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ECONOMIC GEOLOGY
OF
GILPIN COUNTY AND ADJACENT PARTS OF CLEAR CREEK AND BOULDER COUNTIES, COLORADO

BY

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CONTENTS.

ILLUSTRATIONS.

PREFACE.

By F. L. Ransome.

The more productive metalliferous districts of Colorado are not distributed at random, but lie in a northeast-southwest belt, about 250 miles in length, that extends from Montezuma County, in the southwest corner, to Boulder County, in the north-central part of the State. The width of this belt, inclusive of the somewhat outlying deposits of Teller and Custer counties, is about 115 miles. Spurr[1] in particular has called attention to this feature of ore distribution, and has brought out the relation existing between the occurrence of the ores and the general geologic history and structure of the region, especially the dependence of ore deposition upon the kinds and sequence of Tertiary igneous activity.

Owing to their scientific interest and industrial importance, the metalliferous deposits of the Colorado ore belt have been the subject of study by the geologists of the United States Geological Survey from the founding of that organization. In 1879, under the directorship of Clarence King, S. F. Emmons began his investigation of the Leadville deposits, and the complete results[2] appeared in 1886. The first Cripple Creek report[3] was published in 1896, and the reports on the geology and mines of Custer County[4] in the same year.

In 1897 appeared the report on the Telluride district,[5] of the San Juan region, and in 1898 the monograph on the Aspen district.[6] A report on the geology of the Rico district,[7] in 1900, was followed the next year by one on the ore deposits of the same district.[8] The report on the ore deposits of the Silverton quadrangle,[9] in the San Juan region, was also issued in 1901.

The second Cripple Creek report[10] appeared in 1906, and the publication, in 1907, of a bulletin on the Downtown district of Leadville[11] marked the resumption by Mr. Emmons of work in the field where he had previously won such distinction. At the time of his death he and Prof. Irving were at work on a complete revision of the Leadville monograph. The greater part and completion of the task have fallen to Prof. Irving, and the second monographic report on the Leadville district is now nearly ready for publication.

About 1902 Mr. Emmons, then in charge of the Survey's work on metalliferous deposits, made plans to take up the study of the ore deposits at the northeast end of the belt, in Clear Creek, Gilpin, and Boulder counties. It was the discovery of these deposits that precipitated the second great rush of gold-seekers to the West, in 1859, led to the founding of Denver, and marked the beginning of the industrial development of Colorado. Cripple Creek has surpassed these three counties in value of annual output, and at Leadville mining operations have been conducted on a larger scale, but in the combined interest that attaches to a long and significant historical record, to number and variety of deposits, and

[1] Spurr, J. E., and Garrey, G. H., Economic geology of the Georgetown quadrangle, Colo.: U. S. Geol. Survey Prof. Paper 63, pp. 102–132, 1908.

[2] Emmons, S. F., Geology and mining industry of Leadville, Colo.: U. S. Geol. Survey Mon. 12, 1886.

[3] Cross, Whitman, and Penrose, R. A. F., jr., Geology and mining industries of the Cripple Creek district, Colo.: U. S. Geol. Survey Sixteenth Ann. Rept., pt. 2, pp. 1–209, 1896.

[4] Cross, Whitman, Geology of Silver Cliff and the Rosita Hills, Colo.: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 2, pp. 263–403, 1896.

Emmons, S. F., The mines of Custer County, Colo.: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 2, pp. 405–472, 1896.

[5] Purington, C. W., Preliminary report on the mining industries of the Telluride quadrangle, Colo.: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, pp. 745–850, 1897.

[6] Spurr, J. E., Geology of the Aspen mining district, Colo.: U. S. Geol. Survey Mon. 31, 1898.

[7] Cross, Whitman, and Spencer, A. C., Geology of the Rico Mountains, Colo.: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, pp. 7–165, 1900.

[8] Ransome, F. L., The ore deposits of the Rico Mountains, Colo.: U. S. Geol. Survey Twenty-second Ann. Rept., pt. 2, pp. 229–398, 1901.

[9] Ransome, F. L., A report on the economic geology of the Silverton quadrangle, Colo.: U. S. Geol. Survey Bull. 182, 1901.

[10] Lindgren, Waldemar, and Ransome, F. L., Geology and gold deposits of the Cripple Creek district, Colo.: U. S. Geol. Survey Prof. Paper 54, 1906.

[11] Emmons, S. F., and Irving, J. D., The Downtown district of Leadville, Colo.: U. S. Geol. Survey Bull. 320, 1907.

to the place where so much in mining and metallurgic technique had its beginnings, the region is without a peer among the mining districts of the Rocky Mountains. In many respects it holds in this country a position analogous to that of Cornwall in Great Britain.

It had been Mr. Emmons's intention to take up first the Central City quadrangle, but owing perhaps to the fact that the topographic maps of the Georgetown quadrangle were ready before those of the Central City quadrangle, the Georgetown area was the first to be studied, and the report on it, by Spurr, Garrey, and Ball,[1] was published in 1908.

Three years later appeared the report on the Breckenridge district,[2] lying some distance southwest of the Georgetown quadrangle. This study served to link the Georgetown work with that at Leadville. In 1911 also a bulletin by Irving and Bancroft[3] extended and supplemented earlier publications on the ore deposits of the San Juan region.

The present report on the Central City region rounds out the Geological Survey's investigation of the principal districts in the northeastern part of the Colorado ore belt. Creede, an important district in the southwestern part of the belt, has been studied, but the results have not yet been published in full.

In addition to the reports mentioned, the Geological Survey has published a number of folios descriptive of the geology and ore deposits of parts of the Colorado ore belt.

In the present report the ore deposits of the Central City region are divided into five main classes, some of which are of exceptional interest. Special attention may be called to the discussion of downward enrichment, especially in silver, a subject to which Mr. Bastin and his colleague, Mr. Chase Palmer, have devoted special attention during the last two years, and to which they have made important contributions. Enrichment in lead appears to have been slight, a result somewhat unexpected in view of the different conclusions reached with regard to the deposits of the neighboring Breckenridge district.

[1] Spurr, J. E., and Garrey, G. H., Economic geology of the Georgetown quadrangle (together with the Empire district), Colo., with general geology by S. H. Ball: U. S. Geol. Survey Prof. Paper 63, 1908.

[2] Ransome, F. L., Geology and ore deposits of the Breckenridge district, Colo.: U. S. Geol. Survey Prof. Paper 75, 1911.

[3] Irving, J. D., and Bancroft, Howland, Geology and ore deposits near Lake City, Colo.: U. S. Geol. Survey Bull. 478, 1911.

SUMMARY OF RESULTS.

By Edson S. Bastin.

Gilpin County and the adjacent portions of Boulder and Clear Creek counties, Colo., lie nearly west of Denver in the heart of the Front Range of the Rockies. Central City, the seat of Gilpin County, is the oldest lode-mining camp in Colorado and in total production one of the most important.

GENERAL GEOLOGY.

Pre-Cambrian rocks.—Most of the rocks of the region are pre-Cambrian in age. Some of them have undergone severe dynamic metamorphism, during which schistose or gneissic structure has been developed; others are practically unmetamorphosed and are massive. The oldest and most extensive of the pre-Cambrian formations is the Idaho Springs formation, whose preponderant rock type is biotite schist. This is the only one of the pre-Cambrian formations that is believed to be of sedimentary origin, and through it all the igneous rocks of the region have been intruded. Next younger are granite gneisses forming irregular stocks many of which are of large areal extent. Apparently nearly contemporaneous with the granite gneiss is quartz diorite grading into hornblendite, which occurs as a few large dikes. Later than these is the Silver Plume granite. Granite pegmatite is extremely abundant and is not all of the same age, some being contemporaneous with the granite gneiss and some with the Silver Plume granite.

Tertiary (?) intrusive rocks.—The pre-Cambrian rocks are intruded by a great variety of much younger igneous rocks, most of them porphyritic in texture—the "porphyries" of the miners. Though they show some diversity in age, all are believed to have been intruded in Tertiary time. They occur as stocks and dikes and are abundant in all parts of the region. The predominant rock type is monzonite porphyry, which forms the bulk of the larger stocks and is the most abundant dike rock. Magmatic differentiation within the monzonite stocks near Caribou has produced masses of gabbro and iron ore, and it is believed that many of the dike rocks other than monzonite have also been derived by processes of magmatic differentiation from the monzonitic magmas. The Tertiary (?) igneous rocks range from felsic (acidic) varieties, such as granite porphyry, to mafic (basic) varieties, such as basalt porphyry, and the ultramafic titaniferous iron ores. Most of these intrusive rocks, including the monzonites, are older than the mineral veins of the district, but at least one, biotite latite, is younger.

Tertiary (?) terrace gravels.—Certain terrace gravels near Idaho Springs reaching a level 180 feet above the creek are of uncertain age, possibly late Tertiary.

Quaternary deposits.—The Front Range was subjected twice in Pleistocene time to glaciation of the alpine type, and glacial or glacio-fluviatile deposits belonging to both stages (the Wisconsin and pre-Wisconsin) are present in the area surveyed. In Recent time sheets of débris have been developed in the headward portions of unglaciated valleys, talus deposits along the steeper valley walls, and alluvium along the streams.

Structure.—The most notable structural characteristic of the region is the intricate manner in which igneous rocks ranging from pre-Cambrian to Tertiary (?) in age have been intruded into the sedimentary Idaho Springs formation and into one another. The intrusions range in size from mere threads between schist folia to stocks several miles across. Dikes are particularly abundant and a few of them are traceable continuously more than 5 miles. Many of the intrusions are somewhat lenticular, with their long axis parallel to the prevailing trend of the foliation of the inclosing rocks; others are extremely irregular in form.

Purely dynamic processes have also played a part in the structural history, their principal effect being the development of foliation in the older pre-Cambrian rocks—the Idaho Springs formation, the granite gneiss, and some of the quartz diorite. The younger pre-Cambrian rocks are not foliated. During much later periods faulting took place. Some of the faults were formed prior to or contemporaneously with the intrusion of the Tertiary (?) igneous rocks, some were formed shortly after that intrusion and became the sites of ore deposition, and some were formed subsequent to the mineralization and displace the mineral veins. In places faulting may still be in progress. Most of the faults are of small displacement. Joints are numerous in the more rigid rocks and commonly parallel one or more of the directions of faulting.

ECONOMIC GEOLOGY.

General features of the ore deposits.—The region forms part of a broad mineralized belt which embraces most of the economically important mining camps of Colorado. The ores of the region may be classed, according to the metals which give them their predominant value, as (1) gold-silver ores, which constitute the main economic resource of the region; (2) uranium ores, which occur in a few places only but are of much interest as a source of radium; (3) tungsten ores, which form the basis of the tungsten industry of Boulder County, the most productive center for this metal in the United States; (4) ores worked primarily for copper, which are represented solely by the Evergreen mine, near Apex; and (5) titaniferous iron ores, which occur only near Caribou and have not been utilized commercially. Most of the ores occur as veins, as a rule steeply dipping, which are in part fissure fillings and in part replacements of various rocks along zones of fracturing. A few deposits, notably the so-called Patch, near Central City, are stockworks, the copper ores are an integral part of monzonite dikes, and the titaniferous iron ores are irregular bodies within a monzonite stock. The veins and stockworks are, with few exceptions, later than the Tertiary (?) intrusive rocks; the copper and iron ores are contemporaneous with the monzonites within which they occur. The wall rocks have influenced the distribution and character of the ores only through their varying susceptibility to fracturing or replacement.

Gold-silver ores.—The gold-silver ores include both lode and placer deposits. The placers were very productive in the sixties but are now negligible. The lode ores may be classed as pyritic ores, galena-sphalerite ores, composite ores, and telluride ores.

The pyritic ores consist predominantly of pyrite and gangue minerals, with subordinate amounts of chalcopyrite, tennantite, and in places enargite and other minerals. Enargite and fluorite are confined to a single group of pyritic veins. The characteristic wall-rock alterations near the pyritic veins consist in the development of pyrite and sericite; carbonates and silica are locally formed. Pyritic ores are widely distributed in the region and carry much more gold than silver in value; in many places they contain copper in profitable amounts.

In the galena-sphalerite ores the predominant primary sulphides are galena, sphalerite, and pyrite; they contain chalcopyrite and in places other sulphides in smaller amounts. The common gangue minerals in ores that are fissure fillings are quartz and calcite or siderite, but in some veins barite is present, and a single group of veins contains rhodochrosite. The characteristic wall-rock alterations consist in the development of sericite, carbonates, and pyrite; other sulphides occur locally. Certain veins of the galena-sphalerite type carry only negligible amounts of gold, but in others the gold content is considerable. The silver content is in general greater than in the ores of pyritic type and has in many mines been augmented through downward enrichment. The copper content is usually below the commercial limit, but these ores contain considerable lead and zinc. Ores of this type are much less widely distributed than the pyritic ores.

The composite ores have been formed through the fracturing of ores of the pyritic type and the filling of the fractures with ore of the galena-sphalerite type, which also lines vugs in pyritic ore. Certain veins are of the pyritic type at one end, composite at the center, and of the galena-sphalerite type at the other end. Other veins are composite near the surface and become pyritic with increasing depth. Ores of this type occur principally in transition zones between areas characterized by pyritic ores and others characterized by galena-sphalerite ores. Their metal content is intermediate to that of the two simple types.

The telluride ores show more diversity in mineral character than the types already mentioned, and it is not certain that all were formed at the same time. Telluride ores are confined to the region between Central City and Idaho Springs and to Eldora and vicinity. The tellurides commonly occur in a gangue of cherty-looking quartz and in some mines are associated with abundant fluorite or with the vanadium-mica roscoelite. Pyrite is invariably present, and tennantite occurs in some veins. The commonest telluride appears to be sylvanite, but petzite has been reported from one mine. Free gold is usually associated with the tellurides and is especially abundant near the surface.

Uranium ores.—Uraninite or pitchblende occurs in a few of the gold-silver veins, mostly in Quartz Hill, near Central City. Study of polished sections indicates that the pitchblende is contemporaneously intergrown with the same suite of minerals that characterizes the ores of the pyritic type and is cut by veinlets of the galena-sphalerite type. The pitchblende ores are provisionally regarded as a phase of the pyritic type of mineralization.

Tungsten ores.—The tungsten ores of the region are confined to Nederland and vicinity. They were not studied in detail, but from their broader geologic relations and from the observations of others it is thought probable that they are of the same general age as the other ores. In a few places they carry tellurides and other minerals characteristic of the gold-silver ores.

Copper ores.—The copper minerals of the Evergreen mine, near Apex, are bornite and chalcopyrite, which occur as original components of igneous dikes of general monzonitic composition. Wollastonite is locally abundant in these dikes. The ores are believed to have been formed by magmatic differentiation within a body of monzonite, possibly accompanied by some absorption of lime and perhaps other substances from the wall rocks. This is the only ore deposit of the region that is worked primarily for copper.

Titaniferous iron ores.—Several deposits of titaniferous iron ore occur in Caribou Hill, where they form irregular bodies within areas of gabbro and pyroxenite, which in turn are inclosed by monzonite. The gabbros, pyroxenites, and iron ores are believed to have been formed by magmatic differentiation within the monzonite magma. The iron ore commonly carries from 3 to 5 per cent of oxide of titanium (TiO_2). Even if the metallurgic difficulties involved in the high titanium content can be overcome, the inaccessibility and small size of these deposits preclude their successful exploitation under present economic conditions.

Genesis of primary ores.—All the ores of the region are believed to be genetically connected with the Tertiary (?) intrusive rocks. The iron and copper ores are obviously so connected. The gold-silver ores are believed to have been deposited by thermal solutions emanating from the deeper portions of the monzonitic magmas after the portions now exposed at the surface had solidified. Even at the same period the composition of these solutions was somewhat different in different parts of the region, as shown by the highly localized enargite or pitchblende bearing phases of the pyritic ores. The composition of the solutions also varied progressively during the ore-forming period, ores of the pyritic type being deposited first and ores of the galena-sphalerite type later. Physiographic and stratigraphic evidence, as well as the mineral composition of the gold-silver ores, indicates that they were deposited under conditions of moderate intensity as regards temperature and pressure.

The solutions that deposited the gold-silver ores are believed to have been alkaline or neutral in character, rich in alkalies, silica, carbonic and bicarbonic acids, iron, lead, zinc, and arsenic and carrying lesser amounts of copper, antimony, gold, and silver. Locally manganese, barium, the sulphate radicle, tellurium, fluorine, tungsten, uranium, radium, and vanadium were present.

Enrichment.—Enrichment in the Central City region has been confined mainly to the class of gold-silver ores. In these veins enrichment in gold and silver is of considerable economic importance, enrichment in copper of minor importance, and enrichment in lead and zinc negligible.

Enrichment in gold appears to be confined almost exclusively to portions of the ore deposits above or immediately below the ground-water level. It has affected all types of gold-silver ores and has caused a material increase in the value of the ore in the oxidized zone.

