, which up to that time had been shipped to Vivian & Sons, at Swansea, Wales. This change of method made the Black Hawk smelter a financial success, and led finally, in 1878, to the erection of the large plant at Argo, near Denver, where, under the name of the Boston & Colorado Smelting Company, it has since become so well known.

Jas. B. Grant was recently graduated from Freiberg when, in 1878, he built a small one-stack smelter at Leadville. Within a year this was increased to eight stacks; and in 1880 Edward Eddy and W. H. James, who owned sampling works at Leadville, joined Mr. Grant in his smelting venture. That pioneer establishment is gone, but it was the parent of the Omaha & Grant Smelting & Refining Company. Anton Eilers has been referred to already. He was at the Germania plant from 1876 to 1879; in the
spring of 1879 he started grading for the Arkansas Valley smelter, which was blown in on May 20 of that year.

In these early efforts there is a personal equation and a human interest lacking in the larger undertakings of later days because they represent the skill, hopefulness and energy of individual young men, many of whom have proved to be masters of the metallurgical art. While it must be amusing to those who are accustomed to the more patient progress of older countries to read of a period within the memory of active men as being "historical," yet, as time is measured in a rapidly progressive mining region like Colorado, it does indeed seem long ago. "In a remote period of Western history, that is to say, 30 years since," is a sentence not without a touch of humorous exaggeration to a European, but the rapid achievement of a new country outsteps the slow beat of a pendulum.

As we rode along the right bank of the Animas, we passed the North Star mill, where John J. Crooke employed the old Augustin process, roasting silver ore with salt and leaching the resulting chloride with hot water, finally precipitating the silver on copper.

Further up one comes upon the Stoiber residence, "Waldheim," a 30-room house, with all modern appointments, built by the former owners of the Silver Lake mine. Just beyond, in Arrastra basin, one can see the Silver Lake mill and the tramway, which extends in swinging lines to the mine beside the lake at 12,250 ft. above sea level. One of the spans of this Bleichert tram clears a distance of 2,200 ft. In a total length of 8,400 ft., the upper section of the tram descends 2,100 ft., and has only 19 supporting towers. The lower section—from the old mill to the new mill—is 6,300 ft. long, with a fall of 659 ft. The tram from the Iowa mine climbs the neighboring bluffs, and a little further up the Animas the North Star tram reaches the river from near the top of Sultan Mountain, a height of nearly 13,000 ft., making a descent of over 3,200 ft. Silverton itself is situated at 9,300 ft. above sea level.

The North Star tram is 2 1-3 miles long, and connects
IOWA MINE TRAM—Men in Bucket.
the mill on the right bank of the Animas with a loading station at the entrance of an adit at 12,900 ft. above sea level. A two-bucket tramway, having a single span of 1,950 ft., carries the ore to two large storage-bins situated in a gulch 604 ft. lower down. Each of the two buckets carries 1,300 lbs. of ore, the empty one being pulled up by the descending loaded bucket. The carrying cable is 1¼ inch in diameter, and the traction rope, 1½ inch.

The ore-bins, just described, serve as the terminal of a Dusédaü aérial tramway which goes to the mill, two miles down the mountain, making a vertical descent of 2,600 ft. At an altitude of 12,300 ft. the tram crosses a mountain
ACROSS THE SAN JUAN MOUNTAINS.

Lake with a span 1,340 ft. long, and lower down there are other spans of 1,050 ft. and 1,030 ft. respectively. At the lower end, connecting with the mill, the final span is 900 ft. long, with a fall of 380 ft., crossing the Animas river at a height of 150 ft. above the water. The tension station is midway between the mill and the upper terminal. It is said that the gradient of the installation is such that 30 h.p. is developed—but this power is not utilized.

The buckets or cars are 40 in number, and each carries 600 lbs.; they are placed at intervals of 600 ft., and travel at a speed of six feet per second. Fifty towers are stationed along the line, the highest being 71 ft. Two miles of steel ropes are used for this system, the total weight of them being over 30 tons.

These numerous aerial ropes, spanning the intermountain spaces like great spiders' webs, are an important feature of mining in the San Juan region. We had already, on the previous days of our trip, seen the tramways of the American Nettie, Bright Diamond, Grand View, Camp Bird, Smuggler Union, Columbia, Liberty Bell mines, besides others, the names of which we did not know, so that with the group of three just referred to, near Silverton, we had, in the aggregate, observed a good many examples of this kind of mountain engineering. Most of the recent installations belong to the Bleichert and Otto systems, in which the bucket is drawn over a thick stationary cable by means of a smaller traveling rope. The traction rope is usually from $\frac{1}{2}$ to $\frac{5}{8}$ inch in diameter, while the fixed cable is from 1 to 1$\frac{1}{2}$ inches. The older Huson and Hallidie systems, with a single traveling rope, to which the small buckets are attached, are nearly obsolete except for short distances and over easy contours. The need for very frequent supports, the consequent less substantial construction, and their smaller capacity has rendered them less desirable as a means of transporting ore over a rugged country. Experience now favors the double ropeway system in spite of a cost of installation which is 30 to 50 per cent greater than the single rope type, because this difference in first
cost is soon wiped out by the cost of maintenance, which with the Hallidie type is nearly double that demanded by the Bleichert; moreover, in the matter of capacity, it may be said that the former is limited to, say, 75 tons per day of 10 hours, while the substantial construction and larger scale of the latter permits of a capacity that ordinarily reaches from 250 to 400 tons per day of 10 hours.

The first cost of a tramway of this kind depends upon the contour of the country traversed, and the distance from the manufacturer who supplies the material. In the high altitudes of the San Juan, say, 10,000 ft. or over, the cost of material for an installation having a capacity of 200 tons per day of 10 hours would be about $2.10 per foot of tram line, and the cost of freight, plus erection, would be about $1.15 more, so that the total cost would be about $3.25 per foot. A tramway, one mile long, having the capacity mentioned, would entail an expenditure of about $20,000. Actual expenditure for tramways in this district has ranged between $2.50 and $8 per foot; as a rule the cheap one proves the most expensive on account of the greater cost of maintenance and repairs. The Camp Bird tramway is 8,550 ft. long, with an angle station; the fall, in the length mentioned, is 1,840 ft. and the cost, all told, was $55,094. It is a thorough piece of engineering work. At the present time, it is worked on two 8-hour shifts, with a duty of 210 tons per diem. The operating cost is 17.6c. and the maintenance 1.4c. per ton. A large amount of material is sent to the mine, as a back load, and the cost of handling this also is included in the figures just quoted.

The spacing of the supporting towers is of course governed by the contour of the ground. In this regard the double ropeway systems, with their independent fixed cable for bucket-track, permit of a comparatively more direct path and more uniform movement of buckets, because the cable can be stretched to a high tension, diminishing the deflection in the swing of the cable. In the case of the single ropeways, which both carry and propel the bucket, as a high tension leads to overstraining of the rope, it is
avoided, with a consequent greater dip in the cable and the need for a larger number of supports—a decided drawback in a rugged mountain country.

The automatic feature of tramways is apt to be exaggerated. For instance, it is the opinion of certain capable managers that it is a mistake to depend too much upon gravitation, and that auxiliary steam-power will permit of the exercise of better control over the operation of the tram and a consequent possibility of running it at greater speed. There is no doubt that an engine acts as a useful governor, while the attempts to harness a rock-breaker to a tramway having excessive gravitation have failed, because a rock-breaker in operation is essentially a variable machine in its consumption of power. On the other hand an air compressor has not this bad feature, and if a tram worked against an air receiver it would have a self-adjusting governor of a useful kind. Most of the breakages, and much of the hard wear and tear, are due to variations in speed and bad control of tram lines which have a difficult contour and heavy strains.

