

ECONOMIC GEOLOGY

WITH WHICH IS INCORPORATED

THE AMERICAN GEOLOGIST

VOL. II

JULY-AUGUST, 1907

No. 5

SOME GOLD AND TUNGSTEN DEPOSITS OF BOULDER COUNTY, COLORADO.¹

WALDEMAR LINDGREN.

INTRODUCTION

Boulder County has long been known as an important producer of gold and silver. Its deposits form the extension of the gold-bearing belt of Clear Creek and Gilpin Counties, and reach from the southwestern corner of the county well up towards the center. A number of silver deposits were worked in the early days, among which the most prominent was the Caribou mine, but for many years the principal attention has been given to gold. The county is distinguished by a steady, although not very large gold production, and has a great number of small mines. Many of its deposits contain tellurides, and comparatively few of them are of free-milling type. In recent years important deposits of wolframite have been discovered in the southwestern part of the county, especially near Nederland, and the output of this ore has reached very considerable figures. While no exact statistics are available, it is believed that the output of this tungsten ore in Boulder County reached a value of \$350,000 in 1905, and the industry gives good assurance of permanency.

The mineral wolframite, a tungstate of iron and manganese, contains the metal tungsten, which is used as a steel-hardening

¹ Published by permission of the Director of the U. S. Geol. Survey.

material. It is in good demand at prices up to \$12 per unit of tungsten-trioxide, making 70 per cent. ore worth \$840 per ton.

The following paragraphs describe some of these gold and tungsten deposits in the southwestern part of the county, in the vicinity of Eldora and Nederland, from data obtained during a short visit to the county in 1906. The mineral deposits of Gilpin County have been briefly described by G. H. Garrey in Bulletin No. 285, pp. 35-40. The gold and silver deposits of Clear Creek County have been described by Messrs. Spurr and Garrey in Bulletin No. 260, U. S. Geological Survey, pp. 99-120, and a more complete report is now in press. On the other hand, very little has been published in the way of a geological description of the Boulder County mines. Mr. T. A. Rickard has briefly mentioned some of the deposits in a paper entitled, "The Veins of Boulder and Kalgoorlie," in the *Transactions of the American Institute of Mining Engineers*, Vol. XXXIII., 1903, pp. 567-577.

SITUATION.

The narrow gauge road which ascends into the mountains from Boulder follows the canyon of a fork of Boulder Creek westward as far as Sunset, and then winds its way up the hills at steep grades to its terminal point at Eldora, on the Middle Fork of Boulder Creek. Eldora is situated at an elevation of about 8,700 feet, in the narrow glacial valley of Middle Fork, the ridges rising on each side from 1,000 to 1,500 feet above the little town. Going upstream from Eldora the elevations increase rapidly, and in a few miles the Continental Divide, with elevations of from 12,000 to 13,500 feet, is reached. Going downstream the valley soon widens and at Nederland, some four miles below Eldora, the forested hills surrounding it are much more gentle and covered by disintegrated granite. The elevation of Nederland is about 8,000 feet.

GENERAL GEOLOGY.

As in Gilpin and Clear Creek Counties, the prevailing rocks are pre-Cambrian, and consist of granites, gneisses, and schists.

The oldest rocks appear to be biotite and amphibolite schists and gneisses. Into these rocks, the schistosity of which varies considerably in strike and dip, great masses of medium-grained, light-colored granite have been intruded and injected in the most complicated manner. The injection of the granular rock chiefly follows the planes of schistosity, but often also breaks across them. The relations of the two rocks show excellently on the steep and bare rock walls near Eldora. The granite is often pegmatitic, and smaller well-defined pegmatite veins composed of quartz, orthoclase, and white mica, are very common. The pegmatite dikes appear in places to have contact-metamorphosed the amphibolitic schists, for lighter-colored zones a few inches wide often surround these dikes and seem to be produced by the absorption of the hornblende by the intruding magma.

The amphibole schists in places contain segregations of quartz, with epidote and a little pyrite. These segregations are older than the pegmatite dikes which cut across them.

Narrow dikes of porphyry are found in various places along the mineral belt, but their outcrops are hardly ever visible. As exposed in the mines the porphyries are of several kinds, but none thus far encountered are very siliceous. In the Mogul tunnel at Eldora a large porphyry dike occurs about 1,000 feet from the portal. This is a grayish-green rock, very hard, and containing many small, closely crowded feldspar crystals. The phenocrysts consist of small idiomorphic triclinic feldspars, too much sericitized for determination. There are also abundant grains of magnetite and epidote, with some chlorite, the latter two minerals evidently the remains of biotite, hornblende, or augite. The groundmass is microgranular and appears to consist of feldspar, with some quartz.