Enrichment in silver is confined mainly to the ores of the galena-sphalerite type. It appears probable that the relatively low content of pyritic minerals in the galena-sphalerite ores

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and the presence of a carbonate gangue favoring neutral or alkaline rather than acid solutions in the secondary sulphide zone have had an important influence in restricting silver enrichment to ores of this type. In the oxidized zone of these ores there seem to have been impoverishment in silver and enrichment in gold. Silver enrichment is confined to the ground-water zone and consists in the secondary deposition of pearceite and proustite and more rarely of native silver. It is greatest in the first 100 or 200 feet below the natural ground-water level and shows a progressive decrease with increasing depth. The maximum depth at which secondary silver minerals were noted was 700 feet below the surface (about 650 feet below the water level). Two types of mineral association were noted in the rich silver ores. In one secondary sulpho-compounds of silver were associated with secondary chalcopyrite; in the other abundant native silver was associated with chalcocite, bornite, and covellite. The secondary silver minerals are deposited in fractures in the primary ore and also as metasomatic replacements of the primary minerals.

Enrichment in copper is nowhere conspicuous and is confined almost wholly to the ground-water zone of ores of the pyritic type; the oxidized ores were impoverished in copper. The enrichment is greatest in those deposits whose ores are unusually rich in primary copper minerals. Chalcocite is the principal secondary copper mineral and is developed in part as a filling in fractures or a coating in vugs and in part by metasomatic replacement of chalcopyrite and pyrite.

Enrichment in lead was noted in only a few localities and is nowhere important. Zinc enrichment was not observed.

ECONOMIC GEOLOGY OF GILPIN COUNTY AND ADJACENT PARTS OF CLEAR CREEK AND BOULDER COUNTIES, COLORADO.

By Edson S. Bastin and James M. Hill.

PART I.—GENERAL GEOGRAPHY AND GEOLOGY.

By Edson S. Bastin.

Chapter I.—INTRODUCTION.

LOCATION AND AREA OF THE REGION.

The region whose geology is described in this report forms a part of the Central City quadrangle, which lies in the center of the north half of Colorado (fig. 1) between meridians 105° 30′ and 105° 45′ west longitude and parallels 39° 45′ and 40° north latitude. The quadrangle is about 17½ miles north and south by 13½ miles east and west, and its area is approximately 236 square miles. Denver is 26.5 miles east of the southeast corner. The western portion, west of the Continental Divide, is in Grand County. Of the area lying east of the divide the southern part is in Clear Creek County, the central part in Gilpin County, and the northern part in Boulder County. The

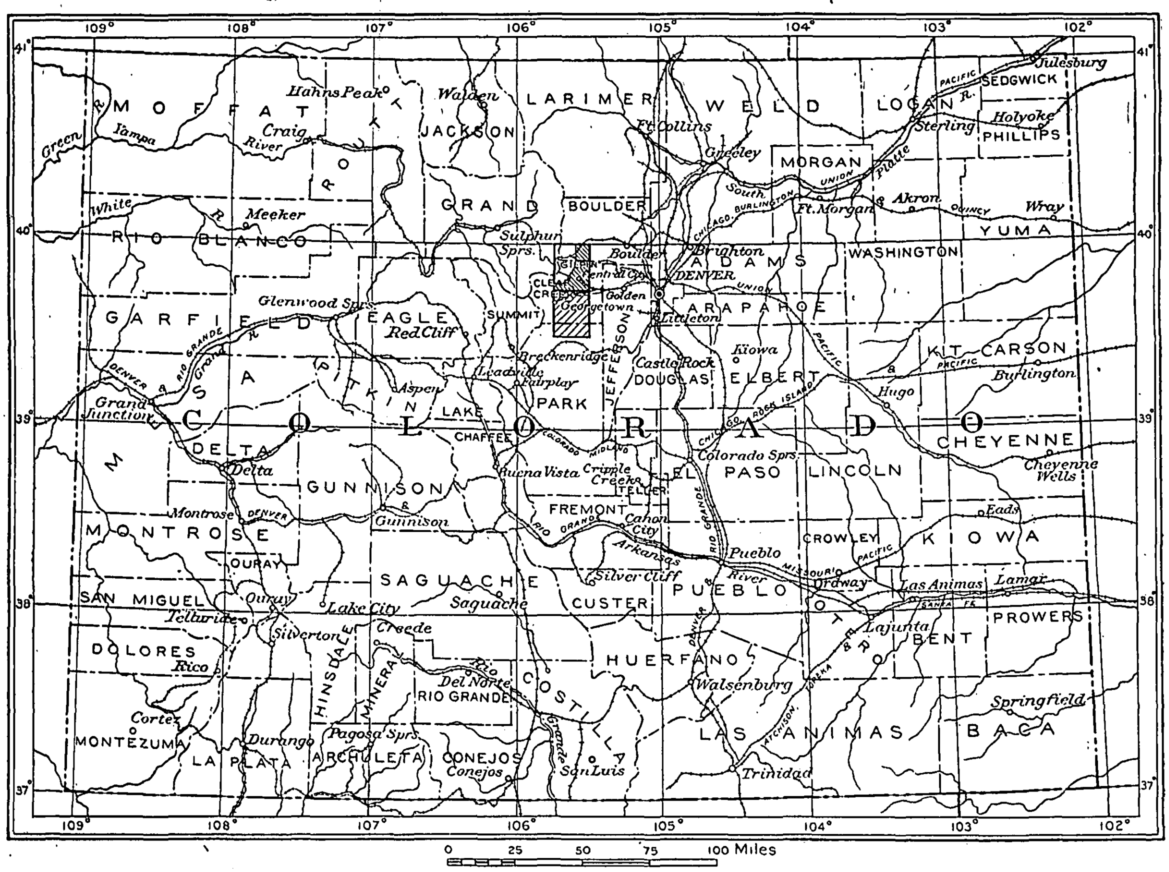


FIGURE 1.—Index map of Colorado showing position of areas covered by this report (dark shading) and by Professional Paper 63 (light shading).

quadrangle is named from Central City, the largest town and the county seat of Gilpin County. (See Pl. I, in pocket.) The quadrangle lies immediately north of the Georgetown quadrangle, whose geology has been described by Spurr, Garrey, and Ball.[1]

As shown on Plate I, only the eastern and southern parts of the Central City quadrangle were surveyed geologically, the higher parts, where little mining has been done, not being covered. The greatest developments in mining are within the areas covered by the Geological Survey's Central City and Idaho Springs special atlas sheets, and the geology of these areas has been studied in especial detail, the plane table being used in the geologic mapping.

FIELD WORK AND ACKNOWLEDGMENTS.

The topographic survey of the Central City quadrangle was made in 1903 by Frank Tweedy, and the map was published on the scale of a mile to the inch. The mapping of the cultural features of this area, such as railroads and wagon roads, was revised by Lee Morrison in 1910, and his revisions appear on Plates I and II of this report (in pocket). In 1904 more detailed topographic surveys were made of the regions about Central City and Idaho Springs by Pearson Chapman and D. F. Moor, as a basis for the preparation of the Idaho Springs and Central City special maps on the scale of 1,000 feet to the inch.

The geologic field work that forms the basis for this report began with a month of reconnaissance by Edson S. Bastin in the fall of 1910. Detailed field work was done in the summers of 1911 and 1912, Mr. Bastin being assisted in 1911 and 1912 by James M. Hill and in 1912 by Charles W. Henderson.

Mr. Henderson also prepared the section on production and collaborated in the preparation of the section on ore treatment, etc.

In a region containing so many mines it would manifestly have been impossible to accomplish the field work in a satisfactory manner and within a reasonable time without the ready and courteous cooperation of the men interested in the mining industry. Their appreciation made delightful a task that might otherwise have been arduous. The following gentlemen rendered especial service: Mr. Percy R. Alsdorf, Mr. George E. Collins, Mr. Henry P. Lowe, Mr. John C. Fleschutz, Mr. Norton H. Brown, Mr. James Underhill, Mr. R. B. Morton, Mr. Philip R. Stanhope, Mr. Henry I. Seeman, Mr. F. D. Wiley, and Mr. Ralph Chase. To these and to others too numerous to mention, whose aid was no less cheerfully given, the writer extends his sincere thanks.

GEOGRAPHY AND GEOLOGY OF THE PROVINCE.

THE SOUTHERN ROCKIES.

The Central City quadrangle lies in the heart of the Front Range of the southern Rocky Mountains. Structurally the southern Rockies, including the Laramie, Front, Sawtooth, Park, Wet, and Sangre de Cristo ranges, may be regarded as an anticlinal or arched region, in which large areas of pre-Cambrian crystalline rocks are exposed between flanking beds of Paleozoic and Mesozoic sediments.[2] On the west the sedimentary beds of the Colorado Plateau sweep at low angles up the arch, but east of the easternmost or Front Range the sedimentary strata are bent upward at steep angles. Although this simple description expresses the broader features, a closer examination shows that the province, instead of consisting of a huge simple arch, comprises a number of diverse anticlinal folds that correspond in a general way to the principal mountain masses, all of which show broad central areas of crystalline pre-Cambrian rocks.

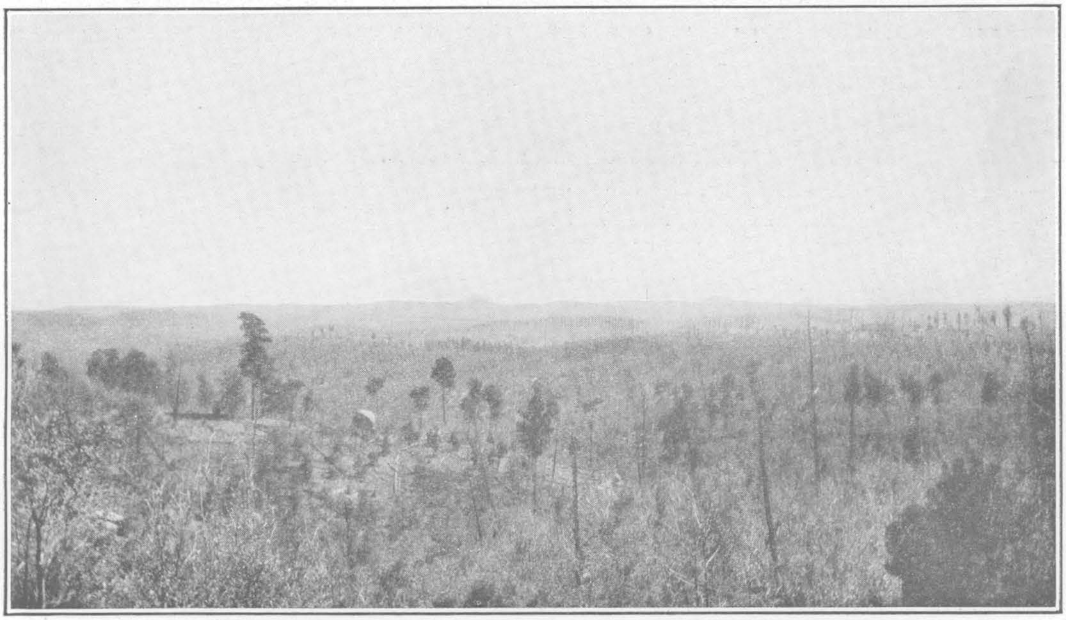
Knowledge of the character of the rocks of the pre-Cambrian areas is derived from a few widely separated regions where they have been studied in detail, so that few generalizations can safely be made for the province as a whole. The rocks include extremely old sedimentary and intrusive igneous rocks that have been severely dynamically metamorphosed, acquiring foliated structure, and younger intrusive igneous rocks that have not been dynamically metamorphosed in any great degree. In a few localities metamorphosed pre-Cambrian igneous rocks of supposed effusive origin have also been found.[3]

The sedimentary beds that flank the pre-Cambrian areas show great diversity not only in lithology but in age in different parts of the

[1] Spurr, J. E., Garrey, G. H., and Ball, S. H., Economic geology of the Georgetown quadrangle (together with the Empire district), Colorado: U. S. Geol. Survey Prof. Paper 63, 1908.

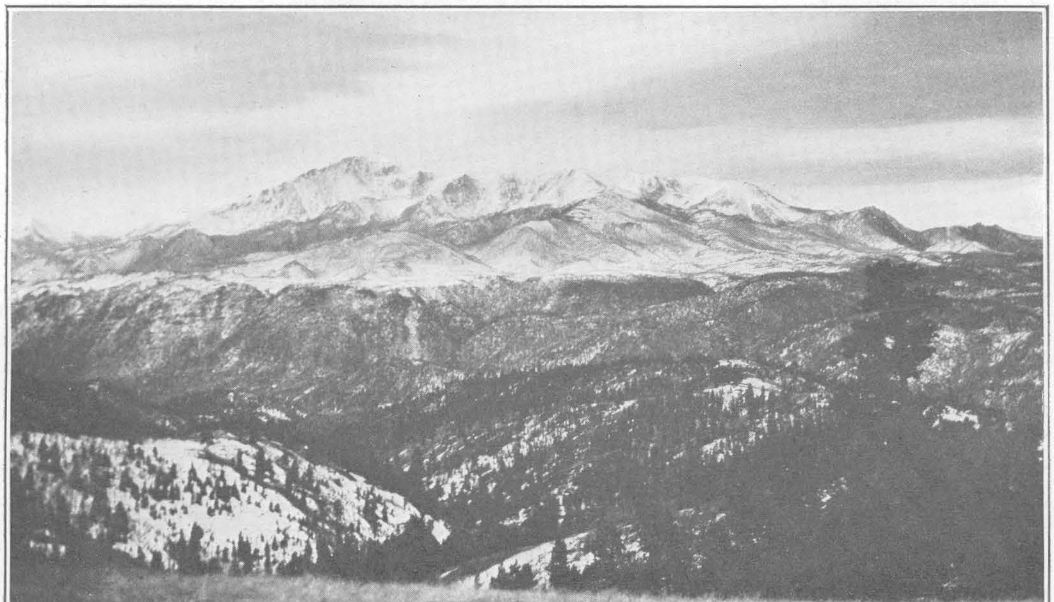
[2] Ransome, F. L., The Tertiary orogeny of the North American Cordillera and its problems: Problems of American geology, pp. 287-376, Yale University Press, 1915.

[3] Darton, N. H., Blackwelder, Eliot, and Siebenthal, C. E., U. S. Geol. Survey Geol. Atlas, Laramie-Sherman folio (No. 173), p. 3, 1910.



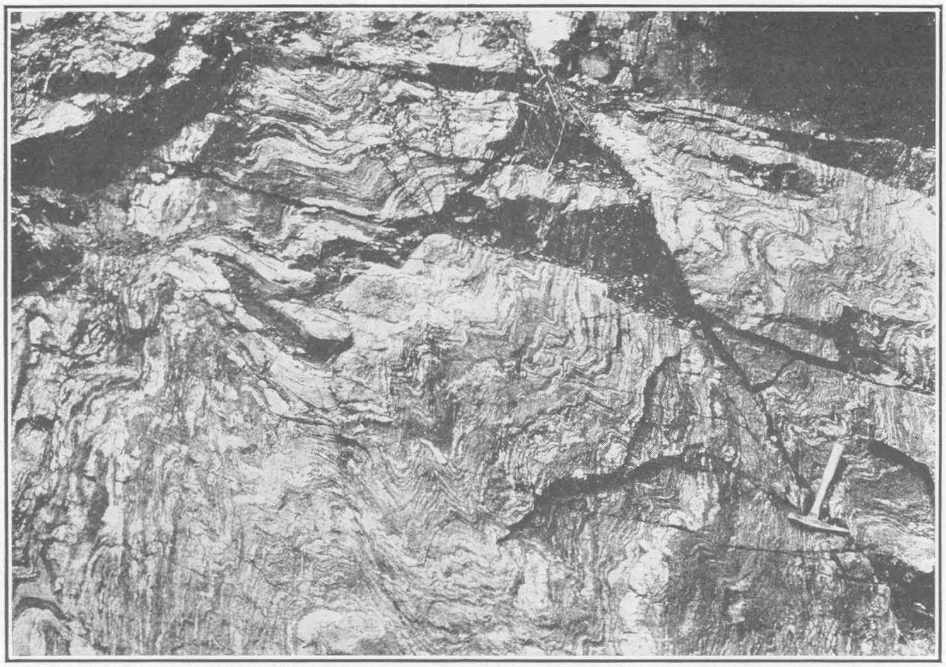
A. DISSECTED TERTIARY PENEPLAIN OF THE FRONT RANGE, LOOKING SOUTHWEST FROM A POINT NEAR PALMER LAKE, COLO.

In the distance the mountain peaks rise above the peneplain. Photograph by G. B. Richardson.