In this connection it is well to point out that the modern tram owes much to the better modes of attaching the bucket to the rope. The use of clips or lugs permanently fixed to the rope and employed as attachments for the bucket was found to develop uneven wear in the cable, and this method had the further drawback of hindering a change in the spacing of the buckets whenever wanted. The modern attachment grips the rope wherever desired, so that the bucket is hung at the will of the loader, and never exactly at the same spot. One of the most popular grips—to be seen on the Camp Bird, Smuggler Union and Silver Lake trams—is the Weber, an illustration of which is given herewith. "The jaws of the grip are operated by a peculiar arrangement of toggle-jointed and self-locking levers that, when properly adjusted, bite the grip with sufficient pressure to hold securely on any grade."25 There is no

doubt but that devices like these do prolong the life of a cable by distributing the wear along its entire length.

We continued on our way up the valley of the Animas and soon passed through Howardsville, which figures largely in the early reports made by R. W. Raymond, F. M. Endlich, and other government officials during the seventies. It is now chiefly populated by Mr. Tom Trippe. Close-by is Cunningham gulch, where the andesite-breccia of the San Juan formation comes down to the Algonkian schists. Several mines, such as the Highland Mary, Ureteba and Green Mountain, exhibit this contact between

Tertiary and pre-Cambrian terrains. The best ore obtained from the lodes, which penetrate both formations, is said to have come from the schist just below the breccia; this was especially the case with the Green Mountain vein which had a large ore-body immediately under the volcanics. The next tributary valley is Maggie gulch, where there are several young mines, one of which, the Ridgway, is of importance.26

The Animas valley swings around to the north, and the road brings the traveler into the main street of Eureka,

the distributing point for the Sunnyside, Mastodon, Silver Wing, and other mines which have proved productive. Just as Tom Trippe occupies Howardsville, so Rasmus Hansen represents Eureka. These are among the very few of the pioneers who are still actively at work—strong, brave men, who have crowded the romance and vicissitudes of mining into their own lives; men with an indomitable pluck and a tireless activity like that of the torrent of the Animas which rushes past their cabin doors—sweeping with a vagrant energy that heeds neither the gladness of the radiant valley nor the gloom of the savage gorge until, after many wanderings, it abates its speed and hushes its voice in the still waters of the darkly flowing San Juan.

Beyond Eureka we passed the Silver Wing and the Tom Moore mines, and just below Animas Forks we turned eastward and started the ascent of Cinnamon pass. This is at an altitude of 12,600 ft. and separates the watershed of the Animas from that of the Lake Fork of the Gunnison river. On the divide is the Isolde mine, in the andesite-breccia, also the Bon Homme, in granite, and lower down we passed the tramway being constructed for the Tabasco mine. The bright glint of a thick copper wire bespoke a line of electric transmission connecting the mine and mill with a power station situated on the further edge of Burroughs Park. As the copper wire caught the sunlight one could not but be reminded of the aid given by one metal to the other; the electric transmission of the energy of water has done much for gold mining at high altitudes, where fuel for steam-power generation entails a cost which is almost prohibitive. Several very successful installations have been made in the Silverton district. The application of this form of engineering was limited until recent years. So long as the direct current only was available the transmission of power by electricity had severe restrictions, because under that system the practical limit was 700 volts;\(^27\) and it was not possible to augment this by the use

\(^{27}\) Although the Virginius mine uses 900 volts. This plant was erected before the introduction of the multiphase alternating cur-
of transformers. Since the introduction of the alternating current these limitations have been swept away, and the voltage can be raised to a degree the practical limit of which is dependent upon the insulation of the transformers. In practice the voltage is usually raised so that the power can be transmitted over a wire not smaller than No. 5, because that size gives the lowest investment in copper. The old and the new systems of electric transmission can be compared by stating that an alternating current at 2,000 volts would require only one-sixteenth of the copper that would be required by the same current at a pressure of 500 volts transmitted by a direct current, per horse-power, per given distance and at a given loss. The cost of power, as sold by the large generating companies in the mountains, to the mines at timber line or near it, averages about $8 per horse-power per month.

The advantage of electric transmission of power in place of the painful transport of fuel to the mines above timber line can be gauged by a look at the trails which frequently afford the only means of communication between the valleys and the mines. This is well illustrated in the accompanying photograph of a trail to one of the Silver Lake group of mines.

The Silver Lake installation was the first multiphase plant in the San Juan region. It was installed eight years ago, and operates a great variety of machinery, such as drills, pumps, hoists, blowers, machine shop, etc. The line is three miles long. A compound condensing engine has replaced water-power because the generating station is on the railroad, so that coal can be delivered cheaply (it comes from near Durango), while the water-power available was both insufficient and precarious on account of the damage to the long flume, brought about by rockslides, snowslides and the other difficulties of a high altitude subjected to violent extremes of heat and cold.

rent, and the high cost for copper wire over a four-mile line prompted the adoption of this unusually high pressure for a direct current.

Below the Tabasco mill we met a wagon heavily loaded with bed-plates, for an engine, bearing the name of the Colorado Iron Works; and soon afterward, riding through a belt of pines, we found ourselves in the open valley of Burroughs Park. This district has been, during the past two years, the scene of active prospecting and some mining. We dismounted and partook of hospitalities tendered by Mr. George Peirce, who subsequently piloted us to the Cleveland group of veins. These are not as yet of economic importance, but they have characteristics which are interesting from a scientific point of view. They penetrate granite; the Monticello vein, which I saw, was about one foot thick; for the first 15 ft. in depth the vein consisted of cellular quartz marked by copper stains, but
otherwise it was said to be barren; lower down it became metal-bearing, and at about 45 ft. deep I found a piece of copper pyrite coated with a gray film of chalcocite, suggestive of secondary enrichment and reminding me of certain experiments made by Mr. H. V. Winchell at Butte, in the course of which the copper of a slightly acid solution of copper sulphate, containing also some free sulphurous anhydride \( (\text{SO}_2) \), was found after a time to have precipitated a film of gray copper sulphide upon the bright facets of crystals of copper pyrite.\(^{29}\)

\(^{29}\) These experiments have been described in detail lately. "The Synthesis of Chalcocite," by H. V. Winchell, *Engineering and Mining Journal*, May 23, 1903.
In the afternoon we left this locality and rode down Burroughs Park and along the Lake Fork of the Gunnison until, in the evening, we pulled up at the Golden Fleece mine, beside Lake San Cristobal. The road at first goes over granite covered with an occasional patch of andesite-breccia, such as the one in which the Champion mine is situated. Then it cuts into the Algonkian schists and quartzites. Just before reaching the lake the road and stream follow close to the contact between upturned schist and the overlying andesite-breccia. Near the lake, decomposed andesite-breccia becomes the prevailing formation. The road follows the contour line of the lake shore and afforded us a glorious canter in and out among scattered young pines; there came glimpses of placid water reflecting the resplendent coloring of the aspens which clustered upon the encircling hillslopes, and the bright warm tints of clouds which caught the sunset glow. Suddenly, in turning a corner, the road ran amid a group of cabins and other buildings, the busy aspect of which told us we were at our destination, the Golden Fleece mine.

In the summer of 1896 the Golden Fleece mine shipped nine carloads of ore, weighing about ten tons each, the poorest of which netted $33,000 and the richest $49,500. In a few months the bonanza yielded $1,600,000. This rich ore was characterized by petzite (Au 25 per cent, Ag 41 per cent, Te 34 per cent) and ruby silver (proustite) scattered through a dark chaledonic quartz or hornstone.