In the mines of the Wofltongue Tungsten Company a fine-grained porphyritic rock cuts the granite. It is extremely sericitized so that the original character is somewhat doubtful. The phenocrysts consist of small foils of muscovite, accompanied by a little rutile, and evidently represent altered primary biotite. The groundmass is fine-grained and consists chiefly of feldspar, probably orthoclase.

On the whole, these rocks belong in the groups of the monzonite-porphry or syenite-porphry. They are distinctly earlier than the mineral deposits in connection with which they occur.

Effusive rocks, such as basalts, rhyolites, and andesites, are entirely absent.

MINERAL DEPOSITS.

The gold belts of Clear Creek, Gilpin and Boulder Counties are not arranged along any one definite line, although their general trend is northeasterly. The veins, as a rule, can not be traced far. The veins of Central City, in southern Gilpin County, trend northeasterly, but no deposits are found in their further extension in that direction. Other veins appear, however, in the northern part of the county, near Tolland and Rollinsville, but even these do not directly extend into Boulder County. A further offset towards the north takes place and at Eldora and Caribou short veins trending northeast or east-northeast again appear to be succeeded in the central portion of the county by a great number of more or less parallel vein zones ranging over a width of fifteen or twenty miles. Near Jamestown the most northerly veins are found and still farther in this direction the granitic rocks appear to be barren.

The ore deposits in the county are of three kinds, first, the sulphide veins; second, the telluride veins; and third, the tungsten veins.

Sulphide Veins.—The sulphide deposits are in general regular quartz veins containing gold and silver-bearing sulphides, principally pyrite, galena, chalcopyrite, and zinc-blende. Most of them contain a considerable proportion of silver, besides gold, and in some the silver predominates entirely. As an example of the gold-bearing veins may be cited the Boulder County mine, which is located near the Caribou station, a few miles northeast of Eldora. This is an old-time producer of considerable importance which has recently been opened by a deep tunnel 3,200 feet in length, exposing a vein 500 or 600 feet below the old workings. The regular and well-defined vein consists chiefly of

quartz, with zinc-blende, galena, chalcopyrite, and some molybdenite. The ore is treated by concentration in a stamp mill.

Another mine belonging to this class is the celebrated Caribou mine, which is one of the old-time producers of Boulder County. It is reported that up to 1880 the mine had yielded \$1,168,000. The mine has been opened by a main shaft to the 800-foot level, and the developments in general are extensive. The ore was formerly reduced in a silver mill, located at Nederland, by chloridizing roasting in Bruckner furnaces, followed by pan amalgamation. The mine has been idle for many years, although it is not impossible that at the present prices for silver a reopening may be attempted.

Telluride Veins.—Many gold deposits of Boulder County contain tellurides, and these minerals were, in fact, identified from this county long before Cripple Creek was discovered. The best known property of this kind near Eldora is the Enterprise vein, the croppings of which may be seen near the summit of Spencer Mountain, and which in former years yielded a considerable amount of gold. A large chlorination mill was erected some years ago half a mile above Eldora, to treat the ores of this deposit, but it was only in operation for a short time. There are several other veins cutting the granite of Spencer Mountain, and most of them are parallel to the Enterprise vein. All outcrops of the deposits are very inconspicuous and more likely to be indicated by little saddles and depressions on the ridges than by prominent croppings. The strike of the veins is a little to the north of east. The Enterprise mine is opened near the summit of the mountain by a shaft 400 feet in depth, with 200 feet of water standing in it at present. Some prospecting work was going on in the upper levels in 1906.

The Mogul tunnel at Eldora, 900 feet below the croppings of the Enterprise vein, cuts a number of parallel veins, most of which belong to the telluride class; some of them, however, are regarded as belonging to the sulphide veins. The tunnel cuts the eastern extension of the Village Belle, which is thought to be the extension of the Enterprise. Disputes between the

owners of the tunnel and the mining companies are said to stand in the way of the successful working of the deposits in Spencer Mountain. No accurate data as to the production of these veins are available. A considerable amount was, as stated, obtained from the upper portion of the Enterprise vein, and in the tunnel much stoping has been done along one of the telluride veins for a distance of about 400 feet. It is believed that the sulphide veins are later than the telluride veins, and one instance was noted in the Mogul tunnel which seemed to confirm this, but the subject requires further examination.