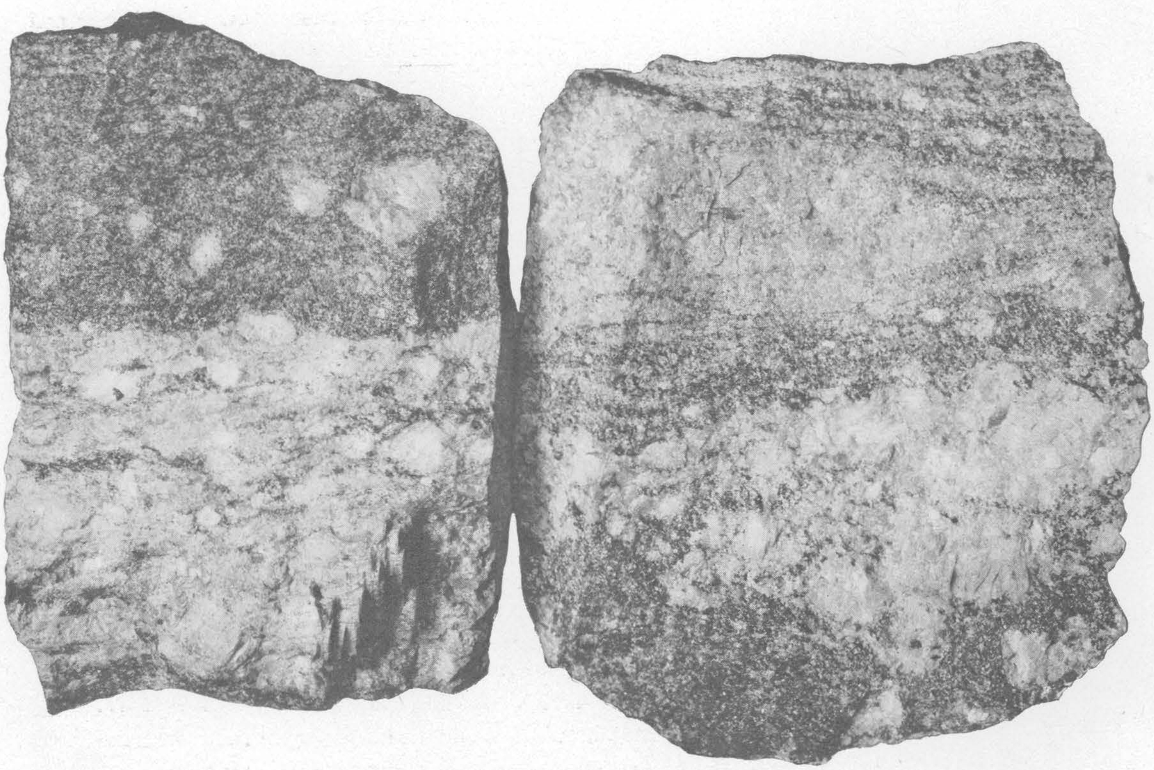
B. ANOTHER VIEW OF THE PENEPLAIN SHOWING PIKES PEAK RISING ABOVE IT.

Taken near the same locality as Plate IX, A, but in a more southwesterly direction.



A. EXPOSURE OF CRUMPLED SCHIST OF THE IDAHO SPRINGS FORMATION IN VIRGINIA CANYON NEAR SEATON GULCH.

The lighter bands are injections of pegmatite.



B. INJECTION GNEISS FORMED BY INTIMATE INTRUSION OF QUARTZ-BIOTITE SCHIST OF THE IDAHO SPRINGS FORMATION BY GRANITE PEGMATITE.

Taken from dump of Golden Rod tunnel, Silver Creek. Natural size.

province. Along the east side of the Front Range, for example, the oldest beds that rest upon the pre-Cambrian rocks are in some places Cambrian and in other places Pennsylvanian or even younger, a diversity that has an important bearing on the Paleozoic and early Mesozoic history, as is more fully explained in Chapter IV (pp. 63–65).

The geologic evidence indicates in general that in early Cretaceous time much of the area that is now mountainous lay beneath the sea, and it is probable that the uplifts which have raised the province to its present elevated position took place in late Cretaceous and Tertiary time, so that the Rocky Mountains are, in geologic terms, of comparatively recent origin. The cause of the uplift was compression along east-west to northeast-southwest lines. Its mechanism was bodily uplift, faulting, and folding. The greater uplifts and most of the folding probably took place at this time, but lesser uplifts occurred subsequently, and it is possible that some movement is still in progress.

In addition to the dynamic processes just described, volcanism played a not inconsiderable part in the history of the province. In late Cretaceous or early Tertiary time[1] monzonitic and other felsic magmas and their derivatives were intruded in great variety of size and form as stocks, dikes, and sills throughout much of the province, and where they reached the surface effusive rocks were developed as flows, breccias, and beds of tuff. These intrusions took place subsequent to the main uplifts of the range, and in some parts of the province subsequent to the complete removal by erosion of the great thicknesses of sediments that originally covered the uplifted areas. At Cripple Creek, for example, the rocks associated with the Tertiary surface volcanic rocks are pre-Cambrian. Nearly all the ore deposits of the province were formed soon after these intrusions, presumably by deposition from solutions that had the same deep-seated source as the igneous rocks.

The physiographic history of the province, in so far as it has an important bearing upon present geographic features, may be said to date from the uplifts of the Rocky Mountains, which probably began in Upper Cretaceous time and continued into Tertiary time. At the time of these uplifts the pre-Cambrian rocks that now constitute the cores of the ranges were probably in most parts of the province buried under several thousand feet of Cretaceous and probably older strata. To these were added later considerable masses of volcanic rocks, the effusive equivalents of the monzonitic intrusives that are so numerous in this province. As the uplift began, stream erosion immediately commenced the task of eroding this great sedimentary and volcanic blanket, and by middle or late Tertiary time it appears to have removed from the mountain tracts not only these beds but considerable thicknesses of the underlying pre-Cambrian rocks as well. By these processes large portions of the province were reduced to a gently sloping peneplain upon which the higher mountains stood as unreduced monadnocks. (See Pl. IX.) Remnants of this old topography are recognizable over wide areas in the southern Rockies.

The next event that had an important influence on the physiographic development of the province was a renewal of uplift in late Tertiary time. Its effect was to stimulate the streams to more active erosion, thus leading to the development of youthful erosion features on the once mature mountain uplands. The valleys were deepened, and steep-walled canyons like that between Golden and Idaho Springs were excavated by the larger streams. The escarpments between the plains and the mountain tracts were made higher. This uplift was not continuous, however; on the contrary, it was interrupted by halts during which considerable areas of the softer rocks flanking the ranges were reduced to gently sloping plains. Remnants of these plains are preserved in many parts of the foothills as mesas, of which those near Boulder afford a striking example.

Finally, as the result of climatic changes at two distinct periods in Pleistocene time, glaciers of the alpine type were formed in some of the higher mountain ranges. By their eroding action they developed steep-walled amphitheaters or cirques near the higher summits, and by their deposits they blocked drainage courses and created numerous small lakes. The waters from their melting laid

[1] In the Breckenridge district (see Ransome, F. L., Geology and ore deposits of the Breckenridge district, Colo.: U. S. Geol. Survey Prof. Paper 75, p. 38, 1911) the monzonites intrude fossiliferous shales of Upper Cretaceous age. In the vicinity of Boulder (see Fenneman, N. M., Geology of the Boulder district, Colo.: U. S. Geol. Survey Bull. 265, p. 39, 1905) dikes and sills of felsic character intrude rocks as young as the Pierre Cretaceous.

down extensive beds of sand and gravel in many of the valleys.

From the disappearance of the glaciers in late Pleistocene time to the present day degradation of the mountain tracts has proceeded under the normal influence of stream erosion, apparently without the stimulus of further uplift.

THE FRONT RANGE.

With the foregoing brief review of the salient features of the southern Rocky Mountain province in mind, attention may be narrowed to its eastern and most prominent element, the Front Range, within which the regions described in this report lie. The Front Range, including as its northern portion the Laramie Mountains of Wyoming, extends from the valley of North Platte River on the north to the valley of Arkansas River on the south, a distance of over 250 miles, and its width is in general from 30 to 45 miles. The plateau portions of the range commonly show altitudes of 8,000 to 9,000 feet; but above the plateau rise isolated summits to altitudes of over 14,000 feet. The range is bounded on the east by the Great Plains, which, from an altitude of 5,000 or 6,000 feet at the foot of the range, slope gently eastward at an average rate of about 10 feet to the mile. On the west the range is bounded by the detached areas of sedimentary rocks in North, Middle, and South parks.

The principal streams draining the Front Range are Platte, Arkansas, and Grand rivers and their tributaries. The waters of the Platte and Arkansas find their way to the Gulf of Mexico, but those of the Grand enter the Gulf of California. Where the larger streams traverse the plateau tracts between the higher portions of the range and the plains on either side, they are as a rule deeply intrenched in canyons that are among the most picturesque of the mountain features. Their main feeding ground is the higher part of the mountains, where, especially on the east or leeward side of the crest, the precipitation is heavy; they receive smaller though important contributions from the plateau tract, and but little from the arid plains. In correspondence with the diminishing altitude and lessening degree of precipitation the higher portions of the range below timber line are characterized by a typical northern moist-climate flora; in the plateau tract many plants of the same types flourish with less vigor and plants adapted to semi-aridity also appear; in the plains tracts a typical arid-climate flora prevails.

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CHAPTER II.—TOPOGRAPHY AND GEOGRAPHY OF THE CENTRAL CITY QUADRANGLE.

RELIEF.

As pointed out in the preceding chapter and well illustrated in Plate IX (p. 20), the pre-Cambrian area of the Front Range of the Rocky Mountains consists of an elevated plateau above which rise the higher peaks. The plateau tract, which is the dissected remnant of a Tertiary peneplain, extends from the escarpment west of Golden and Boulder about to the eastern border of the Central City quadrangle, its western limit being marked approximately by the upper ends of the steep-walled canyons along the larger streams. The canyon of Middle Boulder Creek begins approximately at the power dam 1½ miles below Nederland; that of North Clear Creek begins near Blackhawk, and that of Clear Creek a short distance below Idaho Springs. The major part of the quadrangle lies therefore within the central and more elevated portion of the mountain province, although a few remnants of the dissected peneplain are recognizable between Rollinsville and Nederland and in a few other places. The lowest point in the quadrangle, about 7,600 feet in altitude, is in the valley of Clear Creek below the mouth of Fall River; the highest point is the summit of Parry Peak, 13,345 feet; the extreme relief is therefore about 5,700 feet.

The mountain slopes back from the larger streams are in general only of moderate steepness except where they have been modified by glaciation, but along such streams they are commonly steep, though they do not form canyons except in the plateau tract. The slopes of the highest mountains, formerly gentle, have been sculptured by the glaciers of Pleistocene time into cirques or glacial amphitheaters with bare precipitous walls at their heads and having U-shaped cross sections in contrast with the V-shaped cross sections of the purely stream-cut valleys. Such cirques are particularly numerous and well developed on the east slope of the range, where precipitation was greater than on the west slope; they enhance the picturesque charm of the high mountains but increase the difficulties of travel. Deposits of glacial till have had a minor influence on the topography. Flats or plains are of comparatively rare occurrence and are nowhere of great extent. They have been formed along some of the larger streams by the deposition of outwash gravels by streams flowing from the glaciers. Such plains are particularly well developed near Empire, near Tolland, and between Eldora and Nederland. Another type of flats developed at several places in the eastern part of the quadrangle on upland tracts between the stream valleys is exemplified by Kings Flat, west of Nevadaville. Such flats commonly show few outcrops, being covered with a mantle of angular fragments of the underlying rocks. They are areas that have been long exposed to the disintegrating effects of rock weathering while at the same time protected by their position from active stream erosion, so that the mantle of weathering products could accumulate. Some of them may be remnants of the ancient Tertiary peneplain.

The influence of the structure and character of the hard rocks upon the topography has not been very marked. With the exception of the Idaho Springs formation most of these rocks—granite, granite gneiss, porphyries, and pegmatite—offer nearly the same degree of resistance to erosion, and the streams have sculptured them with very little reference to their boundaries. Certain facies of the Idaho Springs formation which are very massive or intensely injected by granite or pegmatite offer about the same resistance to erosion as the rocks named above, but other facies weather more readily to form gently sloping plains or hills of rounded, subdued outlines. The area west of Central City, between Bald Mountain and Chase Gulch, including Kings Flat, is an example of subdued topography in an area of schists of the Idaho Springs formation. North of Nederland and between Nederland and Rollinsville small isolated masses of granite stand up as knobs above the gently rolling schist surface.

DRAINAGE.

That portion of the region east of the Continental Divide is drained by Clear Creek and its affluents, including Fall River, and by the various branches of Boulder Creek. These waters finally enter the Gulf of Mexico by way of Platte, Missouri, and Mississippi rivers. The portion west of the divide is drained by tributaries of Fraser River, whose waters enter the Gulf of California by way of Grand and Colorado rivers. Most of the streams have high gradients, which in the portions of the valleys free from glacial deposits are as a rule not less than 100 feet to the mile and are locally as great as 600 feet to the mile. Glaciation has produced notable drainage modifications. As a result of glacial erosion in the cirques of the high mountains the headward portions of many streams, instead of having a somewhat uniform gradient descend in steplike fashion, their course being interrupted by small lakes, some of which lie in rock basins while others are retained behind dams of glacial till. Although the glacial features of the west side of the range have not been systematically studied, it is evident from the topographic map that glaciation has been much less severe and probably less extensive on the west side of the range than on the east. The influence of glaciation on the drainage may be appreciated by comparing the even gradient of many of the valleys west of the divide with the irregularities of the lake-dotted valleys just east of the divide. The deposition of glacial gravels to form the outwash plains mentioned in the preceding section has had the effect of lowering the stream gradients somewhat in these portions of their courses.

As a rule only those valleys which head in the high mountains carry permanent streams, and even these are subject to great fluctuations in volume. The absence of permanent streams in the valleys of the plateau tract has been a serious handicap in mining and milling.

A number of small artificial lakes (see Pl. II, in pocket) in the eastern part of the region have been created by the construction of dams to serve as ice ponds or to insure a supply of drinking water for stock.

CLIMATE.

In consequence of the very considerable range in elevation, the climatic conditions show great variations in different parts of the region. Meteorologic observations, though not available for points within the Central City quadrangle, are on record for near-by points similarly situated within the plateau or high mountain tracts. The mean annual temperature at a point near Longs Peak, at an elevation of 8,700 feet, is 38° F., the average ranging from 22.5° in February to 55° in August. At Sugar Loaf, in the plateau tract just north of the quadrangle, the mean annual temperature is 43°.

The mean annual precipitation for the quadrangle as a whole, according to the best available data, appears to be about 50 inches. This is about equal to the mean annual precipitation of the plateau portions of the South Atlantic States from Virginia to Georgia. In the Rockies, however, the rain and snow come for the most part not in storms of long duration but in short showers or flurries, many of which are severe while they last. During the summer, particularly in July and August, there are showers almost every afternoon, and occasional ones of unusual size may produce destructive freshets, towns like Blackhawk, situated in narrow valleys, being especially susceptible to damage from this source. In the lower valleys of the region the mean annual precipitation is very much below the above-mentioned average, being about 20 inches. On the higher slopes east of the crest of the range, on the other hand, the precipitation is considerably greater than 50 inches.

The growing season, even in the lower portions of the region, is short, extending generally from the first of June to the middle of September. The first snow commonly falls in September, but seldom remains on the ground long, and from that time until Christmas there may be little or no further snowfall; the remainder of the winter is commonly rigorous.

The air is dry throughout the region, and the prevailing winds are from the west.

VEGETATION.

Most of the Central City quadrangle lies within the area of the Pike and Arapaho national forests. When first settled most of the quadrangle below timber line (11,500 to 12,000 feet) was heavily forested, but lumbering for fuel and for mine timber has resulted in a practical destruction of the forests near the larger camps, and forest fires have destroyed them in other areas. Near Central City the destruction of timber has been so complete that old stumps and roots are dynamited for firewood. A detailed discussion of the flora would manifestly be out of place in a report of this character, but a few of the more striking silvic features may be mentioned. In the lower portions of the quadrangle, commonly below 9,000 feet, the yellow pine (*Pinus ponderosa*) is common, associated with patches of Douglas spruce (*Pseudotsuga mucronata*). At higher altitudes the yellow pine is replaced by the lodgepole pine (*Pinus murrayana*), which is adapted to moister and cooler conditions and is in general most abundant between 9,000 and 10,000 feet. The lodgepole pine is commonly intermixed with Engelmann spruce (*Picea engelmanni*), and in particularly moist localities, as along the stream courses, on the margins of swampy parks, at the headwaters of streams, and just below timber line, where there is much seepage, the latter becomes the predominant forest tree. With the Engelmann spruce may occur alpine firs (*Abies lasiocarpa*) and occasionally the beautiful silver spruce (*Picea parryana*). At the timber line, on account of the high winds and other climatic rigors, the Engelmann spruce becomes dwarfed to a shrub and is accompanied by herbaceous plants of arctic affinities.