The story of this mine exhibits the uncertainties of digging for gold. In 1874 Captain Enos T. Hotchkiss, connected with a government surveying party which was laying out a toll-road from Saguache to Lake City, caught sight of the outcrop, standing conspicuously above the hill-slope, and examined it. He located it as the “Hotchkiss” mine, and had some assessment work done while he was engaged in his survey-work in the vicinity. As far as is known, he found no ore. A year later, when Hotchkiss had abandoned his claim, it was re-located by George Wil-
son and Chris Johnson, under the name of "The Golden Fleece." They began what is now known as the No. 1 tunnel, but finding only little stringers of rich ore they ceased work. Others did similar desultory prospecting. O. P. Posey found a very rich bunch of ore in thecroppings above the No. 1 tunnel and took out several hundred pounds, which were packed to Del Norte and sent thence to the Pueblo smelter. Then John J. Crooke took a lease and bond; he also extracted about $30,000 from the outcrop above No. 1 tunnel, which had been extended a little further, without result. This was between 1876 and 1878. In 1889 Charles Davis took a lease and bond; he did a good deal of work along the high croppings, and finally sunk a shaft 30 ft. deep, which struck a body of ore yielding $40,000 in a very short time. Late in that year, 1889, George W. Peirce bought the mine for $50,000, and commenced extensive explorations. He found out very soon, indeed, that Davis had extracted all the ore in sight, and the outlook was not cheerful. All the work up to this time had been to the north, on the supposition that the vein had been faulted in that direction. The new owners cross-cut south at the No. 2 tunnel, which had been previously extended a little way, but had found nothing. The vein was picked up, but not much ore was encountered at first. They persisted, however, and within a year rich ore was cut on No. 2, and it was traced upward until it became easy to intercept the same body at No. 1. It was discovered that the former owners had been within ten feet of the main ore-body of the mine, which from that time, and until 1897, was very profitable.

The Golden Fleece vein strikes east and west, approximately; it dips southward at the rate of 33 ft. in 380 ft. In depth it flattens, so that the hade for the lower workings is only 150 ft. in 1,120 ft. In the accompanying drawing, Fig. 8, the upper workings and the geological conditions are both represented. The vein penetrates fine-grained breccia and tuffs, of the San Juan formation, until it runs abruptly into a very coarse breccia, where it scatters
out and ends. The coarse breccia lies on the top of the finer series at an angle of 28°; the difference in the rate of erosion renders the change of rock very easy to recognize at surface, even if the abrupt cessation of the conspicuous outcrop did not incite close observation. The outcrop makes a comb, as much as fifty feet in height, of hard sintery quartz which, on examination, is readily seen to be a decomposed and silicified breccia, exhibiting various degrees of silicification from the vein itself, which is almost entirely quartz, to the outer country, in which the original structure is but slightly obscured. In this outcrop there have been—and still are—found irregular patches of extremely rich ore. In the underground workings it can be seen that the vein itself follows a line of fracture and brecciation; the twice brecciated country has been re-cemented with silicious waters, so as to form a "vuggy" or cellular veinstone. Pieces of country are to be seen inclosed within a coating of quartz. The sheeting of the rock explains the multiplicity of walls and ore-seams which confused those who have at various times exploited this vein.

The outcrop ceases when the vein encounters the coarse breccia; so, also, in the underground workings the vein itself comes to an end with a suddenness which is, however, only comparative. The contact (A B) has been considered a fault; a good deal has been said concerning its regularity and clean-cut character. This, however, does not, I believe, accord with the facts. The so-called "fault" is not a break or dislocation in the rocks; it merely marks the division between the layers of fine-grained breccia and an overlying formation of very coarse breccia; there is no smooth plane or wall or defined parting between these two formations, but only a sudden transition which at a distance is more marked than near-by.

The ore-body of the mine was found in a triangular block of ground bounded on the one side by this "contact," A B, on the other by the hillside, B D, and along the base by the No. 3 tunnel, A D. The outcrop was patchy and
impoverished by leaching, the evidence of which is marked. This robbing of the croppings probably enriched the vein a little lower down. A branch vein, called the Ilma, which comes in from the northeast, appears to have played a part in determining the eastern or outer limits of the ore-body.

Speculation concerning the causes which determined this occurrence of rich ore is not hampered by too many facts. A correct explanation suffers from the lack of them. The contact existed before the vein was formed. The fracture, followed by the ore, passed easily through the finer-grained rock, but ceased abruptly when it met the beds of coarse breccia, because the force of fracturing was not only insufficient to overcome the resistance of the harder fragments contained in the latter, but it must have been dissipated by the encounter with a loose-textured body of rock, much in the way that the power of a diamond drill becomes wasted in passing into a shifting mass of loose conglomerate. As a consequence, the energy of shattering was diverted along the contact, the vein fracture ceased and the later ore-depositing waters were barred from further advance into the coarse breccia, save as a scattering confined to the neighborhood of the contact. At the third level the ore-body, occurring in the fine-grained country, was notably wider immediately at the "contact," and in examining the outcrop of the vein I noticed that it was difficult to decide upon the exact line of separation between the two formations, because the mineralization extended from the fine into the coarse breccia so as to obscure the divisional plane.

The deeper levels have found some small bodies of ore, and a good deal of money has been obtained from isolated bunches all the way down to the main tunnel or adit, about 700 ft. below the third level. Several larger bodies of low-grade ore have also been encountered in the deeper workings. Exploratory work is still going on, especially near the contact, where the chances for finding more ore seem to be reasonably good.

Most of the rich ore of the Golden Fleece mine was
shipped to the smelters, but the low-grade mill-stuff was treated on the spot. As the values were chiefly contained in telluride minerals (principally petzite, but also some hessite) the treatment—by concentration—presents features of interest. The mill was of latest design, erected by Stearns, Roger & Co. It consisted of rolls for crushing, Huntington mills for re-grinding, Wilfley tables for concentration and a canvas plant for slimes. No use was made of amalgamation. The Huntingtons were provided with screens of 30-mesh, and experience showed later that 20-mesh would have been better. In treating 18,000 tons having an average assay value of $10.25, half of which was in gold and half in silver, the extraction averaged between 45 and 60 per cent; 63 per cent was the best result. The concentrates contained 55 to 65 oz. of silver, 1 to 3 oz. gold and 12 to 18 per cent lead, in the form of galena. The concentration was in the ratio of 12 to 1. It may be said that the experience with this ore indicated conclusively that a simple mill, with Wilfley tables and an extended canvas plant as the principal features, would have been adequate.

We remained for two whole days with Mr. Peirce, and early on the 12th of September our journey was resumed. In crossing the valley of the Lake Fork of the Gunnison one cannot help noting the peculiarities of the surface. The eastern range, opposite the mine, is marked by a depression known as Slumgullion gulch. As seen from No. 3 tunnel it looks like a big landslide, the steep slopes of which have been obscured by weathering. However caused, it has extended down to the valley and dammed the stream so as to form Lake San Cristobal. It is said, by those living on the lake shore, to be still in motion and to be extending further across the valley. Slumgullion is commonly imputed to glacial action, but the observed facts do not require us to go so far afield.

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20 The mill was really designed for an ore containing galena and iron pyrite, both of which proved unimportant ingredients when the mine became further developed.
Landslides, some of them of great extent, dating back to early Pleistocene time, have been recognized and carefully studied in the Telluride and Rico regions. They are attributed to the penetration of water along bedding-planes and other lines of parting. In the case of Slumgullion the porosity of the coarse layers of breccia permitted of the entrance of water, which would reach down until a less porous stratum was encountered and then, if the dip-slope was toward the valley, the conditions would be ripe for a landslide. The geological conditions observed in the Golden Fleece mine would favor such movement if the bedding-planes dipped with the hillside; they dip right into the hill, however, and as a consequence the surface slopes steeply, at 30 degrees and over. The same geological structure if carried across to the other side of the valley would explain the landslide of Slumgullion. In the earlier history of these mountains they were bolder than they are now, and when, at the close of volcanic activity, earthquakes supervened, then the landslides occurred on a colossal scale and were accompanied by a shattering of the rocks, covering areas extending over many square miles.

The ascent of Slumgullion was easier than it sounds, and as we filed along we were reminded by the mention of the Cannibal plateau, which arose in bleak ruggedness to our left, of a tragedy the details of which no human witness has truthfully told. In 1873 a party of prospectors, intending to go to Fort Garland, in the San Luis valley, found their way up the river which we had left. It was a very severe winter, so that game was scarce; they were verging on starvation, and on their last legs. Out of the five men, one, named Parker, survived; he claimed that he went out into the woods hunting and on his return one of his comrades, rendered mad by hunger, attacked him with an axe, so that he had to shoot him in self-defense. Then the other three set on him, so that he had to kill them also. It is generally believed that Parker killed them to get the money they are understood to have carried. Game was not so scarce as he represented; at all events he
BURRO TRAIN CROSSING A ROCK-SLIDE.
managed to support himself until he worked his way out, and finally reached Durango, where he was subsequently arrested, convicted and sentenced to life imprisonment. Two years ago he was liberated by the then Governor of the State. In his gruesome story he confessed to having been compelled by hunger to eat portions of his victims; hence the ominous name, which, like the gloomy brow of the Cannibal plateau itself, overshadows the fair valley of San Cristobal.