The structure of the telluride veins has been briefly and accurately described by Mr. T. A. Rickard. In general, the veins consist of several narrow seams forming a more or less regularly sheeted zone, along which partial filling and some replacement have taken place. A gouge separating the vein from the country rock on one side is sometimes present, but more commonly the vein is "frozen to the wall" and the vein matter changes gradually into the country rock. The width of the vein is usually confined to from one to three feet. Within the sheeted zone crushed rock very commonly appears partly cemented by the vein matter. Vugs are of very frequent occurrence and really characteristic of the deposits. Crystals of the gangue very frequently project into the vugs.

The ores contain chiefly gold, with very little silver, and the principal valuable mineral is a telluride of gold believed to be sylvanite. The tellurides usually occur in a flinty vein matter or in the greenish roscoelite distributed as small specks, hardly ever as well crystallized minerals. Pyrite is present in small amounts, chiefly as small grains in the altered country rock. Molybdenite occurs in abundance, but is usually extremely fine-grained, and intergrown with barite. On the dump its presence is indicated by deep blue stains on the ore fragments. This blue molybdenite stain, to which attention has been drawn in the Cripple Creek report,¹ is believed to be the rare mineral, ilsemanite, a compound of the oxides of molybdenum ($\text{MoO}_2 \cdot 4\text{MoO}_3$).

¹ Professional Paper No. 54, U. S. Geol. Survey, pp. 114, 123.

Characteristic among the gangue minerals of the telluride veins are barite, quartz, roscoelite and chalcedony. The quartz occurs in moderate amounts, and more frequently chalcedony takes its place, forming jasperoid masses of brown or black color, locally called hornstone. Barite is also very abundant and often appears crystallized in small and thin plates.

Mr. Rickard, in the article mentioned, has called attention to the general occurrence of roscoelite in the Boulder County mines—an interesting fact not elsewhere recorded. Roscoelite is very abundant in the ores of the Mogul tunnel and the Enterprise mine. It forms dark yellow-green masses intergrown with quartz or irregularly distributed in the ore, and, as stated above, very frequently contains specks of gold tellurides. Sections of this greenish material show the roscoelite as minute greenish-yellow scales of micaceous character, intergrown with pyrite in small crystals. This mixture of roscoelite and pyrite is surrounded and invaded by a later deposited mass of fine granular quartz, with some adularia in the rhombic crystals which are so characteristic in the variety of this mineral called valencianite.

Thin sections of the crusted ore show that the granitic rock on which it was deposited is extensively altered to fine scales of sericite, and in part also replaced by grains of barite. Neither calcite nor chlorite are present, but a little pyrite is distributed through the partially altered granitic rock. The crusted material consists of tabular crystals of barite, on which a layer of very fine-grained molybdenite is deposited. This again is covered by concentric deposits of chalcedonic silica. Next to the crust the silica is of a brownish color, but gradually lightens towards the center, in which large barite crystals are contained. Another specimen of country rock, originally an amphibolitic schist, is found to be converted into a greenish-gray soft rock which chiefly consists of extremely fine and felted sericite, with a little iron pyrite.

Summing up these statements, it will be seen that the telluride veins at Eldora have a very remarkable structure and composition. The structure is characterized by narrow shear zones, vug

holes, and incomplete deposition. The characteristic minerals are gold tellurides, molybdenite, roscoelite, barite, adularia, and chalcadonic silica. The intimate relationship to the Cripple Creek veins is clearly apparent, and the structure, here as there, points to deposition comparatively near the surface. These deposits are emphatically not formed at great depths. The original surface can not have been much different from that general surface of erosion which is marked by the high ridge lines of this part of the Rocky Mountains, and which is supposed to be of late Tertiary age.

Tungsten Veins.—The tungsten mines of Boulder County are situated within a mile of the town of Nederland. The ores do not contain any notable amounts of gold and silver, and the deposits are themselves, at first glance, entirely distinct from the gold and silver veins. Near Sugar Loaf, a half mile to the northeast of Nederland, some gold veins exist which are reported to carry tungsten also, a fact which in no way is surprising, since compounds of tungsten are not uncommon in gold-bearing and silver-bearing veins. A great number of small tungsten veins occur in the vicinity of Nederland. The principal deposits are, however, located on the timbered and moderately high ridge about half a mile north of the town. During 1905 much of the ore shipped came from near the surface, where it was necessarily enriched by a process of natural concentration. At the present time attempts are made to follow the veins in depth by tunnels or shafts. As stated above, the total production is estimated to have had a value of \$350,000 in 1905, and the production for 1906 will probably not fall far short of that figure. Much of the ore shipped has been simply hand-picked, but in most cases a wet concentration is needed in order to bring the ore up to the requisite percentage of tungsten.