Between elevations of about 8,000 and 9,500 feet, where the coniferous trees have been destroyed either by forest fires or by lumbering operations, angiosperm forests, predominantly of aspen (*Populus tremuloides*), have developed and after the first frosts many of the mountain slopes are ablaze with the golden tints of their leaves. In swampy places and along streams alders are common, and the larger gravel flats or "parks" along certain streams are occupied by an association of alders, Gambel oak, and several species of willow, together with grasses, sedges, etc.

INHABITANTS AND INDUSTRIES.

Nearly the entire population of the region is dependent in one way or another upon the mining industry. The railroads, with the exception of the Denver & Salt Lake, were built primarily to serve that industry. The few small ranches in the eastern part of the region are devoted largely to the raising of hay and garden truck to supply the neighboring mining towns. The small alluvial flats along the streams afford proper soil for farming, but only hardy crops that mature quickly thrive in this rigorous climate, where killing frosts sometimes occur in the valleys as late as June and as early as September. During the summer season a few sheep herders from the plains pasture their flocks near timber line. Idaho Springs, Tolland, Nederland, and Eldora attract a few summer visitors, and the railroad journey from Denver to Corona, at the crest of the range, is a favored trip for tourists.

Central City, the county seat of Gilpin County, with a population in 1910 of 1,782, is the center of the oldest and richest mining district of the region. Idaho Springs had a population in 1910 of 2,154 and is a distributing point for the mines near Fall River and Chicago Creek, as well as for mines in its immediate vicinity. Its accessible location, 37 miles by rail from Denver, its natural beauties, and its soda springs make it popular also as a summer resort. The other towns of the region are small mining camps, many of which, like Caribou and Apex, were formerly much more populous than at present.

Railroads

Both Central City and Idaho Springs are served by a narrow-gage branch of the Colorado & Southern Railway that from Denver and Golden ascends the canyon of Clear Creek to "The Forks," from which one branch turns up the valley of North Clear Creek to Blackhawk and Central City (40 miles from Denver) and the other branch follows Clear Creek to Idaho Springs and thence to Georgetown and Mount McClellan. Eldora, in the northern part of the region, is the terminus of the Denver, Boulder & Western Railroad, also a narrow-gage line, and is 36 miles distant by rail from Boulder. Nederland is connected by stage line with Boulder. The Denver & Salt Lake Railroad, which crosses the north-central part of the region, is a standard-gage line extending from Denver to Steamboat Springs, in Middle Park. It crosses the Continental Divide at Corona at an elevation of 11,680 feet. Corona is 65 miles by rail from Denver and Rollinsville is 42 miles.

Roads

Practically all the mines are served by mountain wagon roads that are on the whole good in spite of the vicissitudes of washouts. None are obliged to depend on pack-train transportation.

CHAPTER III.—DESCRIPTIVE GEOLOGY.

STRATIGRAPHY.

PRE-CAMBRIAN METAMORPHOSED SEDIMENTARY ROCKS.

The only pre-Cambrian rocks that can with assurance be classed as metamorphosed sediments are those of the Idaho Springs formation. All other pre-Cambrian rocks of the quadrangle are unquestionably of igneous origin.

IDAHO SPRINGS FORMATION.

NAME.

The Idaho Springs formation was first defined by Ball,[1] who named it from the town of Idaho Springs, near which characteristic exposures are abundant.

DISTRIBUTION.

The formation underlies large areas in the western and northeastern parts of the Georgetown quadrangle and fully one-half of the geologically mapped portion of the Central City quadrangle. It is known also to be widely distributed to the east, in the Blackhawk quadrangle. As its commoner rock types are somewhat less resistant to erosion than most other rocks of the region, it forms few high peaks or ridges, and for this reason it is a fair inference that the formation is not so widespread in the high western unmapped portion of the region as in the eastern portion.

Over certain areas, as, for example, between Nevadaville and Mount Pisgah, the formation is fairly free from intrusive igneous rocks, but in most localities igneous rocks are associated with it in great abundance and in an exceedingly intimate and irregular fashion.

Some idea of this intimate association may be obtained from the large-scale geologic maps (Pls. III and VI, in pocket), but even on these the boundary line drawn between the Idaho Springs formation and granite pegmatite or granite gneiss indicates in many places a somewhat arbitrary separation of an area occupied mainly by the Idaho Springs formation from another area occupied mainly by igneous rock. On the small-scale geologic map (Pl. I, in pocket) no attempt is made to subdivide the formation into its different rock types, but on Plates III and VI the more unusual hornblendic and lime-silicate phases are differentiated by separate colors from the commoner phases.

LITHOLOGY AND STRUCTURE.

General features.—The predominant rocks of the Idaho Springs formation are light to dark gray quartz-biotite schists, in places carrying some hornblende or muscovite. With these are associated lesser amounts of biotite-sillimanite schist, quartzitic gneiss, dark-green hornblende schist and gneiss, and lime-silicate rocks that represent metamorphosed limestones. In a few places the formation includes rocks that are supposed to be metamorphosed conglomerates. These diverse phases are interbanded, show transitional varieties, and are clearly integral parts of one formation.

The less common facies occur mostly in lens-shaped masses, such as the areas of lime-silicate rocks near Central City (see Pl. III), and not in continuous bands that might serve as indicators of structure. Throughout most of the formation bedding planes have been entirely obliterated by the development of schistose structure, the biotite and biotite-sillimanite schists in particular being highly foliated. On the other hand, certain bands of quartzitic schist that in places persist with fairly uniform width for several hundred feet are interpreted to represent beds, originally more sandy than their neighbors, that have preserved their integrity because the constituents required for the development of platy minerals during metamorphism were scarce.

The general strike of the foliation is, in some parts of the region, fairly uniform over a number of square miles, but in most places the schists have been so disturbed by numerous igneous intrusions that all conceivable inclinations can be observed within a single square mile, and faulting has produced added irregularities. The foliation exhibits no broad parallelism with the axis of the range.

The character and distribution of the principal rock types will be briefly described. It

[1] Ball, S. H., General geology [of the Georgetown quadrangle]: U. S. Geol. Survey Prof. Paper 63, p. 37, 1908.

should be understood, however, that most of these types pass into one another by gradations.

Quartz-biotite schist.—The commoner facies of the formation as developed in this region may be included under the term quartz-biotite schist. These rocks range from light gray to very dark gray in color, depending on the abundance of biotite, and may be either coarse or fine grained. In the coarse phases mica plates may be 3 to 6 millimeters in diameter and quartz and feldspar may form aggregates of comparable size; in the finer phases the average size of grain is 1 millimeter or less, and the contrast between light and dark constituents gives the rock a "pepper and salt" appearance. Schistosity is commonly better developed in the coarse than in the fine varieties, and in the former crumpling such as is shown in Plate X, *A* (p. 21), is common.

The principal minerals are quartz, biotite, muscovite, and feldspar. Microcline is the most common feldspar, but plagioclase (usually oligoclase) is very abundant in some specimens, and microperthite is locally present. The proportion between biotite and muscovite is extremely variable, but biotite usually predominates, and muscovite may be entirely absent. Minerals usually present in subordinate amounts are apatite, magnetite, and zircon. As a rule the magnetite shows irregular outlines and the zircons are somewhat rounded. In some places, especially near pegmatite intrusions, the rock contains one or more of the minerals garnet, tourmaline, hornblende, corundum, rutile, and andalusite. Some hornblendic facies carry a little titanite.

The foliation is due mainly to the subparallel orientation of biotite or muscovite plates and is therefore most highly developed in the more micaceous varieties.

Analysis of quartz-biotite schist obtained near Penn mill, just below Blackhawk.

[George Steiger, analyst.]

SiO_2	64.23	TiO_2	0.80
Al_2O_3	16.45	ZrO_2	None.
Fe_2O_3	2.40	CO_2	None.
FeO	4.31	P_2O_5	.10
MgO	1.68	S	.03
CaO	3.11	MnO	.08
Na_2O	3.75	BaO	.02
K_2O	2.14	SrO	Trace.
H_2O-	.02		
H_2O+	.89		100.01

This rock is a fine-grained schist which has a "pepper and salt" appearance as a result of its evenness of grain and the strong color contrast between its quartz and biotite. The principal minerals, named in the order of abundance, are brown biotite, plagioclase, and quartz. Orthoclase, muscovite, apatite, magnetite, and well-rounded zircons occur in minor amounts.

A somewhat unusual variety from the southwest slope of Cone Mountain shows grains of magnetite surrounded by small halos of quartz and feldspar unmixed with biotite. These halos, which are pink, contrast strongly with the gray surrounding areas, which are rich in biotite and give the rock a peculiar spotted appearance. Similar rocks were noted by Ball in the Georgetown quadrangle.

Biotite-sillimanite schist.—According to Ball[1] the greater part of the rock of the Idaho Springs formation as exposed in the Georgetown quadrangle contains sillimanite, a silicate of alumina. In the Central City quadrangle sillimanite-bearing schists are not abundant except in the vicinity of Empire. They do not differ greatly in general appearance from the quartz-biotite schists already described and except for the presence of sillimanite have a similar mineral composition. Ball says:

> The white or greenish-white sillimanite occurs in single rods and bundles of rods, elongated in the plane of schistosity, which are cut by transverse fractures whose interstices are filled by biotite flakes and magnetite or pyrite grains. In places the component rods of the aggregates cross one another, forming confused meshes.

The elongation of the sillimanite crystals parallel to the biotite plates is an important element in the development of the schistose structure.

Quartz gneiss.—Highly quartzose facies of the formation that are believed to be metamorphosed sandstones underlie considerable areas on Sugarloaf Mountain, in the Georgetown quadrangle, but no large amounts of such rocks are noted in the Central City quadrangle. A small body of rock on the southwest slope of Cone Mountain, consisting mainly of quartz with some biotite and very little feldspar, may be a metamorphosed argillaceous sandstone or an unusually quartzose phase of the granite gneiss.

[1] Ball, S. H., op. cit., p. 38.

Ball[1] describes the quartz gneiss of the Georgetown quadrangle as follows:

> The quartz gneiss is a well-banded rock formed of fine to broad laminæ, varying in color from gray to brown, red, or black. The texture is as a rule dense and vitreous, although in places it is saccharoidal. Lit-par-lit pegmatitic injections are rare, as is natural in a rock with imperfect gneissic banding. Under the microscope quartz is shown to be the essential constituent. The accessory minerals include all the minerals present in biotite-sillimanite schist, with the addition of shreds of green hornblende. The gneissic parting is due to the elongation of intricately interlocking quartz lenses, to the variation in granularity of the quartz of adjacent bands, and to the linear arrangement of discontinuous sheets of biotite blades and magnetite cubes. The darker color of certain bands of the gneiss is due to an unusual abundance of this biotite and magnetite.

Hornblende schist and gneiss.—The presence of hornblende in small amounts in some of the quartz-biotite schists has already been mentioned. In other schists and gneisses hornblende is the predominant mafic mineral.[2] Such rocks commonly form small bands or lenses along the contact between areas of quartz-biotite schist and areas of granite gneiss, granite, or granite pegmatite, or occur wholly within the igneous rock near such contacts. This characteristic association is shown on Plates III and VI (in pocket), on which the hornblendic phases of the formation are indicated by a separate symbol.

Near Central City, as is also well shown on Plate III, some of the lenses of hornblende schist inclosed by granite gneiss lie not far from lenses and irregular masses of lime-silicate rocks, and both types bear similar relations to the more common phases of the Idaho Springs formation and to the granitic igneous rocks. The trend and degree of foliation in the hornblende schists is similar to that in neighboring areas of quartz-biotite schist. The close and invariable association of the hornblende schists and gneisses with the quartz-biotite schist of the Idaho Springs formation on the one hand and with the granite gneiss and granite pegmatite on the other hand is believed to indicate that they are parts of the Idaho Springs formation that have been metamorphosed by the granitic intrusions.

The texture of the hornblendic rocks ranges from schistose to gneissic, depending on the degree of segregation of felsic and mafic minerals into separate bands. The schistose structure is due almost entirely to subparallel elongation of the hornblende crystals. The average size of grain ranges from less than 1 millimeter to about 3 millimeters, but individual hornblende crystals may reach a length of 5 millimeters. The principal mineral constituents, named in the order of abundance, are green hornblende, quartz, and plagioclase feldspar. Minor constituents usually present are titanite, magnetite, and zircon; the grains of zircon are commonly well rounded. Minerals present in some places are augite, apatite, and garnet. The plagioclase in the specimens studied microscopically ranges from oligoclase to andesine in composition. Varieties with abundant garnet were noted along the valley of North Clear Creek about half a mile north-northwest of the summit of Maryland Mountain. The garnet is in skeleton crystals inclosing small crystals of quartz, magnetite, and hornblende.

The hornblende schists and gneisses contrast strongly with the quartz-biotite schists with which they are associated in showing little evidence of mechanical deformation subsequent to their crystallization. This characteristic is in harmony with the view already expressed that they have been formed from the commoner rock types of the Idaho Springs formation by contact-metamorphic processes.

Lime-silicate rocks.—Under the term lime-silicate rocks are included rocks usually massive but in places gneissic, composed of quartz, epidote, and garnet with locally some pyroxene, zoisite, hornblende, titanite, magnetite, pyrite, or calcite. Some varieties are very coarse grained; Ball[3] mentions crystals 6 inches in diameter.

The texture is generally very irregular, resembling that of certain pegmatites, the various minerals penetrating one another irregularly and having apparently crystallized simultaneously. The general color effect of the rocks ranges from brown to green or gray, depending on the proportions of the component minerals.

Lime-silicate rocks are not abundant in the Central City quadrangle and are mainly confined to a few small areas just west and northwest of Central City. As shown on Plate III

[1] Ball, S. H., op. cit., p. 41.

[2] Mafic is a term suggested to replace the objectionable term basic as applied to rocks. (See Cross, Whitman, Iddings, J. P., Pirsson, L. V., and Washington, H. S., Jour. Geology, vol. 20, p. 561, 1912.)

[3] Ball, S. H., op. cit., p. 42.

(in pocket), these areas are irregularly lenslike in form and are inclosed by granite gneiss. Near them, also inclosed by the granite gneiss, are lenses of hornblende schist and gneiss and some of quartz-biotite schist.

In texture and mineral composition these rocks are similar to certain rocks in other districts known to have been formed by the metamorphic action of intrusive igneous rocks on limestones. Their distribution within an igneous rock near its contact with the Idaho Springs formation and the close proximity and general similarity in form of the areas of lime-silicate rocks to areas of recognizable schist belonging to the Idaho Springs formation inclosed in the granite gneiss point also to a contact-metamorphic origin in this district. The lime-silicate rocks are therefore believed to represent calcareous sediments of the Idaho Springs formation that have been completely recrystallized and changed in mineral composition through the influence of granitic rocks that intrude them. Near Central City the intrusive rock was granite gneiss; in other localities it was granite pegmatite. Dynamic metamorphism may have played some small part in their formation, but their massive and locally coarse-grained character shows that it was not the principal process concerned.

Supposed metamorphosed conglomerates.—At a few places in the Georgetown quadrangle, notably on Chief and Pendleton mountains, certain of the schists of the Idaho Springs formation contain lenticular or ellipsoidal bodies from half an inch to 4 inches long that resemble pebbles flattened in the plane of the schistosity. These rocks have been described and figured by Ball[1] and are regarded by him as dynamically metamorphosed conglomerates. Rocks of this character were not found in the Central City quadrangle.

Injection gneiss.—As discussed at more length on pages 34–35, the Idaho Springs formation was invaded by granitic material during at least two periods in pre-Cambrian time. The larger bodies of these intrusive rocks are characterized by fairly uniform texture and composition and are shown on Plate I (in pocket) as areas of granite gneiss and granite. Most of the smaller granitic masses and a few of considerable size (which commonly inclose many patches of schist) are of coarser and more irregular texture and are classed as pegmatite. Some of the pegmatite came from the same deep source as the granite gneiss and some from the later granitic intrusions.

All these granitic rocks but in particular the pegmatites in many places intrude the schists of the Idaho Springs formation in a very intimate and irregular manner. Most of the small intrusions have the form of long, narrow lenses or pinching and swelling dikes lying parallel to the foliation of the schists or cutting the foliation at low angles, and in many places the injection of granitic material is so intimate that the rock becomes an injection gneiss such as is illustrated in Plate X, *B* (p. 21). Such injection is more common and more intimate in the highly micaceous schists than in those which are highly quartzose, but there is hardly any area of the Idaho Springs formation an acre in extent that does not contain some injection gneiss. The manifest impracticability of showing the smaller details of distribution of schist and pegmatite necessitates much generalization in the geologic mapping. Even on the large-scale maps the boundaries between the Idaho Springs formation and granite pegmatite are arbitrarily drawn where predominance of one gives way to predominance of the other.