At the top of Slumgullion gulch the road turns eastward to Creede; we turned northward and, picking up a trail which plunged into a pine forest, we eventually found ourselves at the headwaters of the Cebolla and followed it down. We were soon on a well-beaten path—the old Ute trail, used by the Indians in their migrations across the Gunnison country. They are gone from these hills and huddled on the reservation; so also the game which they hunted; that too has been driven away by the restless prospector. As we rode along in single file there was no sign of living thing for hours of travel; we followed the Cebolla, fringed with willows and threading narrow valleys overshadowed by cliffs of architectural aspect, battlemented masses and monumental pillars, like Egyptian pilons, among which a babbling trout-stream took its quiet way. The mountain flanks appeared to be built of rhyolite and rhyolite breccia. Occasional fragments of obsidian were found. Later we were in a granite country.

While picking our way over the talus at the foot of high cliffs and noting the general air of destruction which had characterized much of the rock structure seen during this particular morning's ride, it was impressed upon the observer that frost action was very apparent. To most people who travel among mountains, and even to those who live at their feet, it is often a wonder how the rocks are broken, and when. Anyone who sleeps outdoors will note the fall of rock-fragments during the night, and to this fact, I think, is due the general immunity from such danger. The patient leverage of the frost is the chief agent in disin-
integrating the rocks, for, the maximum density of water being at 4° C. or 39° F., one of the most powerful of nature's silent forces is set to work upon the water, which, having sought out the cracks and crannies of the rocks, is in the act of expanding. By day the temperature in the high mountain country is raised by reason of the penetration of sunlight through the clear atmosphere, but at the approach of night there is a sudden cold, which is succeeded next day by another relaxation. During these variations of temperature the moisture in the rock-cleavages undergoes an alternation of contraction and expansion which serves as an intensely powerful agent of disintegration.

At noon we pulled up at a spot marked in large letters on the map as "Cathedral" and found a solitary log cabin with a hospitable woman in command, who gave us dinner. Subsequently, when smoking a soothing pipe, we could appreciate the simple grandeur of the granite forms, sculptured by Time and chiseled by the heat of day and the frost of night into buttresses and pinnacles simulating all the stern magnificence of a Gothic ruin—of a cathedral not made with hands, domed by the sky and aisled with the green of the peaceful valley.

All of the succeeding afternoon was spent in a comfortable ride down the expanding valley of the Cebolla, which now began to exhibit cultivation, until, with a long gallop through the cool air of the twilight, we reached the Hot Springs. Here we put up overnight. From a distance the patches of white incrustation and clouds of steam told us of our approach to this scene of thermal activity. The links between vein-formation and hot springs which are to be seen throughout this region are not lacking in suggestion. The mining districts of the Rocky Mountains are rich in hot springs. In Colorado there are Hot Sulphur, Idaho Springs, Manitou, Cañon City, Glenwood, Poncha, Wagon Wheel Gap, Pagosa, Trimble Springs, Ouray and others of less importance. Similar conditions obtain in the States of Idaho, Montana, Utah, etc. The occurrence of these thermal springs, rich in alkaline and
other salts, in the midst of a very productive mineral region, is not without significance. Apart from their scientific aspect, the hot springs play a useful part in the economy of man. They are the resort of people troubled with ailments requiring rest and change of food; to the miners, who come to them with rheumatism, indigestion, alcoholism and similar troubles, they are beneficial, chiefly by reason of the opportunities for cleanliness, abstinence and a simple diet—the last, to my mind, the especial boon of the thermal spring resort, because the miner lives in a world of sin and canned vegetables from which "ranch food" and early hours of sleep will rescue him, bringing his inner man to a condition of normal healthiness.

Next morning, September 13, we turned eastward from the Cebolla valley and struck across country for Vulcan. At the foot of a high ridge we passed the Old Lot mine, cheerfully active. The dump indicated a vein carrying two or three feet of dark quartz streaked with galena. Close to the latter occasional spots of native gold could be seen—a handsome-looking ore. On the top of the ridge there was afforded an extensive view of the Gunnison plateau, bounded to the north by the deep gorge through which the swift Gunnison rushes, and to the south by the bold outlines of the San Juan mountains. Looking eastward the outlying summits of the Cochetopa hills broke the sky-line, but westward the sage-clad ridges stretched in sober gray until they faded into the blue of farthest distance. Though tame as compared to the grandly picturesque mountain-land from which we had just emerged, this plateau yielded a pleasure of its own in the glorious spaciousness and atmospheric radiance of a boundless horizon.

This billowy succession of rounded hills is built up of Archean granite and Algonkian schists. We saw several outcrops of the latter, especially in the Vulcan district. Flows of Tertiary lava and layers of breccia form occasional flat-topped ridges with broken edges and tumbled talus slopes. The occurrence of an area of schist is an interesting feature, because while there are other stretches of these
rocks, represented by the actinolite schists of the Arkansas valley and the hornblende schists of the western slope of the Sangre de Cristo, this particular rock is unusual to the mining regions of Colorado, and is not regarded as a favorable terrain for precious-metal mining, a fact which is in striking contrast to California, South Dakota and other very productive regions.

On arrival at Vulcan we proceeded at once to the Good Hope mine, owned by Dr. Loui Weiss and others, who invited us most cordially to see the workings. This we did very gladly because the mine was well known as having been the source of the handsome specimens of native tellurium, which are to be found in many mineral collections; furthermore, I had heard of several peculiarities of lode-structure which aroused curiosity.

The Good Hope vein penetrates a greenish-gray sericite or hydrous mica schist, which has the greasy feel and fine texture characteristic of that rock. It forms part of the Algonkian series of crystalline schists which overlie the Archean granite of the Gunnison plateau. The vein has an approximately east and west strike; it dips northward, the hade being 40 ft. in 500 ft. At surface the vein has an outcrop of heavy iron sinter which eventually gives place underground to a band of country thickly impregnated with iron pyrite. The walls of the vein are smooth and soft, both features being due to a parallelism with the schistosity of the enclosing country. No selvage or casing was noticed, but the lode-matter breaks rather readily away from the country on account of a blocky jointing, which, added to the fissile character of the rock itself, makes mining operations dangerous unless the timbering is well attended to. The rich ore is associated with streaks and lenses of iron-stained schist traversed by stringers of quartz. Native tellurium is frequently present, but the mineral which carries the gold has not been detected with certainty. I found some spots of petzite, and it is likely that this is one of the enriching minerals.

The accompanying sketch (Fig. 9) of the lode, as seen
at the fifth level, will illustrate its structure. From A to B is the main pay-streak. On the hanging wall there are 3 to 5 inches of quartz, usually iron-stained; then comes a bleached decomposed schist carrying a little quartz throughout. It is this white silky schist which usually carries the telluride minerals. The band B is soft white schist.

C is 3 feet wide and consists of massive granular-crystalline iron pyrite in finely shaded bands which reproduce the lamination of the schist. D is another band of bleached schist. E is similar to C, but not so solid. The enclosing country also carries a scattering of pyrite.

In the upper levels there is evidence concerning the origin of the vein and its contents. The occurrence of a
body of native sulphur has been emphasized practically, by its combustion to an extent that endangered the mine. The adjoining ground in the Chimney and Vulcan claims was abandoned on account of the burning of a similar body of sulphur. In the Good Hope there is a body of it 105 ft. deep, 4 to 6 ft. wide, and of a length which the owners thought it unwise to determine by further drifting. The top of the sulphur very nearly coincided with the first level, 90 ft. from the surface. This substance, occurring as a grayish-yellow loosely coherent powder, was shipped in car-load lots to the Western Chemical Company, at Denver. It averaged 80 per cent sulphur and also 3 to 20 dwt. of gold per ton. The water of the mines on this vein is very acid and green in color. It carries over 1 per cent copper and 1.5 per cent of sulphuric and sulphurous acids.