The Wolfstongue Mining Company, of Pittsburg, have erected a twenty-stamp mill at Nederland, with five Wilfley tables and six slime tables. In the summer of 1906 chiefly custom ores were treated in this mill. It is estimated that the world's output of tungsten ore in 1905 was about 3,000 tons. Of this amount,

Boulder County contributed perhaps one third, or 1,000 tons. The deposits occur in a coarse-grained, granitic rock injected into biotite and hornblende schist just as at Eldora. The exposures on the rounded hills surrounding the town are, however, much poorer than at the first mentioned place. The deep mining has revealed the presence of a strong dike of syenite-porphry or monzonite-porphry, which appears to be followed by the vein.

The deposits are well-defined fissure veins from a few inches to six feet in width, striking about north and south and dipping at steep angles.

The three most important mines are situated on a granite ridge about half-way between Nederland and Tungsten Siding on the railroad. The Wolf tongue Mining Company owns the Oregon mine, now 200 feet deep, in which some exploratory work was in progress in 1906. Adjoining this and a little to the north, is the Boulder County tungsten mine, which was closed down at the time of visit. A third mine is located on a parallel vein a few hundred feet to the west, and is owned by the Colorado Tungsten Company. This mine is opened by a vertical shaft 300 feet in depth, and development work was progressing at the time of visit. The Wolf tongue Company owns a number of smaller mines, among which the Clyde and the Hosea are the most important.

The veins form narrow shear zones, in which open vugs coated with quartz and wolframite crystals are very common. Extensive shattering has also taken place in some places after deposition, and has been followed by re-cementation by silica. Wolframite, poor in manganese and entirely opaque in thin section, is practically the only ore mineral present. "Graphite" is reported to have occurred in some batches of ore mined by the Wolf tongue Company. It is more likely that this so-called graphite is molybdenite. Small specks of pyrite occur in the decomposed country rock and in the wolframite, but on the whole is very inconspicuous. No other ore minerals have been noted. The principal gangue mineral is quartz, most of it fine-grained. It contains microscopic inclusions of cubical, colorless crystals, probably iso-

tropic, which were thought to be fluorite. This was not, however, confirmed by a careful chemical test for fluorine. The country rock, whether granite or porphyry, is, adjoining veins, rather strongly sericitized but contains no calcite or any other mineral except a little pyrite. The hornstone, or chalcedonic silica, so characteristic of the Eldora veins, does not occur here. In some places, however, the country rock next to the vein has apparently been silicified, and now looks like a dark-gray, fine-grained quartz. The principal ore from the deep levels consists of narrow stringers of a fine-grained intimate mixture of wolframite and quartz, which requires fine crushing for the purpose of concentration. The vugs are frequently lined with wolframite crystals, some of them of large size and very perfect and the central cavity of the druses is often, especially near the surface, filled with a soft material resembling kaolin.

Although the filling of these veins is very different from that of the telluride veins at Eldora, there is unquestionably a strong resemblance between them as far as the structure of the vein and sericitization of the country rock are concerned, and this leads to the belief that the tungsten veins are also a product of comparatively recent thermal activity, and that they are deposited at only a moderate depth below the original surface.

Wolframite is found in pegmatite veins, in company with cassiterite, and other minerals of rarer kind. More commonly it is found in quartz-filled veins similar to the ordinary gold-quartz deposits of California. The tungsten deposits of Boulder County differ from both of these types.

Postscript.—A recent number of the *Engineering and Mining Journal* (May 18, 1907) contains an interesting and valuable article by Mr. W. E. Greenawalt on "The Tungsten Deposits of Boulder County, Colorado." It is difficult, however, to agree with the author when he characterizes the dikes as andesite, and when he finds evidence in the extensive brecciation of "igneous conditions in the formation of the deposits."

Three analyses of concentrates, given in this article, run as follows:

ANALYSES OF CONCENTRATES.

	Beaver Creek per Cent.	Nederland per Cent.	Gordon Gulch per Cent.
Tungsten trioxide	66.41	63.20	60.84
Ferrous oxide	24.31	20.36	18.36
Manganese oxide	3.25	1.10	4.73
Silicon	6.00	15.00	16.28
Phosphorus	trace	trace	.05
Sulphur02	.50	.20
Gold	trace	trace	trace
Silver	1.20 ¹	2.40 ¹	3.10 ¹

¹ Ounces per ton.