ORIGIN.

The Idaho Springs formation is believed to have been formed by the general dynamic metamorphism and local igneous metamorphism of a thick series of sedimentary rocks. Its original sedimentary character is inferred from the highly aluminous composition of many of its rocks, the local appearance of structures resembling bedding, the presence in minor amounts of highly quartzose facies and of others that appear to be deformed conglomerates, and finally the occurrence of massive lime-silicate rocks of a type characteristically formed through the metamorphism of limestone. Opposed to the supposition of an igneous origin for any part of the formation is the fact that no facies of the formation have anywhere been observed transecting other facies. The single analysis made throws no light upon its origin.

According to this interpretation the biotite and biotite-sillimanite schists and hornblende gneisses were originally shales and arkoses, the

[1] Ball, S. H., op. cit., pp. 41, 177; pls. 7 and 8, *A*.

quartzitic gneiss was originally an impure sandstone, and the lime-silicate rocks were originally limestones.

AGE.

The Idaho Springs formation forms an intimate part of the complex of crystalline rocks which at certain points on the flanks of the range is overlain unconformably by sediments carrying Upper Cambrian fossils.[1] The unmetamorphosed character of the Cambrian rocks as compared with the highly metamorphosed character of the Idaho Springs formation indicates that the latter is very much older; its age may therefore be placed as certainly pre-Cambrian. Among the pre-Cambrian rocks of the quadrangle it is the oldest, being intruded by all the others, which, as already stated, are without exception of igneous origin. It is therefore the basement formation and probably originally underlaid all the region covered by this report. Adequate information is not at hand for correlating its rocks with any rocks from parts of the Front Range outside of the Georgetown and Central City quadrangles. Its highly metamorphosed character indicates that it is much older than the slightly metamorphosed pre-Cambrian quartzites of certain parts of the range, which have been provisionally classed by Van Hise[2] and others as Algonkian.

PRE-CAMBRIAN IGNEOUS ROCKS.

Igneous rocks of pre-Cambrian age underlie nearly half of the area surveyed and include granite gneiss, granite, granite pegmatite, and hornblendite.

GRANITE GNEISS.

DEFINITION.

The granite gneisses of this district have acquired a gneissic structure through dynamic metamorphism. As in the massive granites, their essential minerals are quartz, alkali feldspar, and either muscovite or biotite. Similar rocks in the Georgetown quadrangle have been described by Ball[3] under the name gneissoid granite.

[1] Cross, Whitman, U. S. Geol. Survey Geol. Atlas, Pikes Peak folio (No. 7), 1894.

[2] Van Hise, C. R., and Leith, C. K., Pre-Cambrian geology of North America: U. S. Geol. Survey Bull. 360, p. 827, 1909.

[3] Ball, S. H., op. cit., p. 49.

DISTRIBUTION AND GENERAL STRUCTURE.

As shown on the geologic map (Pl. I, in pocket), granite gneiss is comparatively rare in the northern part of the area mapped but underlies nearly half of the central and southern parts. The areas of granite gneiss, though of irregular outline, are commonly elongate in a northeasterly direction parallel to the predominant trend of the inclosing schists of the Idaho Springs formation. Some of the areas are 4 to 5 miles long and 2 to 3 miles across, but most of these large masses inclose small areas of the Idaho Springs formation. Excellent exposures of the granite gneiss are numerous on the surface and in the mines near Central City and along the lower course of Fall River. Exposures in many parts of the region show that the granite gneiss intrudes the rocks of the Idaho Springs formation. At one place on the road in the upper part of Virginia Canyon the granite gneiss incloses fragments of schist of the Idaho Springs formation. In the valley of Fall River about 1¼ miles above its mouth the transition from an area of granite gneiss to an area of the Idaho Springs formation takes place gradually in a distance of 200 to 300 feet. In passing from the schist toward the gneiss a gradual increase is first noted in the amount of pegmatite that injects the schist, then a few bands of granite gneiss appear in the pegmatized schist, and finally both schist and pegmatite decrease in abundance, eventually leaving only granite gneiss.

The relations of the granite gneiss to the granite pegmatite are twofold. Pegmatitic transition zones, such as that described in the last paragraph, at the borders of areas of granite gneiss indicate that some of the granite pegmatite is merely a phase of the granite gneiss intrusion. At many other localities the granite gneiss was observed to become pegmatitic near schist contacts; thus on the south wall of the valley of Middle Boulder Creek about 1½ miles east of Eldora the schists of the Idaho Springs formation, which are here in part hornblendic, are intruded by granite gneiss. The contact between the two is in most places parallel to the schist foliation, but in places transgresses it at a small angle. The granite gneiss is commonly pegmatitic next to the schist and in places sends off pegmatitic apophyses that cut bluntly across the schist folia. In some localities irregular bodies of granite pegmatite occur wholly within areas of granite gneiss, the two rocks grading into each other. In contrast to these relations, which indicate contemporaneity, other pegmatites sharply cut the granite gneiss and are therefore of later origin. Near the head of Virginia Canyon both the granite gneiss and the Idaho Springs formation are sharply cut by pegmatite dikes, some of which parallel the foliation while others transgress it. Similar relations were noted half a mile north-northwest of the summit of Maryland Mountain. Where the granite gneiss and the Idaho Springs formation are adjacent the foliation of the two is usually about parallel.

LITHOLOGY.

The granite gneiss shows much diversity in different parts of the region and even within a single outcrop. The color on fresh surfaces varies from light gray through pale pink to dark gray; weathered surfaces may be deeper pink or buff from oxidation of the mafic (basic) minerals. The average size of grain ranges from 1 millimeter or even less to 4 or 5 millimeters. Gneissic structure is commonly well developed but in some places is lacking; massive facies are separable from the later granites only where actual gradation into typical granite gneiss can be traced. In the region southwest and northeast of Dumont, for example, much of the rock mapped as granite gneiss is a fine-grained massive granite, but in a few localities it shows well-defined foliation striking about N. 20° E. The breadth and conspicuousness of the folia commonly increases with the coarseness of grain. As shown later, the gneissic structure is due mainly to the segregation of biotite along certain discontinuous bands and of quartz and feldspar along others. The folia are nowhere crenulated. Pegmatitic facies are present here and there as bands parallel to the foliation and of fairly even width within the main body of the gneiss or in less regular relations near the contact between the granite gneiss and the Idaho Springs formation. In general pegmatite is much less abundantly associated with the granite gneiss than with the schists of the Idaho Springs formation.

The constituents of the granite gneiss visible to the unaided eye, named in the usual order of their abundance, are white or pink feldspar, quartz, and biotite. An unusually dark phase of mottled appearance seen about 1½ miles southwest of Dumont is about one-half biotite but is interbanded with the more common varieties. In some varieties muscovite is also abundant, and rarely it is present to the practical exclusion of biotite, as in the Lucania tunnel from about 4,450 to 6,200 feet from the portal. Microscopic study reveals the presence in most specimens of magnetite in small irregular grains and of zircon and apatite. Garnet is present locally but is generally not conspicuous. The texture is allotriomorphic granular. The feldspars include orthoclase, microcline, and oligoclase. Ball[1] has shown that a part of the microcline replaces other feldspars and quartz and was therefore formed somewhat later than the general recrystallization of the rock. Micrographic intergrowths of one or more of the feldspar varieties with quartz are common. Weathered phases show the secondary minerals usual in altered granitic rocks, which require no special mention.

The gneissic structure has evidently been developed by complete recrystallization under high pressure. During this process the mica plates assumed subparallel orientation at right angles to the direction of compression, and in some varieties of the gneiss were more or less segregated in discontinuous bands separated by bands wholly free from mica. Many of the quartz grains also became more or less elongate in the same direction.

ORIGIN.

The granite gneiss is believed to be a granitic intrusive rock that has received a foliated structure as a result of dynamic metamorphism subsequent to its intrusion. Its intrusive character is attested (1) by apophyses from the gneiss masses that penetrate the rocks of the Idaho Springs formation, transgressing their foliation, (2) by angular schist fragments inclosed in the granite gneiss, and (3) by contact-metamorphic effects produced in rocks of the Idaho Springs formation inclosed by or bordering on masses of granite gneiss.

Subsequent to their intrusion, perhaps long afterward, the rocks were subjected to dynamic metamorphism that in some places produced partial recrystallization, with the devel-

[1] Ball, S. H., op. cit., p. 50.

opment of foliated structure. The fact that the mechanism of this change was recrystallization rather than fracturing and granulation indicates that the metamorphism took place under high pressure, presumably while the rocks were deeply buried.

Long after the recrystallization, when the rocks were no longer deeply buried, the granite gneiss was locally fractured and granulated.

Attention has been directed to the variable character of the granite gneiss, but these variations are of an order common in granitic intrusive rocks and are readily attributable to magmatic differentiation or to varying amounts of recrystallization during dynamic metamorphism; they are not at all comparable with the much greater variations characteristic of the Idaho Springs formation.

AGE.

The granite gneiss is a part of the pre-Cambrian axis of the Front Range. Its structural relations and its degree of metamorphism indicate that it is intermediate in age between the oldest and the youngest of the pre-Cambrian rocks. It is distinctly younger than the oldest pre-Cambrian formation, the Idaho Springs, which it intrudes. Moreover, the Idaho Springs formation was evidently schistose prior to the intrusion of the granite gneiss magma, and the magma in many places followed this schistosity as the direction of easiest access. At least one considerable period of dynamic metamorphism therefore intervened between the deposition of the sediments of the Idaho Springs formation and the intrusion of the granite gneiss magma. On the other hand, the granite gneiss is itself intruded by granite pegmatite and massive granite of later pre-Cambrian age.

QUARTZ DIORITE AND ASSOCIATED HORNBLENDITE.

DEFINITION.

The next group to be described consists of massive to slightly gneissic coarse-grained rocks varying from quartz diorites to hornblendites in mineral composition. Similar rocks occurring in the Georgetown quadrangle were described by Ball.[1] They intrude the granite gneiss and the rocks of the Idaho Springs formation.

[1] Ball, S. H., op. cit., pp. 54-57.

DISTRIBUTION.

These rocks occur principally in the central and southern parts of the area surveyed. The largest body extends from a point 1¼ miles east of Yankee northeastward to Montana Mountain and Pine Creek, and its width for most of this distance is nearly half a mile. Most of the other bodies form broad dikes whose trend is northeast, parallel to the prevailing trend of the foliation in the inclosing schists and gneisses. The longest of these dikes extends northeastward from the summit of Mount Pisgah for about 2¼ miles, with outliers on both the southwest and the northeast. In the northern part of the area surveyed quartz diorite has been observed only in two small patches north of Nederland. (See Pl. I, in pocket.)

CHARACTER.

The commonest rock type belonging to this group is a true quartz diorite, a wholly crystalline rock of medium grain (most of the mineral grains being 1 to 5 millimeters across), mottled black and white on fresh surfaces and having a general tone effect of dark gray. The rock is usually massive, though locally it shows faint foliation. The weathered surfaces are somewhat lighter in color, and some are rusty through the oxidation of the iron-bearing minerals. Microscopic study of fresh specimens shows that the fabric is seriate homeoid,[2] and the original minerals, named in the order of general abundance, are plagioclase (mostly near $Ab_{45}An_{55}$), brown biotite, green pleochroic hornblende, quartz, magnetite, apatite, and zircon. In some specimens from the Georgetown quadrangle Ball[3] noted small amounts of original rutile, orthoclase, ilmenite, and titanite. Apatite and zircon form small euhedral grains, and some grains of hornblende and magnetite are subhedral, but the other constituents are anhedral. In a few localities pyroxene is present in addition to hornblende. In the section studied the pyroxene was partly altered to hornblende and its original character was not accurately determinable. Ball[3] noted diallage in some of his specimens.

In many localities variations may be observed from the commoner type described

[2] The term seriate as applied to the fabric of igneous rocks signifies that the size of the grains varies gradually or in a continuous series. Homeoid signifies that the range in size of the grains is small. See Iddings, J. P., Igneous rocks, vol. 1, p. 196, 1909.

[3] Ball, S. H., op. cit., pp. 54-55.

above to varieties poorer in iron-bearing minerals and of light-gray color. The lighter rock commonly occurs as irregular lenses in the darker. Ball[1] describes phases from the adjacent Georgetown quadrangle that are almost wholly plagioclase. Still more common are variations toward rocks that are richer in iron-bearing minerals and are termed hornblendites from the great predominance of hornblende. A typical hornblendite from the valley of the West Fork of Clear Creek is nearly black and of medium grain (1 to 5 millimeters for most of the mineral grains) and consists of green hornblende, plagioclase, quartz, magnetite, and apatite, named in the order of abundance. The apatite crystals are euhedral, but the other minerals are anhedral. The rock shows a faint foliation which appears to be the result of flowage while the magma was still viscous. Ball[2] recognized enstatite in some of the hornblendites of the Georgetown quadrangle. In mineral composition these hornblendites somewhat resemble the hornblende schists of the Idaho Springs formation, but they may usually be differentiated from the schists by their more massive and coarser texture, by their gradation into quartz diorite, and by the fact that, unlike the hornblende schists, they are not characteristically associated with lime-silicate rocks or biotite schists of the Idaho Springs formation.

Weathering produces the usual suite of secondary minerals, such as sericite, chlorite, epidote, and calcite, in more or less abundance.

RELATIONS TO OTHER ROCKS.

The quartz diorite and hornblendite are clearly intrusive into the rocks of the Idaho Springs formation. In the lower part of the valley of Elk Creek, southwest of Apex, angular fragments of schist belonging to the Idaho Springs formation are inclosed in the quartz diorite. A number of the quartz diorite dikes lie parallel to the prevailing trend of the foliation of the inclosing Idaho Springs formation.

At many localities quartz diorite or hornblendite is intruded by granite pegmatite, and at a few places, as $3\frac{1}{2}$ miles west of Empire, they are intruded by the Silver Plume granite.

The relations of the quartz diorite and hornblendite to the granite gneiss are not so clear. Three-quarters of a mile southwest of Apex the quartz diorite appears to be intrusive in the granite gneiss. At other localities the relations, although somewhat obscure, suggest that the quartz diorite is intruded by granite which is now somewhat gneissic; in such areas, however, it can not be definitely shown that this granite is contemporaneous with the typical granite gneiss. There is a somewhat striking resemblance between some varieties of the quartz diorite and certain dark-colored rocks that are clearly differentiation products of the granite gneiss magma.

ORIGIN AND AGE.

It is clear from the relations already set forth that the quartz diorite and its associated lighter and darker colored facies are intrusive igneous rocks of pre-Cambrian age. They were intruded subsequent to the development of most of the foliation in the Idaho Springs formation but before the intrusion of the Silver Plume granite and its associated pegmatite. The relation of the quartz diorite to the granite gneiss, though far from clear, suggests that the two rocks are of nearly the same age and possibly came from a common magmatic source. An alternative hypothesis suggested by Ball[2] assumes that the quartz diorites and hornblendites are derived from the same magmatic source as certain pre-Cambrian quartz monzonites that occupy large areas in the Georgetown quadrangle but are not exposed within the surveyed portions of the Central City quadrangle.

GRANITE PEGMATITE.

DEFINITION.

Under the name granite pegmatite are included rocks of coarse and usually irregular texture containing the same minerals as are found in normal granites. The principal constituents are potash feldspar, quartz, biotite, and muscovite, but many other minerals are present in subordinate amounts. As explained later, all the granite pegmatite of this region is not of the same age.

DISTRIBUTION.

Granite pegmatite in masses too small to map is abundant throughout most of the area mapped as Idaho Springs formation on Plate I (in pocket). Most of these small intrusions have the form of long, narrow lenses or pinch-

[1] Ball, S. H., op. cit., pp. 54-55.

[2] Idem, p. 56.

ing and swelling dikes lying parallel to the foliation of the schists or cutting it at small angles. Other masses of pegmatite are exceedingly irregular and may transect the schist foliation in various directions and even inclose angular fragments of schist. In many places the intrusion of pegmatite is so intimate that the rock becomes an injection gneiss, and locally the pegmatite magma penetrated the schist so intimately that isolated "eyes" of pegmatite were developed (see Pl. X, *B*, p. 21), which show no evidence of strain and can not be regarded as pegmatite fragments isolated as a result of shearing. The mechanism of the development of most of the bands and lenses appears to have been intrusion under pressure, but many of the small isolated "eyes" of pegmatite may have been formed through metasomatic replacement. Hardly any area of schist an acre in extent is wholly free from pegmatite. (See Pl. XII, *B*, p. 53.) Conversely, there is more or less schist in the areas that are largely pegmatite.

Although some areas of pegmatite are closely associated with areas of granite gneiss or of the Silver Plume granite, pegmatite is in general most abundant between the larger areas of these rocks. A peculiar and as yet unexplained feature of the distribution of the pegmatite is its rather intimate association with many of the masses of quartz diorite and hornblendite.