On inquiry I was given the analysis of the water from the shaft on August 15, 1901:

<table>
<thead>
<tr>
<th>Per Cent.</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium chloride</td>
<td>1.82</td>
</tr>
<tr>
<td>Sodium sulphate</td>
<td>3.39</td>
</tr>
<tr>
<td>Calcium sulphate</td>
<td>4.35</td>
</tr>
<tr>
<td>Calcium carbonate</td>
<td>4.61</td>
</tr>
<tr>
<td>Magnesium carbonate</td>
<td>6.52</td>
</tr>
<tr>
<td>Silica</td>
<td>0.23</td>
</tr>
<tr>
<td>Organic and volatile matter</td>
<td>3.87</td>
</tr>
</tbody>
</table>

The water contained no free $\text{H}_2\text{SO}_4$, or at most a trace; there was only a trace of copper. It is the opinion of Dr. Weiss that the sulphuric acid and copper now found in the mine water come from the adjoining Vulcan ground and are traceable to the effects of the burning of the native sulphur, which lasted for two weeks in the neighboring Vulcan and Mammoth-Chimney workings. There was no acid nor copper in the water from the Good Hope shaft until after the fire, and it is probable that surface waters have since then percolated through the Vulcan workings and thence downward to the fifth level of the Good Hope, which is 100 ft. deeper than the Vulcan shaft. Apart from this fact, it is worth noting that the copper in the Good Hope ore is increasing in amount with depth, specimens of the
native metal having been found in the quartz from the lowest level.

At the first level there is evidence that the vein was shattered and that a certain part of it, at least, served as the vent for a thermal spring of comparatively recent date. Figs. 10 and 11 were taken, the first within 100 ft. of the shaft and the other further eastward. They exhibit the shattering of a vein of opalescent quartz and the filling of the vein-fracture with geyserite, for a width of 4 to 5 ft.

The substance, which is here termed "geyserite," has a specific gravity of 1.96 to 2. It is porous, with scattered bits of opal within a mass of grayish-white crumbly hard non-crystalline silica. On comparing it with a piece of geyserite from the Yellowstone, the identity was apparent. The banded opalescent quartz, so abundant in the upper part of the vein, has all the characteristics of such a substance when deposited from thermal springs, and it occurs in the Good Hope vein in various stages of hardness and
texture. Fire-opal is to be seen in occasional brilliant specks, and all sorts of dark jasperoid quartz are found, beautifully banded.

The gradation from geyserite to white sericite schist indicates that the latter contributed toward the material now occupying the vein-fracture, and the occurrence amid the silicious sinter of occasional dabs of a very smooth unctuous white powder suggests remnants of the mica which characterizes the inclosing country.

![Diagram](Image)

**FIG. 11.**

These facts point irresistibly to the activity of thermal waters, that is, waters having a temperature higher than the mean annual temperature at the surface. Geyser action has, so Dr. Weiss tells me, been quoted in this connection by other visitors to the mine, but a geyser is a thermal spring which gushes⁵² out at the surface, and in this case we have no reason to suppose that such action occurred.

⁵² Geyser is an Icelandic word, meaning literally “a gusher.”
IN HIGH ALTITUDES.
across the San Juan Mountains.

Geyser are apt to be the last resort of a perplexed geologist. The supposition of thermal activity is based on the occurrence, in the vein, of substances which are actually deposited from the hot springs in the Yellowstone and other places.

In connection with this occurrence it is well to refer to the evidence of vein formation at hot springs which Mr. Walter H. Weed observed at Boulder, in Montana. At that hydropathic establishment there are two groups of hot springs, issuing from fractures in the granite and having a temperature ranging from 120° to 164°. These waters do not form a surface deposit of sinter, but the fissures from which they issue are found to contain a mineral deposit. Many of the fissures have been sealed up with this deposit so as to form veins, the outcrops of which enable one to trace their course across the country. The vein-filling consists of a white or dark-gray material which is mainly a mixture of chalcedony and stilbite, but also contains patches and bands of jasper, as well as included fragments of the granitic country. The illustrations given by Weed resemble the structure to be seen in the first level of the Good Hope mine. Opaline silica, in bands and curly layers, is seen throughout the mass. When freshly fractured it is usually dark-gray and very hard. The surrounding surface shows scattered fragments of jasper, chalcedony and other substances evidently derived from these deposits. On analysis they were found to contain an appreciable amount of gold, as much as 0.05 oz., and silver, as much as 0.4 oz., so that the connection between ore formation and thermal activity is manifest. It is interesting to note that the author does not impute the source of the heat to "unknown depths," but to meteoric origin as "a part of the normal underground circulating water of

the region, heated by physical conditions giving it access to the still hot rocks underneath."36

It would seem37 that the Good Hope vein existed as a pyritic band in the schist, formed by the action of feebly active underground waters such as, with extreme patience and slowness, are supposed to form similar lodes. Long duration of time for action and immense volume of solution compensate for feeble chemical activity and extreme dilution. The formation of the fracture occupied by the vein and the circulation of underground waters which supervened may both have come in the wake of dying volcanic energies such as were manifested in the adjoining region of the San Juan mountains.

At a later date, after the Good Hope vein had been formed, it became the line for a repetition of fracturing along which more intense thermal activity had play. A part of the vein served as a vent for a hot spring. This shattered the pre-existing vein and led to the decomposition of the pyrite, with the elimination of sulphuric acid, the formation of an iron sinter and the accumulation of a large mass of native sulphur. It is also probable that the liberation of iron salts, such as the proto-sulphate, afforded solvents for the gold which was re-deposited in the lower parts of the vein so as to make valuable ore.

The Good Hope vein is rich in uncommon minerals. Tellurium occurs native, as a tin-white mineral with a metallic luster. Occasional specimens exhibit rhombohedral prisms. It is associated with petzite, the telluride of gold and silver, and a new mineral, the telluride of copper. A greenish-brown micaceous substance suggests roscoelite, a vanadium mica, which occurs in association with telluride gold ores in Boulder county and at Cripple Creek, Colorado, as well as at Kalgoorlie, Western Australia.

37 The reader is reminded that these data were gathered during a visit of a couple of hours while on a horseback reconnaissance across the country, so that the writer's explanation of the origin of the vein is only a suggestion, prompted by the interesting features which have been briefly sketched.
One specimen, secured on the occasion of our visit to the mine, contained fine needles of berthierite, a sulph-antimonite of iron, which bears some resemblance to stibnite. The opal of the upper levels is said to have been very rich, especially in the purple-tinted spots; this may have been due to a telluride salt. The distribution of the tellurides, together with the native element itself, is another suggestion of the instability of these compounds in nature. So far as is known they are not characteristic of very deep mining, but are more especially distinctive of that bonanza zone of gold lodes which is measurable from the surface and appears to be connected in origin with the conditions obtaining at the groundwater level. Of course, "depth" is a relative term, and in this connection refers rather to the vertical distance from the lower limit of oxidation.

From Vulcan our trail took us over the eroded stumps of granite hills and across the river into the level stretch over which the town of Gunnison spreads itself drearily and wearily. Gunnison was a boom town, and when the wind goes out of a boom the wreckage is not enlivening. In 1880-1885 there were three smelters at work, and the combination, in the neighboring mountains, of iron, coal and precious-metal deposits won for Gunnison the splendid title of a "new Pittsburg." The town attempts to cover an area of two miles square, so that when you think you are in Gunnison you are out on the prairie, and when you imagine you are out in the country you are on a main street. In spite of it all, Gunnison wears an aspect of resignation, as if to say "it is better to have boomed and bust, than never to have boomed at all."