CHARACTER.

The predominant constituent of the pegmatites of this region is potash feldspar (orthoclase or microcline), in places perthitically intergrown with soda feldspar (albite); next in abundance is gray quartz, which commonly carries numerous fluid inclusions. Muscovite or biotite, or both, are usually present, together with minor amounts of magnetite and black tourmaline. Red garnet, apatite, zircon, allanite, and beryl occur locally in small crystals. In a few pegmatite masses magnetite is fairly abundant. One such mass lies near Central City, on the ridge between South Willis Gulch and Pleasant Valley, and it carries magnetite crystals as much as 1 inch in diameter. Ball[1] mentions localities in the Georgetown quadrangle where magnetite forms over one-third of the volume of the pegmatite and occurs in single crystals as much as 4 inches across and in aggregates as much as 6 inches across. It is locally the only iron-bearing mineral present. Lithium and boron minerals and minerals containing the rare earths, such as are found in granite pegmatites in some parts of the United States, were not noted in the Central City quadrangle. If present they are certainly in small amounts.

Highly quartzose varieties of the pegmatite are very rare. A lens of white quartz 15 feet in maximum width lying parallel to the schist foliation just southwest of the summit of Pewabic Mountain may represent an extreme product from a pegmatite magma. It can not, however, be traced into pegmatite, and no minerals other than quartz were noted in it. There is certainly no genetic connection in this region between pegmatites and metalliferous veins, even the more quartzose vein types.

The granite pegmatites of the Central City quadrangle are characterized by erratic variations in coarseness and by a wholly irregular association of their component minerals; cavities of any kind are rare, and extreme coarseness is also rare. In one of the coarsest bodies, about half a mile southeast of Pisgah Lake, there are masses of pure white quartz 4 feet across, single feldspar crystals 1 foot across, and abundant graphic granite ranging from coarse to fine.

The relations of the pegmatites to the schists of the Idaho Springs formation show that the pegmatites were intruded after most of the dynamic metamorphism in this region took place. None of them show any appreciable deformation that can not be explained by faulting and its attendant shearing.

RELATIONS TO OTHER ROCKS.

It has already been stated that the granite pegmatites are intrusive into the rocks of the Idaho Springs formation. Some of the pegmatite clearly came from the same magmatic source as the granite gneiss, as is shown, for instance, by exposures near the head of Missouri Creek, where irregular masses of pegmatite including much graphic granite grade into and are wholly inclosed by granite gneiss. Certain bands forming an integral part of granite gneiss may exhibit pegmatitic textures. Commonly granite gneiss takes on pegmatitic textures next to schist contacts and even sends off pegmatitic dike offshoots cutting the foliation of the schist.

[1] Ball, S. H., op. cit., p. 61.

Other masses of granite pegmatite show transitions to the Silver Plume granite and evidently came from the same magmatic source. Numerous examples are found near Rollinsville and Nederland. Most of the pegmatites that cut sharply across the foliation of the granite gneiss probably belong in this group, though others may be late offshoots from the granite-gneiss magma itself. Finally, certain pegmatites sharply cut the Silver Plume granite and are regarded as late offshoots from still molten interior portions of the granite mass after the exterior portions had crystallized and become somewhat fractured.

ORIGIN AND AGE.

In practically all districts where pegmatites are found they are associated more or less intimately with certain types of massive igneous rocks. Pegmatites of the type here described are invariably associated with granites or similar rocks, and the association is so intimate and so invariable as to suggest at once that the massive and the pegmatitic rocks were derived from a common magmatic source. In the opinion of most geologists the pegmatites crystallized from portions of the magma that were richer than the average in the elements of water and in some localities in other so-called mineralizers, such as lithium and boron. The abundant presence of these mineralizers permitted the magma to remain fluid to a lower temperature than that at which the normal granite solidified and facilitated the development of large crystals. Many granite pegmatites appear to have come from the interior fluid portions of granitic masses after the exterior portions had crystallized as massive granite; a granite pegmatite dike cutting massive granite may therefore be only slightly younger than the granite itself.

The granite pegmatites of the Central City quadrangle are believed to have been derived in part from the granite gneiss magma and in part from the Silver Plume granite magma. As the pegmatites derived from each of these sources are similar in mineral character, it is possible to distinguish them only in the relatively few places where they can be traced into granite gneiss or granite. The relative importance of the two magmas as sources of pegmatites can not be estimated; it seems probable, however, form the areal distribution of granite gneiss and granite that the pegmatite of the southeastern part of the quadrangle came mainly from the granite gneiss magma and that of the northeastern part of the quadrangle came mainly from the Silver Plume granite magma. As already stated, the granite gneiss and the Silver Plume granite, though probably of widely diverse ages, are both believed to be pre-Cambrian. So far as observed the Tertiary (?) porphyry magmas yielded no pegmatitic facies.

SILVER PLUME GRANITE.

DEFINITION.

The name Silver Plume granite was applied by Ball to a medium-grained, usually porphyritic biotite granite that forms numerous stocks and dikes in the vicinity of Silver Plume and Georgetown. In the present report all the granite of the region that is distinctly younger than the granite gneiss is classed under this heading, although there may be some question whether all of it is the precise equivalent of the granite of the type locality near Silver Plume.

DISTRIBUTION.

The Silver Plume granite is widely distributed through all but the southeastern portion of the region, as is shown on Plate I (in pocket). It forms irregular stocks, commonly more or less elongate parallel to the prevailing trend of the foliation in the inclosing schist of the Idaho Springs formation or the granite gneiss. The largest body, just northeast of Caribou, is about 3 miles across.

CHARACTER.

The Silver Plume granite ranges in color from light gray or pale pink in the commoner varieties to dark gray in facies richer in iron-bearing minerals. The texture is medium to coarse grained and commonly massive, although some varieties are porphyroid from the development of crystals of potash feldspar as much as 2 or 3 centimeters in length. In a few localities the texture is typically porphyritic, phenocrysts of potash feldspar as much as 3 or even 5 millimeters long lying in a uniformly even-grained groundmass. Such a porphyritic granite occurs 1½ miles west of Phoenixville. The rocks in a few places show faint gneissic structure, especially near the borders of the granite areas.

Typical representatives of the commonest type are well exposed near Empire station and Empire and may be described as light-gray to pinkish, wholly crystalline medium-grained massive rocks, most of the mineral grains being 1 millimeter to 5 millimeters in diameter. The fabric is seriate homeoid to porphyroid.[1] Microscopic examination shows that the original minerals, named in their usual order of abundance, are oligoclase, orthoclase and microcline, quartz, biotite, apatite, magnetite, and muscovite. The mineral grains are anhedral with the exception of the small well-crystallized apatite prisms. There are in a few places micrographic intergrowths of quartz and oligoclase. Slight mechanical deformation since crystallization is evidenced by straining and some granulation of the quartz, much of the granulated quartz showing a coarse mosaic pattern. As a result of weathering sericite is developed from oligoclase and chlorite from biotite; some epidote and calcite may also form.

Pegmatitic varieties are common in association with the normal facies of the Silver Plume granite, as pointed out on page 35.

In places rocks of dioritic appearance are associated with the common facies of the Silver Plume granite. Gradations in some places between the two types indicate that both came from a common magmatic source. Where the two types do not grade into each other it is usually the light-colored rock that intrudes the darker, indicating that the dark varieties were differentiated early in the process of intrusion. Most of the dark-colored varieties differ from the commoner types mainly in the absence or scarcity of potash feldspar and the proportionally greater abundance of iron-bearing minerals. Titanite and zircon may appear. The plagioclase, as in the commoner types, is oligoclase or oligoclase-andesine. In some of the darkest rocks hornblende is nearly as abundant as biotite. Dark-colored varieties are well exposed in the cliffs west of Silver Lake, near Alice.

Dark-colored granite forms a lens-shaped mass about three-fourths of a mile long just south of Central City, and a small mass of granite of identical appearance occurs in the valley of Missouri Creek about 1 mile north of Missouri Lake. In spite of the fact that most of the dark-colored facies of the Silver Plume granite are of small areal extent as compared with the dark granite near Central City, it is thought probable that the latter is correctly classed as a variety of the Silver Plume granite. At one place near Central City a dike of biotite pegmatite 4 to 6 inches wide cuts the dark granite, and near the head of Spring Gulch the dark granite cuts sharply across the foliation of granite gneiss. Its relations to other rocks are therefore consistent with the interpretation that it is a differentiate from the Silver Plume granite. Moreover, there are local gradations into relatively small areas of light-gray to pinkish granite which closely resembles the normal Silver Plume granite except for the presence of a few small crystals of purple fluorite and numerous small yellowish-brown garnets. The dark-colored granite forming the greater part of the mass south of Central City may be described as a massive dark-gray medium-grained rock with seriate homeoid fabric. The original minerals, named in the order of abundance, are plagioclase (oligoclase-andesine), biotite, quartz, magnetite, titanite, and apatite. The apatite crystals are euhedral, the magnetite subhedral, and all the other minerals anhedral. There is no evidence of any great amount of mashing or recrystallization subsequent to solidification.

RELATIONS TO OTHER ROCKS.

The Silver Plume granite is intrusive into most of the pre-Cambrian rocks of the quadrangle. At an elevation of 9,950 feet, on the crest of Red Elephant Hill, near Lawson, a mass of this granite (too small to map) cuts across the foliation of the granite gneiss and incloses angular fragments of the gneiss, which show no evidence of absorption. The granite of the southeast slope of Boulder Hill shows numerous included masses of schist of the Idaho Springs formation. About three-quarters of a mile west of Lawson the Silver Plume granite appears to intrude quartz diorite; near this point also the granite cuts not only the schist of the Idaho Springs formation, but also stringers of granite pegmatite in the schist.

The only rocks observed to cut the Silver Plume granite are the porphyries of probable Tertiary age and a few dikes of pegmatite which probably came from the same magmatic

[1] For explanation of terms see Iddings, J. P., Igneous rocks, vol. 1, p. 196, 1909.

source as the granite itself. A 2-foot dike of coarse pegmatite, composed wholly of quartz and pink feldspar, cuts the granite on the cliffs just northwest of Empire station. In the Oro Verde tunnel, near Alice, the granite is intruded by coarse biotite pegmatite.

To summarize, the Silver Plume granite intrudes all the rocks that in the preceding pages have been referred to the pre-Cambrian and is itself intruded by pegmatite and by Tertiary (?) porphyries.

AGE.

The Silver Plume granite is believed to be pre-Cambrian in age, and with the exception of its own pegmatitic phases it is the youngest of the pre-Cambrian rocks of the region. The possibility of a Paleozoic age for this granite can not be excluded on the basis of any evidence found within the Central City quadrangle, but where Paleozoic rocks are exposed on the flanks of the Front Range no granites intrusive in them have been noted.

CARBONIFEROUS (?) SANDSTONE.

Residual bowlders of silicified sandstone and quartzite occur at three points in the Georgetown quadrangle. At one of these localities, Cascade Creek, the bowlders are so abundant that the original exposure of the sandstone could not have been much above the present surface. No residual sandstone or quartzite were noted in the area covered by the present report, but as these rocks presumably once covered at least part of this area Ball's description of their appearance in the Georgetown quadrangle[1] is inserted here.

> The medium-grained, well-silicified sandstone and quartzite is yellowish brown, pink, red, or purple in color. The semiporous character of certain bowlders indicates that some lime carbonate as cement may have been associated with silica. Well-rounded pebbles of quartz monzonite, hornblende gneiss, and pegmatite are embedded here and there in the finer matrix. Under the microscope the silicified sandstone proves to be composed of well-rounded grains of quartz with one or more grains of plagioclase and rounded rock fragments in most of the thin sections. The quartz, which contains zircon granules, was derived partly from the gneisses and partly from the plutonic rocks of the pre-Cambrian formations. Quartz in optical continuity with the rounded grains, from which it is separated by a film of limonite, is the chief cement, although a little hematite and chlorite also occur.
>
> The well-sorted character of the sandstone indicates lacustrine or marine origin, while from the thorough cementation and the almost complete removal by erosion of what was once perhaps an extensive formation it may be inferred that the rock is of considerable age. It is, however, much younger than the youngest pre-Cambrian pegmatite, since before the deposition of the pebbles in the sandstone the pegmatite must have cooled beneath a considerable cap of overlying rock, which was removed by erosion prior to the depression of the land beneath the water in which the sand was deposited. Five miles south of the quadrangle, on North Fork of the South Platte about 1 mile above Shawnee, a lithologically similar sandstone rests unconformably upon the Idaho Springs formation at an elevation of approximately 8,200 feet. Similar sandstone is exposed on the north bank of the same stream at Pine post office, 15 miles south of east of the southeast corner of the quadrangle. This sandstone belt strikes N. 60° W. and dips 70° to 80° SW. and is probably a block dropped by parallel faults into the Rosalie (pre-Cambrian) granite. The sandstone, which includes small pebbles of the Rosalie granite, is similar to that of the residuals in the Georgetown quadrangle, although the red and white coloring matter is somewhat more unevenly distributed. Lithologically this rock is very like the Fountain sandstone (Carboniferous) of the foothills of the Colorado Range. This portion of the range was at some time covered by the sea, which extended over the whole or a part of the Georgetown quadrangle, and if the above correlation be correct the submergence was in late Carboniferous time, although a different age is quite possible.

[1] Ball, S. H., op. cit., pp. 66-67.

TERTIARY (?) INTRUSIVE ROCKS.

GENERAL CHARACTER AND RELATIONS.

In all parts of the area surveyed igneous rocks intrusive in the pre-Cambrian formations are of common occurrence. These intrusives form irregular stocks and dikes whose form and distribution are well shown on Plate I (in pocket). The commonest rock types are monzonites and related quartz monzonites, in large part porphyritic in texture. These rocks make up practically the whole mass of the larger stocks and many of the dikes and quantitatively far exceed all other types among the Tertiary (?) intrusives. The remaining types occur (1) as dikes and small stocks and lenses and (2) to a lesser extent as irregular masses within monzonite stocks. The second mode of occurrence finds its principal exemplification in the titaniferous iron ores and associated gabbros, peridotites, etc., near Caribou, which are clearly differentiation products from a monzonite magma. The first mode of occurrence is represented by the bostonites of the southern part of the region and the andesites, diorites, and basalts of the northeastern part. Although many of these dike rocks differ greatly in mineral composition from the quartz monzonites, it is probable that most of them came from the same magmatic source as the monzonites and are essentially contemporaneous with them. Their different mineral composition is attributed to magmatic differentiation at considerable depth prior to their intrusion.

There are cogent reasons for the belief expressed above that most of the rocks that intrude the pre-Cambrian rocks, the "porphyries" of the miners, were derived from a common source or sources and are of essentially the same age. First, in spite of the presence of stocks of monzonite in the northeastern part of the quadrangle, monzonite dikes are practically absent, their place being taken by dikes of andesite, diorite, and basalt. In view of the abundance of monzonite dikes in other parts of the quadrangle their absence in that region is difficult to explain except on the assumption that more mafic (basic) dikes are themselves differentiation products from the monzonitic magmas and so supplement the monzonite dikes of the regions of lesser magmatic differentiation. Second, the only district in which the more mafic dikes are abundant, the area about Nederland and Caribou, is adjacent to the one monzonite stock which shows within itself a notable amount of differentiation into more mafic rock—that is, the Caribou stock, which carries the titaniferous iron ores. This association suggests that both the mafic dikes and the iron ores are the result of magmatic differentiation within a magma of monzonitic composition, the iron ores having been formed by differentiation in place or nearly so and the dikes by differentiation followed by intrusion. This view receives substantial confirmation from the apparent passage of some of the dikes at their west ends into the monzonite stock.

That the bostonites and alaskites of the southeastern part of the Central City quadrangle are genetically connected with the monzonites can not be so confidently asserted. The bostonites and alaskites have nowhere been observed in contact with the monzonites. In certain areas, as near Idaho Springs, both bostonite and monzonite dikes are abundant, but in other areas, as between Central City and Yankee, all the dikes are bostonite, even though stocks of monzonite occur close by. Both bostonite and monzonite are older than the mineral veins. Although the evidence for a genetic connection of these other rocks with the monzonites is therefore not so strong as in the case of the dikes of the northeast corner of the quadrangle, such a connection is regarded as probable. From a study of the relations of these rocks in the Georgetown quadrangle Spurr and Garrey[1] reached the same conclusion. These writers regarded the alkali syenite and the biotite latite of the Idaho Springs region as later than the monzonite and bostonite and later than the mineral veins. The writer found no additional evidence bearing on this point.

As monzonitic rocks constitute most of the stocks and many of the dikes, their total volume is many times the combined volume of all other types. It is therefore probable that the parent magma from which the various rock types arose through differentiation had very nearly the average composition of the large monzonite stocks.

As the Tertiary (?) intrusive rocks are not greatly different in their resistance to erosion from the pre-Cambrian rocks with which they are associated there is little correspondence between the topography and the form of the intrusive masses. The dike outcrops are usually not conspicuous, and many dikes are traceable only with difficulty by the presence of "float" material between scattered outcrops or by "float" alone.

As clearly set forth in a summary by Ball,[2] the intrusive porphyries and related rocks of the Georgetown and Central City quadrangles form part of an extensive belt of intrusive porphyries that extends from the vicinity of Boulder southwestward to Breckenridge, Leadville, and Aspen. In sedimentary rocks they characteristically occur as sheets; in the pre-Cambrian complex, as dikes and stocks. The predominant types throughout the belt bear a general resemblance to one another and in a broad way are probably contemporaneous. In this porphyry belt are situated many of the most productive mining camps in Colorado.

[1] Spurr, J. E., and Garrey, G. H., U. S. Geol. Survey Prof. Paper 63, pp. 135-136, 1908.

[2] Ball, S. H., op. cit., pp. 67-70.

AGE.

The geologic relations within the Central City and Georgetown quadrangles indicate merely that the "porphyries" are younger than the pre-Cambrian rocks, which they cut, and are with a few exceptions older than the ore deposits. The geology of neighboring areas, however, gives much additional light on their age relations.

At Leadville S. F. Emmons [1] found evidence that the porphyries were of late Cretaceous age. Spurr [2] assigned the same age to the porphyries of Aspen, and Ransome [3] believes that the intrusion of the porphyries of Breckenridge took place at the end of the Cretaceous period.

The intrusive sheets of porphyry in the vicinity of Boulder were examined by Ball [4] and R. D. George and were found to be lithologically similar to certain of the porphyries of the Georgetown quadrangle. These sheets were found to cut the Niobrara and Pierre formations and the "Red Beds," and they are therefore late Cretaceous or younger in age, a conclusion in accord with the views of Fenneman.[5]

In the sedimentary formations flanking the pre-Cambrian core of the Front Range west of Denver débris of volcanic rocks first appears, according to Cross,[6] in the Denver formation. This débris is andesitic and may well have been derived from flows that were the surface equivalents of the monzonites and related intrusive rocks. The Denver formation is of early Tertiary age. Beds composed largely of coarse andesitic material, resting unconformably on upturned Cretaceous rocks, have been noted also in Middle Park, on the west side of the Front Range.

All the evidence available therefore indicates an early Tertiary age for the intrusive porphyries and related rocks of the Central City quadrangle and adjacent regions.

[1] Emmons, S. F., Geology and mining industry of Leadville, Colo.: U. S. Geol. Survey Mon. 12, p. 294, 1886.

[2] Spurr, J. E., Geology of the Aspen mining district, Colo.: U. S. Geol. Survey Mon. 31, p. 53, 1898.

[3] Ransome, F. L., Geology and ore deposits of the Breckenridge district, Colo.: U. S. Geol. Survey Prof. Paper 75, p. 182, 1911.

[4] Ball, S. H., op. cit., p. 71.

[5] Fenneman, N. M., Geology of the Boulder district, Colo.: U. S. Geol. Survey Bull. 265, pp. 35-40, 1905.

[6] Cross, Whitman, Geology of the Denver Basin in Colorado: U. S. Geol. Survey Mon. 27, pp. 34-202, 1896.

QUARTZ MONZONITE AND QUARTZ MONZONITE PORPHYRY.

GENERAL CHARACTER.

The quartz monzonites of the Central City quadrangle are composed of orthoclase feldspar, calcic plagioclase feldspar, some quartz, and usually some iron-bearing minerals. There are great variations in the proportions of the minerals, in coarseness, and in the degree to which phenocrysts are developed. In many localities iron-bearing minerals are not conspicuous, but in certain types they may be present in amounts reaching 30 or 40 per cent by volume and give to the rock a dark-gray color. In the porphyritic varieties the phenocrysts may be wholly feldspar or there may also be some of quartz or iron-bearing minerals. The phenocrysts may be small or large, ranging from 1 millimeter to 3 centimeters, and may be all of the same order of magnitude or of heterogeneous sizes. The groundmass appears structureless (aphanitic) to the unaided eye and in fresh specimens is light gray to purplish gray in color. In the nonporphyritic varieties the texture may be porphyroid or, more rarely, rather evenly granular. A few dikes are coarsely porphyritic at the center and more finely porphyritic or massive at their borders. Many varieties are usually present within the same monzonite stock, and even along a single narrow dike there may be very considerable variations in character. The monzonites are usually massive; only in a few places do they show a slight banding attributable to differential movement during crystallization.

Quartz monzonites and monzonite porphyries are present in nearly all parts of the area surveyed. The largest masses are the stocks near Apex, Ute Mountain, and Caribou. Dikes are particularly abundant in the vicinity of Idaho Springs. The details of distribution are fully shown on the geologic maps (Pls. I, III, and VI, in pocket).

PRINCIPAL VARIETIES.

Uniformly porphyritic quartz monzonites.—A variety of quartz monzonite which is common in the area between Perigo, Phoenixville, Tolland, and Apex but is not abundant elsewhere in the region shows in fresh specimens a blue-gray to purplish-gray fine-grained (aphanitic) groundmass through which are scattered a profusion of pink feldspar phenocrysts, commonly 2 to 3 millimeters in diameter. A few quartz phenocrysts are present. In altered specimens the groundmass may be lighter gray or pale lilac-colored and the feldspar phenocrysts white through the development of sericite or green through the development of chlorite.

A particularly fresh specimen of monzonite of this type from a point about 2 miles due north of Apex may be described as follows: Texture porphyritic, abundant euhedral phenocrysts of pale-pink feldspar, mostly 2 to 3 millimeters in diameter, and a few of quartz, lying in a blue gray aphanitic groundmass. Under the microscope the feldspar phenocrysts are seen to be in part plagioclase (near $Ab_{70}An_{30}$) and in part orthoclase; the two varieties are apparently about equally abundant. Some of the few quartz phenocrysts are euhedral, but most of them are rounded or have embayments as a result of resorption. A few small biotite phenocrysts or biotite aggregates about 0.7 millimeter in greatest dimension were also noted. The groundmass is microgranular and appears to be mainly feldspar (species indeterminate) with some quartz and biotite and abundant minute grains of magnetite. A few of the grains of magnetite attain a diameter of 0.2 millimeter.

In a porphyry of very similar appearance from the Champion mine, near Phoenixville, the phenocrysts are all orthoclase, but plagioclase and quartz as well as orthoclase occur in the microcrystalline groundmass, which in hand specimens appears purplish gray.

A few monzonite dikes present a peculiar "pepper and salt" appearance, euhedral crystals of feldspar, mostly 1 to 2 millimeters in diameter, being scattered in unusual profusion through a dark-gray to brownish-gray aphanitic groundmass. One of these dikes was an offshoot from the Gregory Hill stock of monzonite. The specimens collected proved to be too much altered for careful microscopic study.

Other monzonites that are also uniformly porphyritic in texture differ from those just described principally in the larger size of the phenocrysts and the slightly greater coarseness of the groundmass. These are dike rocks of the series of monzonite intrusions within the area shown on Plate VI. The fresher specimens of these rocks show a blue-gray to pinkish-gray aphanitic groundmass, through which are scattered abundant phenocrysts of pink feldspar, mostly 3 to 5 millimeters in diameter. In altered specimens the groundmass is commonly light gray to buff and the phenocrysts white or pale greenish. The groundmass of one of the freshest rocks is pinkish gray; through it are scattered salmon-colored phenocrysts of feldspar from 2 to 5 millimeters in diameter, and a smaller number of inconspicuous gray phenocrysts of feldspar. Under the microscope the pink phenocrysts are found to be euhedral crystals of orthoclase. The gray phenocrysts are plagioclase, variety not determinable. The microgranular groundmass carries quartz, orthoclase, plagioclase, and magnetite, the last in irregular open aggregates.

Seriate porphyritic quartz monzonites.—In the rocks termed seriate porphyritic quartz monzonites the phenocrysts, even of the same mineral species, show great variations in size and may be numerous or scattered. In general these rocks are more prevalent than the uniformly porphyritic rocks. One of the freshest specimens illustrative of this type was obtained from the dump of the Almaden tunnel on Fall River. This rock carries phenocrysts of pink orthoclase from 2 to 10 millimeters in diameter and phenocrysts of light-gray plagioclase from 2 to 8 millimeters in diameter, scattered through a dark-gray aphanitic groundmass. Prisms of green hornblende as much as 3 millimeters in length, and of magnetite and titanite as long as 1 millimeter are also recognizable. Microscopic study shows that many of the plagioclase phenocrysts show zonal structure, the central portions being oligoclase (about $Ab_{85}An_{15}$) and the outer portions appearing to be andesine. All the above-mentioned minerals show euhedral forms. The microscope reveals the presence of quartz in phenocrysts as much as 0.5 millimeter in diameter, some showing rounding of corners and formation of embayments as the result of resorption and others being ragged in outline. The groundmass, which is finely microgranular, carries quartz, orthoclase, and possibly plagioclase and is dotted with small magnetite grains whose abundance gives the dark-gray color to the groundmass in the hand specimen.

In porphyry from the southwest slope of Seaton Mountain, near Idaho Springs, some feldspar phenocrysts reach the unusual size of 1½ centimeters, though the majority are less than 3 millimeters in diameter.

In a few localities the monzonite porphyry carries abundant quartz phenocrysts, some of which may reach 5 millimeters in diameter. One dike of this type is cut 4,800 feet from the portal in the Marshall & Russell tunnel at Empire station. Another occurs a quarter of a mile northeast of Dumont. The specimens obtained were all much altered, but microscopic study of the specimen from the Marshall & Russell tunnel showed that phenocrysts of both orthoclase and plagioclase were present in addition to those of quartz, which were more or less rounded by resorption. Quartz also occurs in small amounts in the groundmass.

A number of dikes in the region between Idaho Springs and Lawson carry small prisms of pyroxene in notable amounts and may therefore be termed pyroxenic quartz monzonite porphyries. These rocks have a gray groundmass which under the microscope is found to be a microgranular association of quartz, orthoclase, plagioclase, and small grains of magnetite. The abundant phenocrysts, originally pyroxene, as shown by their form, are now an aggregate of chlorite, calcite, and magnetite.

Nonporphyritic quartz monzonites.—Many of the quartz monzonites are porphyroid to massive in fabric and therefore can not be called porphyries in the strict sense of the term. In general these are stock rocks of fine to medium grain, ranging from light to dark gray in color according to the abundance of iron-bearing minerals present. The main mass of the Caribou stock of monzonite, which may be taken as representative of the darkest-colored varieties, is described on page 42, and an analysis of it is given on page 43 (analysis 1).

A slightly lighter colored variety of the quartz monzonite is typified by a rock from the Alice mine, near Alice. This is a light-gray rock of porphyroid fabric, few of the mineral grains exceeding 2 millimeters in diameter. The larger euhedral or subhedral crystals that give the rock its porphyroid texture are orthoclase and andesine; biotite, quartz, and magnetite in smaller anhedral grains make up the rest of the rock except for a few prisms of apatite. Monzonite of almost identical appearance occurs at the east end of Ute Mountain.

Monzonite forming a small stock in the valley of Fall River about three-quarters of a mile above the mouth of York Gulch is unusual in carrying numerous quartz phenocrysts as much as 5 millimeters in diameter. Biotite is also abundant in plates 1 millimeter or less across. Monzonite from another locality near by carries some quartz phenocrysts nearly 2 centimeters long, many of which show perfect crystal forms.

In the extreme northeast corner of the area covered by Plate VI occurs a medium-grained monzonite that has gray feldspar for its chief component. In general appearance it is strikingly similar to certain anorthosites, but the microscope shows that the predominant gray feldspar is orthoclase. Plagioclase (near $Ab_{70}An_{30}$, oligoclase-andesine) and quartz are present in lesser amounts and in smaller crystals. Magnetite occurs in numerous small euhedral or subhedral grains, titanite in perfect crystals, apatite in small prisms, and purple fluorite in irregular grains that appear to be primary. Monzonite of practically identical character is cut in the Phillips tunnel, on Fall River, and monzonite from the southeast slope of Cone Mountain, 2¼ miles west-northwest of Empire, is similar but carries numerous prisms, originally green pyroxene but now in large part altered to hornblende.

Unusual varieties.—A specimen collected 1 mile south-southeast of Apex, within the quartz monzonite stock that makes up most of Utah and Oregon hills, proved on microscopic examination to be massive, medium grained, and composed of orthoclase, augite, titanite, and magnetite, plagioclase and quartz being entirely absent. This rock is therefore an augite syenite, but it grades into the typical quartz monzonite that makes up most of this stock.

ROCKS FORMED BY MAGMATIC DIFFERENTIATION WITHIN MONZONITE STOCKS NEAR CARIBOU.

GENERAL CHARACTER.

The monzonite stocks of Caribou and of Bald Mountain, northwest of Caribou, are unique for the region covered by this report in showing in a marked degree the effects of magmatic differentiation—that is, the separation of the molten magma into portions that were chemically different and that on cooling formed rocks of different types. The extreme product of this process of differentiation has been the formation of several bodies of titaniferous iron ore, whose economic features are discussed elsewhere in this report (pp. 129–130). It is probable also, for the reasons set forth on page 38, that the andesite, diorite, and basalt dikes between Caribou and Nederland were also formed by differentiation from a monzonite magma just prior to their intrusion into their present position.

It was not found practicable in the field to obtain a complete series of fresh samples along any one line extending from the iron ore of Caribou out into the normal quartz monzonite, but samples were selected so as to be as nearly as possible representative of the variations along most of these contacts. Chemical analyses of six of these samples, made by George Steiger in the laboratory of the United States Geological Survey, are given in the table on page 43, together with three analyses made by E. P. Jennings.[1]

The greater part of the Caribou and Bald Mountain stocks is composed of monzonites and quartz monzonites of gray color and medium coarseness. Inclosed by these rocks and forming not more than 5 per cent of the whole volume of the stock are a number of small irregular bodies of dark-colored rocks which are rich in iron-bearing minerals and whose form and position are indicated on Plate I (in pocket). In places a complete gradation may be traced from the monzonites into these mafic rocks, and within the latter there are transitions from gabbros to rocks composed mainly of magnetite and ilmenite. In other places the contacts are not gradational, the monzonite abutting sharply against the mafic rocks and even inclosing angular fragments of them. In general, however, the evidence is clear that the iron-rich rocks are differentiates from the monzonite magma and that the differentiation was followed locally by intrusion of the iron-rich product into the more silicic types. In the iron-ore body half a mile south of Caribou the eastern contact with the monzonite is gradational but the western contact is sharp. The principal types in these gradational series are briefly described below, the textural terminology proposed by Cross, Iddings, Pirsson, and Washington[2] being used.

FELSIC (ACIDIC) AND INTERMEDIATE TYPES.

A rock collected 1 mile southeast of Caribou will serve to illustrate the commonest type of the quartz monzonite.

Quartz monzonite (shoshonose; analysis 1, p. 43). In megascopic appearance this rock is light-gray, holocrystalline, and composed of crystals nearly all of which are less than 1 millimeter in diameter. The microscope shows that most of the crystals are between 0.1 and 1 millimeter in diameter and that the fabric is seriate porphyroid. The major constituents are orthoclase, plagioclase, augite, and biotite. The minor constituents are magnetite, apatite, and quartz. The plagioclase is mostly labradorite near $Ab_{40}An_{60}$, although a few crystals show zonal structure with more sodic feldspar near the borders. The crystals are subhedral. Orthoclase is nearly equal to plagioclase in abundance and forms anhedral (or allotriomorphic) masses between the plagioclase crystals. Augite is abundant in pale-green and nonpleochroic grains showing extinction angles ($c:\mathfrak{c}$) as great as 46°. It forms anhedral to subhedral crystals. Brown biotite is about as abundant as the augite and forms anhedral crystals closely associated with augite and magnetite. The few small quartz grains present are intersertal in position. Apatite forms many small prisms that are especially abundant in or near the crystals of biotite and augite and in the orthoclase. They are only here and there inclosed by plagioclase. Magnetite is present in anhedral grains, as a rule partly or wholly inclosed by augite or biotite, though in places inclosed by feldspar. The general order of crystallization appears to have been (1) apatite and magnetite, (2) plagioclase, augite, and biotite, essentially contemporaneous, and (3) orthoclase and quartz. The specimen shows practically no alteration by weathering.

[1] Jennings, E. P., A titaniferous iron-ore deposit in Boulder County, Colo.: Am. Inst. Min. Eng. Trans., vol. 44, pp. 14–25, 1913.

[2] Jour. Geology, vol. 14, pp. 692–707, 1906. See also Iddings, J. P., Igneous rocks, vol. 1, pp. 191–204, 1909.

Analyses of stock rocks from Caribou and vicinity.