The next day, September 14, we started for Crested Butte, the center of an important coal region. The road follows the main branch of the Gunnison, a famous trout-stream known to every follower of Izaak Walton; the valley broadens at times into a goodly expanse of farm-land, dotted with cheerful homesteads. A few miles below Crested Butte the river is flanked by mountains, among which the rhyolite cone of Round Mountain and the basalt-
capped mass of Mt. Wilkinson are conspicuous. Finally the traveler reaches the confluence of several streams and a wide basin, on the western edge of which the town of Crested Butte has been built. A noble mountain, buttressed with steep cliffs and massive as an anchorage for an aerial tramway to Mars, overlooks the town from the east, and has given it the name of Crested Butte. It is a big stock of porphyrite. 38 On the west and south the gentler slopes of Mt. Wheatstone, fringed with pines, merge with the valley, and to the north a perspective of successive peaks indicates the Ruby range. These gain height and mystery as seen through the smoke from the coke-ovens of Crested Butte, lying huddled under the long shadows of evening. In the center of the town we found a barracks-looking building, which turned out to be a very clean and comfortable hostelry. Next day, the 15th, saw us on the Coal Creek road, en route to Irwin and Floresta. On both sides of the cañon the hillslopes were a desolation of burnt timber, a glimpse of that destruction, through careless fires, which is gradually causing the deforestation of Colorado. The actual burning up of good trees is bad enough, but the effect of such fires on the young growth does the most serious injury to the possibilities of a future supply of timber from these devastated tracts of mountain-land.

As the higher altitude was gained, the scenery improved and became bolder. We were passing through a porphyrite country, and the large fragments which had rolled to the roadside showed handsome crystals of feldspar. A winding trail took us northward from the westbound road and brought us to the deserted hamlet of Irwin. The Irwin mining district was active in 1880 and succeeding years. The Forest Queen mine is credited with a production of over a million dollars. In 1893 the fall in the price of silver flattened out the life of the camp, and until lately it has remained practically deserted. Quite recently a consolidation of a group of mines has been effected, and there

is now promise of some activity. We visited the Ruby Chief mine, under the kind guidance of Mr. P. F. Ropell.

The Ruby Chief vein traverses a bedded series of coarse sandstones and shales belonging to the Ruby formation of the Upper Cretaceous. The vein occupies a fault-fracture, as was indicated by a break in the continuity of a layer of shale seen underground. The strike is northeast-southwest,

while the dip, northwestward, departs only slightly from the vertical. The accompanying sketch, Fig. 12, gives a typical section of the lode. In the footwall there is a band of shale. From A to B is a laminated casing of sandstone streaked with veinlets of quartz, which exhibit comb structure. BC is a 6 to 8-in. vein of white quartz, streaked with arsenical pyrite, mispickel. This is the best ore.
ACROSS THE SAN JUAN MOUNTAINS.

It usually carries ruby silver (proustite) and brittle silver (stephanite). Selected ore contains 65 to 100 oz. silver, and from 10 dwt. to 1 oz. of gold, per ton. This vein or 'leader,' B C, is usually characterized by a definite streak of pyrite, accompanied by zinc-blende, which speckles the quartz in lines parallel to the walls of the vein. C to D is mottled, obscurely brecciated country, with quartz surrounding the fragments of sandstone, and impregnated with arsenical pyrite. D to E is an outer band of obviously brecciated sandstone containing very little evidence of mineralization. The crystalline quartz, lining cavities or 'vugs,' is a very marked feature of the lode, more especially because this structure is so noticeable in the independent quartz-veins which occur in the outer country alongside of the vein. The quartz incrusting the brecciated sandstone within the lode, appears banded, due to the contrast between layers of quartz and mispickel. Rhodochrosite was seen in a few specimens. Mr. Ropell informed me that the best ore had been obtained from the vein at the horizon where it traversed the conglomerate beds which form an integral portion of the Ruby formation. To these notes may be added the fact that porphyrite occurs in the vicinity. Mr. Emmons states that the porphyrite is found apparently as an intrusive sheet following the bedding of these sedimentary rocks, although the compound fracturing associated with the vein-structure "often gives it the appearance of a dike within the mineralized zone."  

Leaving Irwin, we retraced our steps for a mile and crossed the shoulder of Ohio peak at Kebler pass, named after the president of the Colorado Fuel & Iron Company. The winding road was followed through a pine forest until, on the northwestern slope of the ridge, it descended abruptly into a narrow ravine. To ride over a deserted mountain road and then to come suddenly into full view of a compact little mining settlement is a sensation which does much to break the monotony of cross-country riding.

This was Floresta, boasting the only anthracite mine west of Pennsylvania. The old anthracite mine, known as Smith's, near Crested Butte, is now worked out, and the new anthracite region, tributary to Paonia, now being prospected between the Gunnison river and the Anthracite range, is yet in an immature stage of development.

A note on the Smith anthracite mine will be proper here. It was located 21 years ago, and opened up in 1882 by George Holt, now of Chicago, Howard F. Smith, now of Elkhart, Ind., and Dr. William A. Bell, of Colorado Springs, Colo. They erected a breaker, installed the requisite machinery and operated it for several years, until it was acquired by the White Breast Fuel Company, in which Messrs. J. A. and J. T. Kebler were interested. Shortly afterward it was acquired by the Colorado Fuel & Iron Company, which has since held and steadily worked the mine until April of this year, when it was abandoned as worked out.

The vein averaged from three to four feet in thickness, and the coal was of excellent quality. An approximate production of 5,000 tons a month was maintained. A spur of the Denver & Rio Grande Railroad from Crested Butte connected with the breaker. The incline from the mine to the breaker is 1,800 ft. in length, with a pitch of 45°, and is the longest and steepest in the State. The gravity system was employed.

The coal seam at Floresta is three feet thick, and dips north at an angle of about 20°. It lies with the hillslope, the ravine having cut into the seam so as to give a line of outcrop on both sides. The agency which was chiefly instrumental in the development of anthracite from bituminous coal is indicated by the porphyrite, which appears in the form of dikes in the railroad cutting and is clearly to be seen capping the hillside. The coal now being exploited occurs at a geological horizon which is 115 ft. above the base of the Laramie formation, belonging to the Cretaceous. There is also another, poorer seam, one hundred feet higher. These coal-measures are covered by a sheet of
MAP OF COLORADO ANTHRACITE REGION, AFTER U.S.

- **pt**: Porphyrite
- **Kr**: Ruby formation (Conglomerate sandstone and tuff of andesitic materials)
- **Kl**: Laramie formation (Sandstone and shale containing 3 coal beds generally workable)
- **Km**: Montana formation (Fox Hills sandstone and Pierre shale Brick clays)
- **Coal**
porphyrite which extends for more than a mile along the north slope of the Anthracite range, the name of the much serrated ridge behind the mine. The metamorphic effect of the porphyrite on the coal is readily apparent; where the metamorphism of the sedimentaries is least, non-coking bituminous coals are found; where the metamorphism has been present, but not severe, the coking coals occur and in regions of intense local metamorphism the coal has been changed to anthracite. It has also been observed\(^9\) that a dike cutting across a coal seam affects its chemical and physical composition for a short distance only, but an intrusive sheet will affect it for a greater distance and over an area commensurate with the extent of the eruptive itself.

The output of the mine at the time of our visit was 100 to 125 tons per day. The manager, Mr. Thos. McLaughlin, to whom we were indebted for many courtesies, informed me that there is much difficulty in keeping miners at Floresta, because the mine is not in operation, on account of snow, for more than half the year, which prevents men with families from going there. Moreover, the narrowness of the seam and the conditions of working are such that only the most experienced miners can earn a good living. The work is much more arduous than that of ordinary lode mining, because of the cramped space and the subsequent disposal of the output. Owing to the slight dip of the seam, it is difficult to handle the coal underground; the chutes which carry the product of the face to the entry are made of No. 16 steel sheets, 3 ft. wide, laid on the footwall, and nailed onto sides made of 2 by 6-inch scantling. When in constant use the angle of inclination is sufficient to keep the chute clear, but if the steel lining becomes at all rusty, the slope proves inadequate for the automatic descent of the coal, and the miner jumps into the chute and toboggans down the incline, pushing the coal before him with his feet. The men get 90c. for 2,600 lb., of which it is estimated that 2,000 lb. is clean coal, the balance going over the culm.

heap. Wages, as I got them from a scrutiny of the pay-rolls, averaged $4.25 per day, with about 30 men at work. The men are largely Austrians; scarcely one-half of the workmen are English-speaking.

In the mine we found that pillars to support the roof were left 15 ft. wide, while the rooms or stopes were 25 ft. The drilling is done with machine augers, the hole being begun with a 2¼-inch bit, and finished with a 1½-inch. Holes are made from 4 to 6 ft. deep. Coarse black powder is used; it costs the miners $3 per keg of 25 pounds. The product of the mine is sent to the breaker, which has a capacity of 600 tons per day. Five sizes are made. The coal from the tipple goes over two sets of screen-bars, the fines going direct to the picking tables and the lump to the breaking rolls. These are toothed rolls of the usual type. Then follow revolving screens. The culm is handpicked as it runs down the chutes. These chutes for slate-picking are double. Each picker (boys and old or crippled miners) draws past him just as much coal as he can thoroughly clean, so that the coal is handled once only.

The upper landing is 10,175 ft. above sea level. This makes Floresta the highest coal mine in the United States, if not, indeed, the highest in operation anywhere. An average analysis of the anthracite shows:

<table>
<thead>
<tr>
<th></th>
<th>Per Cent.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed carbon</td>
<td>87.51</td>
</tr>
<tr>
<td>Volatile comb.</td>
<td>7.62</td>
</tr>
<tr>
<td>Moisture</td>
<td>0.72</td>
</tr>
<tr>
<td>Ash</td>
<td>4.15</td>
</tr>
</tbody>
</table>

The roof of the seam is a 30-ft. bed of sandstone, the floor is in shale. Along the railroad grade there are afforded several good sections of the sedimentary rocks, enclosing the coal, where they are intruded by porphyrite. A typical section (Fig. 13), exhibits a dike, evidently a porphyrite containing large distinct crystals of feldspar. The bed of shale traversed by the dike is, near the porphyrite, hardened, and otherwise altered into a dark, massive rock. Fragments of shale are included within the dike. The joints in the sedimentaries cross the dike clearly,
and are, therefore, later than the intrusion of the latter. There is no distinct parting or wall between the sedimentaries and the eruptive.

On the railroad grade, and about a mile from Floresta itself, a promontory of rock gives a magnificent view of the Anthracite and Ruby ranges. To the left are dark pine woods sloping from Ohio peak with an inclination which reproduces the dip of the porphyrite flow and the coal beds underneath; in the middle distance, and contrasting with

the dark array of pines, are brilliantly tinted foothills whose rounded contour indicate the softer sandstones of the Cretaceous. Above these rises the abrupt mass of Mt. Beckwith, built of porphyrite. To the right, and coming down to meet the other half of the picture, is the red Ruby range with its serrated comb of dikes, which can be seen extending in jagged line down to the valley itself through which a trout-stream winds in and out until it is hidden by the pre-
cipitous face of Mt. Marcellina, a dome-shaped laccolith of porphyritic diorite. Far off, palpitating amid the haze of forest fires, are ranks of distant hills athrob with that soft enchantment in which the distance fades from view.

We left Floresta the next morning, September 16, and crossed the Ohio pass, on our return to Gunnison, by a route different to that of our previous journey, which had now taken us around a group of three mountain peaks, Mt. Wheatstone, Mt. Axtell and Mt. Carbon, and from the watershed of the Slate river to that of Ohio creek, both tributaries of the Gunnison, into which they merge a little to the north of the town itself. Ohio pass, 10,033 ft. above sea level, is similar to other mountain crossings; there is a defunct sawmill with an untidy sawdust heap; an abandoned railroad grade, as though engineering skill had failed of breath; a scattering of pines, the straggling procession which is all that is left of the serried ranks that came up the mountain side in proud array until they encountered an invisible bar to further advance—that "timber line" which, like the shore of an ancient sea, belts all the mountains and marks the upward limit of the conditions favorable to forest growth.

We passed Carbon and Castleton, two coal camps, with all the hideousness which belongs to those unhappy-looking settlements; then a short stay, pleasant for man and horse alike, at a roadside ranch, prepared us for a long canter over the wide, dusty road which finally, but we could never tell when, brought us into the unlimited city of Gunnison.

That night at Gunnison we heard the fishermen's tales. It is a great resort for the manipulators of rod and line. It is also a mining center for the surrounding hill country, so that there is no lack of fishy yarns. The unwary will hear of mountains of iron and acres of gold ore; but behind the exaggeration there is the fact that the Gunnison country, with the Elk mountains to the north and the

41 A laccolith is a body of intrusive lava. It does not spread in dikes or sheets, but gathers into a mass or core, which lifts the overlying strata.
granitic foothills which lead to the San Juan ranges, to the south, is extremely rich in a variety of mineral wealth—coal, iron, gold and silver—which would have undergone more substantial exploitation if the windy breath of a premature boom had not blighted it in the infancy of its development.

On September 17 we rode from Gunnison to Gate View. The road follows the Gunnison until it crosses the river at Iola, the shipping point of the Vulcan district. Taking a cross-country trail, we filed through the sage-bush, covering monotonous, low hills, the remnants of granite mountains which had yielded to the leveling hand of Time. Spencer and Dubois, two mining camps, were found almost deserted. Then, surmounting a ridge, we saw again the splendor of the San Juan ranges and the pleasant valley of the Lake Fork. After weary miles of sage-brush hillocks it was singularly refreshing to look upon a landscape through the diversified beauty of which the modifying influence of geological structure could be plainly discerned. At Gate View we passed a night. The name is given to a ranch and railroad section-house near the natural gateway of the Lake Fork, which flows through a gap cut into the andesite. A tongue of this eruptive crosses the broad valley; the river has cut its way through; high, nearly vertical cliffs arise on either side; then steep debris slopes, making a broad V, at the bottom of which the road, the railroad and the river jostle each other for passage; this frames a view of hills rich in the gold and russet of the aspen, surmounted by the high peaks of the San Juan mountains.

Looking through the portals of the river, one is reminded of Ruskin's question, concerning a similar natural structure: "When did the great spirit of the river first knock at those adamantine gates? When did the porter open to it and cast his keys away forever, lapped in whirling sand?" It is a fine similitude; but geology, with less poetic diction, says that the rock is not adamant to the instrument of erosion as used by the running stream with patient persistence through long time, and that no porter was needed to open
the gate; the river found it in obeying the laws of its being—gravity—which impelled it to seek the lowest channel and to deepen that channel continually, for fear the onlooking hills should fill it up too fast with their discarded débris.

The road, further on, alternately crosses flat stretches of partially cultivated land and descends into the bed of the stream amid narrow gorges cut into andesite-breccia and tuffs, until at the confluence of Henson creek we rode, amid a sharp downpour of cold rain, into the town of Lake City.

We reached Lake City at noon amid a rainstorm which was remarkable for the reason that it was the first bit of bad weather encountered during twelve days. It cleared in the afternoon, so, leaving our horses to rest, we walked the seven miles up Henson creek to the Ute and Ulay mines. These have been the mainstay of Lake City through all the vicissitudes of the past twenty years. The two veins have been worked at various times both jointly and separately. When I was last there the Ulay lode was the chief source of production; on the present occasion we found that the Ute vein was affording the principal stoping ground. This was above the main adit. The vein is from four to five feet in width; it is a simple quartz-vein containing argentiferous galena. Iron pyrite and zinc-blende are present in relatively small quantity. The lode is essentially an impregnation following a sheeted band in the andesitic breccia of the San Juan formation and has the characteristics already noted at the Camp Bird, Smuggler Union and other mines in the same region. Stopes extend, more or less continuously, for half a mile. The Ute dips westward at 63° and is worked in the adjacent California mine. The Ulay had been worked 700 ft. below Henson creek through old workings which were in bad repair; a new vertical shaft had just been started to open up the lower ground on this lode.

The mill reminds one, in its method of treatment, of the old Foxdale mine, in the Isle of Man, where, however,
raff-wheels are used instead of elevators and the plant is spread over a much larger area. The treatment of the

Diagram of treatment at the Ute & Ulay Mill.

Ute & Ulay ores is simple and well adapted. The mill has a capacity of 90 to 100 tons per day. The ore goes
first to a rock-breaker (Blake, 9 by 15) and then to three sets of rolls (Allis-Chalmers, 16 by 30), then through four successive trommels; 36 inches in diameter and 7 ft. long, which size the crushed ore to 8, 6, 4 and 2½ millimeters. The coarse, which passes through the trommels, goes to the jigs, a double-compartment jig for each trommel. The fines, which escape from the last trommel, pass into two hydraulic sizers, the coarse being sent to jigs while the fines go into a third sizer. The coarse from this last sizer goes to a jig and the fines run to the buddies. There are

![Image of the Henson Creek Mills]

two plain buddies, 16 ft. in diameter, and four double-deck buddies, 24 ft. in diameter, the tailings from which pass into settling tanks where the slime is arrested. The treatment is illustrated graphically on the diagram given herewith.

The concentrates are dried and mixed by passing through a heated revolving cylinder. About 1½ per cent of moisture is left in the concentrates in order to lessen the leakage arising from the bad flooring of the railroad cars, which would be a greater source of loss if the concentrates were dry enough to run readily. The concentrates con-
tain 58 to 61 per cent lead, 13 to 15 oz. silver and 0.05 to 0.06 oz. of gold per ton. They represent about 16 per cent in weight of the original ore and an extraction of about 80 per cent of the lead and 65 per cent of the silver.

Next day, September 18, saw us started on our final stage, from Lake City to Ouray. Our way took us again past the Ute & Ulay, where we stopped to get some further data from the millman. As we rode along up Henson creek it was pleasant to notice a good deal of mining activity; we passed under the Bleichert tramway of the Hidden Treasure, past the Moro mill, with a Leschen tram connecting it to an unseen mine on the pine-clad mountain-side and then, just below Rose's Cabin, the Bonanza tunnel, with a new mill in course of construction. Mr. Philip Newitt, superintendent of the Henson Creek Lead Mines Company, as it is officially styled, was kind enough to take us underground. The lode is the usual sheeted band of breccia-country carrying four to five feet of quartz, in which gold, silver, copper and lead are carried by copper pyrite, galena and other less conspicuous minerals. The mine afforded an example of the use of electric drills; the Gardner and Durkee were both in use and the superintendent expressed himself as disappointed with them; in each case the motor is carried on a truck and power is transmitted through a flexible shaft. The practical efficiency of the electric drills is a subject too large for a passing comment, but it is fair to the inventors to say that the machines suffer from their unpopularity among miners and the frequent lack of technical skill on the part of the operator. As a rule the first drill tested in a mine is handled by an expert provided by the company which sells the drill; then, results being deemed good by a manager or director, others are ordered. The drill company's man and his skilled assistants depart, leaving a delicate piece of electrical machinery to the tender mercies of a muscular workman who starts with a prejudice against anything new and unfamiliar, and is apt to be confirmed in his prejudice by his own inexpert handling of the ma-
chime. This, of course, is, in a way, the drawback to all electrical machinery—it requires workmen who know something about it—but this is an obstacle which the increasing application of electricity will overcome, surely. In the meantime I unite with others in the hope that the electric drill will be further improved, because it can facilitate and cheapen mountain mining to an extraordinary degree.

The new mill, in course of erection, will be operated by electricity, generated at the power-plant, three miles lower down on Henson creek, where a 6-ft. Hugg wheel does the work. The mill will have a Blake rock-breaker, a Sturte-

ROSE'S CABIN. AN OLD STAGE HOUSE.

vant crusher and three pairs of rolls. Then will come Bartlett concentrating tables provided by the Colorado Iron Works and Standard tables supplied by Fairbanks, Morse & Co., the latter being also responsible for the general design of the mill.

This pleasant interlude at the Bonanza mine was supplemented by a hearty dinner at the miners' boarding-house before we mounted again.

Rose's Cabin, at 10,850 ft., just above the Bonanza mine-buildings, is a landmark. It was a stopping place in the
THE CANON OF THE UNCOMPAHGRE.
old days of transmontane travel when long lines of pack mules and horsemen were wont to file up Henson creek on their way to Silverton, Rico and Ouray. We took the right-hand trail, past the Palmetto mill and along the old grade to the Frank Hough mine.

As we climbed the range the snow-mists gathered, and when we finally reached the crest, at 12,850 feet, the mountains were robed in all the magnificence of the storm. The cold blast from the cañon below swept up to the summit of the range, driving a chilly mist which flung itself fiercely around every crag and threw great shadows that stalked swiftly across the darkening slopes. Here and there amid the gloom a lonely peak caught the light, a Titan head above the sea of cloud. Thus we saw old Uncompahgre and the Wetterhorn, besides many another unnamed crest. While we waited, the hail and snow came fast, and so, without further delay, we began the slow descent of the other side, leading and pulling our shivering horses down the tedious talus slopes.

Soon we reached the warmer air of Bear creek basin, a spacious amphitheater near the timber-line, from which a well-marked trail took us into Bear creek cañon, a narrow gorge, lined by the most astounding precipices and picturesque to a degree which was astonishing even after two weeks of mountain scenery. The andesite-breccia, in nearly level layers, forms cliffs which sweep from an eery height of a thousand feet, and more, down into the hidden bed of a torrent. The sheeted structure, due to parallelism of nearly vertical fractures, is very evident, and the sympathetic structure of the veins, whosecroppings are clearly visible ribbing the rock-faces with broken lines of quartz, is apparent even at a distance. We passed the Yellow Jacket and the Grizzly Bear mines, huddled under the beetling brows of breccia cliffs, where, here and there, a cluster of courageous pines clung hungrily for life, or a solitary cabin looked calmly over the abyss, or faint trails in unexpected tracery of line wound in and out of dark
ravines with the veritable unconscious air of gentlemen who have no visible means of support.

Our progress, over a trail which was a narrow, albeit quite safe, ledge between rock and torrent, was necessarily, with horses, a slow business. At length, after hours of continuous descent which seemed interminable and gave one a singular feeling of going right into the depths of the earth, we emerged suddenly into full view of the Uncompahgre valley. It is no exaggeration to say that all four of us, some of whom had done our voyage round the world more than once, were amazed at the grandeur of the great picture before us. Scattered already to the four winds, as becomes mining engineers, we shall, I believe, always remember that "polychrome of splendor, an exultation to recall." Ruskin would have rhapsodized and Clarence King could have described it.

The storm had swept northward, the sky was still partly overcast with flying cloud, a luminous atmosphere, pure as inter-planetary space, filled the cañon depths, and from the west the sunlight pierced the lingering mists with mellow light. We stood on a narrow promontory. Across the cañon terraced slopes descended in parklike gradation, resplendent with the livery of autumn, and above their aspen gold the bastions of blue-gray andesite rose tier after tier in Gothic severity of line until belted with the rising mists. Up the valley to the left the winding thread of the river led to the pyramid of Mt. Abram, his sentinel head aglow with sunlight, while further south rose the Red Mountains, shrouded in cold vapor that dimmed their volcanic tints. Straight in front and northward, overtopping these swiftly changing visions of rich coloring and sculptured line, there gleamed the Mt. Sneffels ranges, freshly ennobled with a coronet of snow, with a great passion of light glowing about their lordly summits, while in the darkening east

42 One is in Western Australia, another in California, the third is in Mexico, and the fourth in New York City.

43 This gives me the opportunity of recommending to my friends that most delightful book of Clarence King, "Mountaineering in the Sierra Nevada."
there trailed away "a gray-wingéd form, the ghost of wind and rain."

It will seem something of an anti-climax to state that the trail subsequently led us to an interesting geological section, where the breccia of the Eocene period was found resting upon the upturned edges of pre-Cambrian slates and quartzite, with only a thin layer of conglomerate, possibly a representative of the San Miguel formation, between them. We reached Ouray before dark, having completed a ride of fully 400 miles.
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