[In the second column under each number are given the molecular proportions calculated from the percentage weights given in the first column.]

	1		2		3		4		5		6		7		8		9	
SiO_2	56.64	0.944	53.95	0.899	52.10	0.870	51.43	0.857	44.26	0.738	36.77	0.613	30.47	0.508	27.71	0.462	9.60	0.160
Al_2O_3	17.00	.167	18.56	.182	19.35	.189	19.35	.189	13.95	.137	10.29	.109	9.04	.089	2.92	.028	6.27	.062
Fe_2O_3	3.11	.019	3.86	.024	4.63	.029	5.32	.033	7.84	.049	10.54	.066	16.37	.103	21.80	.136	44.72	.279
FeO	5.06	.070	4.23	.058	4.16	.058	4.70	.065	8.87	.124	12.11	.168	14.91	.207	15.70	.218	25.31	.351
MgO	2.79	.070	2.35	.059	3.19	.080	3.05	.076	6.59	.165	9.34	.234	7.86	.197	17.98	.450	5.16	.129
CaO	6.20	.111	6.58	.118	7.15	.128	7.09	.127	10.41	.186	12.26	.219	9.33	.166	6.83	.121	3.75	.067
Na_2O	3.16	.051	3.36	.054	3.39	.055	3.54	.057	1.81	.029	1.16	.019	.77	.012	.19	.003	.15	.002
K_2O	3.40	.036	3.88	.041	3.77	.040	3.52	.037	1.75	.019	1.38	.015	2.89	.031	None.	None.	Trace.	Trace.
H_2O-	.31		.30		.06		.08		.33		.36		.32		.54			
H_2O+	.70		.68		.13		.35		1.54		1.70		1.32		3.51		.51	
TiO_2	.81	.010	.76	.010	.94	.012	.85	.010	1.41	.018	2.49	.031	2.52	.032	2.69	.034	4.48	.056
ZrO_2	None.		None.						None.									
CO_2	None.		.85						.33		.18		.21		.22			
P_2O_5	.44	.003	.60	.004	.71	.005	.60	.004	.85	.006	1.40	.010	2.87	.020	None.	None.	.08	.001
SO_3	None.		None.						None.									
Cl																		
F	None.		None.						None.									
S	.03		.06						.13		.33		.69		.04			
Cr_2O_3	None.		None.						None.									
NiO	None.		None.						None.		None.		None.		None.			
CaO											.03		.03		.05			
MnO	.20	.003	.17	.002	.10	.001	Trace.		.19	.003	.23	.003	.39	.006	.22	.003		
BaO	.06		.13						.03		.04		.09		Trace.			
SrO	Trace.		.07						.03		.02		.04		Trace.			
Li_2O																		
	99.91		100.39		99.68		99.88		100.32		100.63		100.12		100.40		100.03	
Specific gravity (powder)	2.837		2.783		Undet.		Undet.		3.074		3.288		3.374		3.564		Undet.	

1. Quartz monzonite (shoshonose), 1 mile south of Caribou. Grades into No. 5. Analysis by George Steiger.
2. Monzonite (shoshonose), half a mile south of Caribou. Analysis by George Steiger.
3. Monzonite (shoshonose), Caribou. Analysis by E. P. Jennings. Jennings (op. cit., p. 21) states, referring to rocks 3 and 4: "I would classify the rock as an orthoclase-biotite gabbro in preference to calling it a monzonite, on account of the predominance of the plagioclase."
4. Monzonite (shoshonose), Caribou. Analysis by E. P. Jennings.
5. Gabbro (delondose), 1 mile south of Caribou. A border differentiate from No. 1. Analysis by George Steiger.
6. Hornblendite (caribose), dump of Up to Date tunnel, 1 mile northwest of Caribou. Analysis by George Steiger.
7. Magnetite-rich gabbro (eldorose), dump of Caribou mine. Analysis by George Steiger.
8. Magnetite peridotite (cardinalose), half a mile south of Caribou. Analysis by George Steiger.
9. Iron ore (pomerose), Caribou. Analysis by E. P. Jennings (op. cit., p. 23).

The norm as calculated by H. S. Washington is as follows:

Quartz	7.62	Q= 7.62	Sal, 76.60
Orthoclase	20.02	F=68.98	
Albite	26.72		
Anorthite	22.24		
Diopside	4.80	P=15.25	Fem, 22.19
Hypersthene	10.45		
Magnetite	4.41	M=5.93	
Ilmenite	1.52		
Apatite	1.01	A=1.01	

$\frac{Sal}{Fem}=\frac{76.60}{22.19}$, Class II, dosalane.

$\frac{Q}{F}=\frac{7.62}{68.98}$, order 5, germanare.

$\frac{K_2O'+Na_2O'}{CaO'}=\frac{87}{80}$, rang 3, monzonase.

$\frac{K_2O'}{Na_2O'}=\frac{36}{51}$, subrang 3, shoshonose.

Formula, II.5.3.3.

Quartz monzonite from the Up to Date tunnel, typical of much of the rock of the Bald Mountain stock, northwest of Caribou, is identical in nearly every particular with that just described.

Another monzonite, collected half a mile south of Caribou, was also analyzed by Mr. Steiger (analysis 2, p. 43). Although it differs only slightly from the rock described above, mainly in being slightly coarser in grain, its petrographic description is inserted for the sake of completeness.

Monzonite (shoshonose; analysis 2, p. 43). In megascopic appearance this rock is dark gray, holocrystalline, and medium grained, most of the crystals ranging from 0.25 to 3 millimeters in diameter. The microscope shows the fabric to be seriate homeoid. The major constituents are orthoclase, plagioclase, augite, and biotite, and the minor constituents apatite, magnetite, and quartz. The feldspars are slightly more abundant than the ferromagnesian constituents. The orthoclase occurs in anhedral crystals and is nearly equal in abundance to plagioclase. The plagioclase, in subhedral crystals, is andesine-labradorite, about $Ab_{50}An_{50}$, showing very little zonal development. The augite is pale green and nonpleochroic and in a few places shows alteration to green pleochroic hornblende; the crystals are subhedral. The biotite is brown and forms anhedral crystals about equal to augite in abundance. The apatite forms short, small prisms and is associated mostly with the ferromagnesian minerals. The magnetite forms anhedral grains associated with the augite and biotite. Quartz is present as occasional minute grains. The general order of crystallization appears to have been (1) apatite and magnetite, (2) augite, biotite, and plagioclase, nearly contemporaneous, and (3) orthoclase and quartz. In the quantitative system this rock, like that above described, falls in shoshonose (II.5.3.3).

The two rocks described by Jennings[1] (analyses 3 and 4, p. 43) also fall in the subrang shoshonose [II.5.3.3″ and II.5.3.3(4)].

[1] Jennings, E. P., op. cit., p. 16.

Specimens showing interesting variations from the commoner type of monzonite were collected from the dump of the Caribou mine. One of these differed from the normal monzonite in being much coarser, crystals of orthoclase and aggregates of augite and biotite reaching 5 millimeters in diameter, and in showing a very great preponderance of orthoclase over plagioclase. Another specimen carries all the minerals of the normal monzonite except quartz, and in addition carries a few crystals of olivine associated with and in places inclosed by the augite and biotite. The olivine, which is somewhat serpentinized, was plainly one of the first minerals of the rock to crystallize. The feldspars predominate somewhat over the ferromagnesian minerals, so that the rock may properly be termed an olivine monzonite.

Olivine monzonite of finer grain was observed in place on the eastern border of the ore-bearing gabbro half a mile south of Caribou, where it appears to grade into gabbros of various types. Its petrographic features are briefly as follows:

Olivine monzonite. Greenish gray, holocrystalline, and medium grained. Most of the mineral grains are between 0.3 and 3 millimeters in diameter. The major constituents are plagioclase, orthoclase, augite, and biotite; the minor constituents apatite, magnetite, and olivine. The plagioclase is andesine close to $Ab_{60}An_{40}$ in composition; it forms euhedral to subhedral grains. The orthoclase is about equal to plagioclase in abundance. The augite is pale green, nonpleochroic, and in euhedral to subhedral grains. Biotite is abundant in anhedral grains. Apatite is present as small short prisms. Magnetite forms subhedral to anhedral grains and constitutes perhaps 5 per cent of the volume of the rock. Olivine, which is altered along cracks to iron oxide and serpentine, is present as scattered grains of irregular outline. The general order of crystallization was (1) apatite; (2) magnetite and olivine; (3) augite, biotite, and plagioclase. Feldspars and iron-bearing minerals are about equally abundant, and there is a marked tendency for the iron minerals and apatite to group themselves in irregular aggregates.

The presence of olivine in rocks so rich in orthoclase is noteworthy.

MAFIC (BASIC) TYPES.

The transition, as a result of magmatic differentiation, from monzonite into darker-colored rocks, to which the name monzonite can not be applied, was first studied at a locality 1 mile south of Caribou. There the main body of the intrusive is the quartz monzonite, already described (No. 1, p. 43). This rock grades at the border of the stock into a darker-colored rock, whose analysis is given in column 5 on page 43. The darker rock shows faint foliation parallel to its contact with the schists, probably the result of flowage during crystallization. Its petrographic description is as follows:

Gabbro (delondose; analysis 5, p. 43). In megascopic appearance the rock is dark gray and holocrystalline. Most of the mineral grains are between 0.25 and 3 millimeters in diameter. Microscopic study shows that the fabric is seriate homeoid. The major original constituents are plagioclase, augite, and biotite; the minor original constituents apatite, magnetite, pyrite, titanite, and quartz. Secondary minerals are hornblende, epidote, calcite, chlorite, and sericite. Feldspar constitutes about 35 to 45 per cent of the rock, and iron-bearing minerals make up the other 55 to 65 per cent. The plagioclase, which occurs in euhedral to subhedral crystals, commonly shows zonal structure and ranges from labradorite ($Ab_{40}An_{60}$) in the center of the crystals to andesine-labradorite ($Ab_{55}An_{45}$) at the borders. The augite is pale green and nonpleochroic and forms anhedral to subhedral grains. Most of the original augite has been altered to green, highly pleochroic hornblende, which in turn has altered in a few places to epidote. Brown biotite forms anhedral crystals, slightly altered to chlorite in places. Magnetite is abundant in anhedral grains associated with the ferromagnesian minerals. Apatite forms numerous short prisms associated principally with augite, hornblende, and biotite. Titanite and pyrite form small grains with the ferromagnesian minerals. Calcite and sericite are present in small amounts as alteration products of plagioclase. In general, magnetite, apatite, and titanite appear to have crystallized first, the other primary minerals forming a later and practically contemporaneous group.

The norm of this rock as computed by H. S. Washington is as follows:

Orthoclase	10.56	Sal, 50.50
Albite	15.20	
Anorthite	24.74	
Diopside	17.30	Fem, 47.70
Hypersthene	9.54	
Olivine	4.71	
Magnetite	11.39	
Ilmenite	2.74	
Apatite	2.02	

$\frac{Sal}{Fem}=\frac{50.50}{47.70}$, Class III, salfemane.

$\frac{Q \text{ or } L}{F}=\frac{0}{50.50}$, order 5, gallare.

$\frac{K_2O'+Na_2O'}{CaO'}=\frac{48}{89}$, rang (3) 4, auvergnase.

$\frac{K_2O'}{Na_2O'}=\frac{19}{29}$, subrang 3 (4), delondose (new name).

Formula, III.5.(3)4.3(4).

For this rock the writer proposes the name delondose, from Delonde Creek, about 1 mile northeast of Caribou.

In general the rock differs from the common type of quartz monzonite into which it grades (No. 1, p. 43) in being slightly coarser grained, in lacking orthoclase, and in containing a greater abundance of ferromagnesian silicates and magnetite and small amounts of titanite and pyrite. It also shows considerable alteration. The chemical differences are apparent from the table on page 43 and figure 3 (p. 49).

Rocks in which iron-bearing minerals were even more abundant than in the specimen just described were collected from the immediate vicinity of the iron-ore bodies at Caribou village and half a mile to the south. An especially instructive locality was the eastern margin of the ore body lying half a mile south of Caribou. At this place there appears to be a gradual passage from olivine monzonite into even-grained gabbro, then into gabbro with large hornblende crystals, and then into a rock whose most conspicuous mineral is biotite in plates as much as 15 centimeters in diameter. The gabbros are notably richer in magnetite than the olivine monzonite, and they appear in turn to grade into the iron ores. The petrographic character of the olivine monzonite, which forms the most silicic member of the series as there exposed, has already been described (p. 44). This monzonite appears to pass by gradual transition into a mottled gabbro, which differs from it in being of coarser grain, in lacking orthoclase and olivine, and in having slightly more calcium in the plagioclase ($Ab_{50}An_{50}$ instead of $Ab_{60}An_{40}$), but in which magnetite is not notably more abundant and, as in the olivine monzonite, feldspar and iron-bearing minerals are present in nearly equal amounts. This gabbro in turn appears to grade within a few feet into a hornblende gabbro characterized by single crystals of hornblende as much as 1 centimeter across or groups of such crystals as much as 3 centimeters across, lying in a fairly even grained groundmass. The texture of this rock is coarsely porphyroid. The microscopic features are as follows:

Hornblende gabbro. The groundmass shows as its most abundant constituents augite and sericite, and as minor constituents magnetite and apatite. The augite is pale green and nonpleochroic and shows some alteration to green hornblende. Sericite forms aggregates of small shreds covering considerable areas and is believed to be a product of feldspar alteration. Apatite is abundant in short prisms. Magnetite appears to constitute about 15 per cent of the rock. It is in places inclosed by augite but more commonly lies between the augite grains, conforming to their outlines. The phenocrysts are greenish-brown, slightly pleochroic hornblende without crystal outlines and inclosing numerous small crystals of augite, apatite, and magnetite and a few of plagioclase. The plagioclase is the only unaltered feldspar in the rock, its inclosure in large hornblende crystals having had a protective effect.

Noteworthy features of this rock are the coarsely porphyroid texture, the presence of primary hornblende to the complete exclusion of biotite, which is an abundant constituent of most of the associated rocks, and the large percentage of magnetite. Another rock that is closely associated with the porphyroid gabbro just described and apparently grades into the iron ore is nearly half brown biotite in plates reaching 2 centimeters in diameter. Fresh samples of this rock suitable for the preparation of thin sections could not be found.

Another type of differentiate from the Bald Mountain monzonite mass was collected from the dump of the Up to Date tunnel, 1 mile northwest of Caribou. It is a coarse hornblendite whose petrographic features are as follows:

Hornblendite (caribose; analysis 6, p. 43). Green hornblende in prismatic crystals as much as 1.5 centimeters in length is the principal component. The crystals are oriented in all directions. The hornblende appears to be original rather than an alteration product after pyroxene, but there may be some doubt on this point. The mineral is perfectly fresh in appearance. Plagioclase is present in small amounts and has the composition of labradorite near Ab_{40} An_{60}. The minor constituents are biotite, apatite, magnetite, and titanite. Magnetite forms anhedral crystals and constitutes perhaps 5 per cent of the volume of the rock; adjacent to it or intergrown with it are small amounts of pyrite, which appears to be original. Titanite is present in a few scattered grains. The general order of crystallization appears to have been (1) apatite, (2) titanite and magnetite, and (3) hornblende, biotite, and plagioclase.

The norm of this rock as calculated by H. S. Washington is as follows:

Orthoclase	8.34	F=31.02	Sal, 35.33
Albite	1.83		
Anorthite	20.85		
Nephelite	4.31	L= 4.31	
Diopside	24.74	P+O=40.04	Fem, 63.42
Olivine	15.30		
Magnetite	15.31	M=20.02	
Ilmenite	4.71		
Apatite	3.36	A= 3.36	

$\frac{\text{Sal}}{\text{Fem}}=\frac{35.33}{63.42}$, Class (III)IV, dofemane.

$\frac{\text{P+O}}{\text{M}}=\frac{40.04}{20.02}$, order 2(3), scotare.

$\frac{\text{P}}{\text{O}}=\frac{24.74}{15.30}$, section (2)3, texiare.

$\frac{\text{MgO+FeO}}{\text{CaO}''}=\frac{405}{144}$, rang 2, uvaldase.

$\frac{\text{MgO}}{\text{FeO}}=\frac{234}{168}$, subrang ″3, caribose (new name).

Formula (III)IV.2(3).(2)3.2.″3.

For this rock the name caribose is proposed, after the town of Caribou.

Highly hornblendic phases like the rock above described grade into phases rich in biotite. The contacts between these hornblende and biotite rocks and the monzonites are in some places sharp and in others gradational. Specimens on the dump showed sharply angular fragments of hornblendite in the monzonite.

ULTRAMAFIC MAGNETITE-RICH TYPES.

Rocks which are richer in magnetite than those thus far described and some of which may properly be termed iron ores are irregularly distributed within the gabbro masses. One of these rocks collected on the dump of the Caribou mine is described below.

Magnetite-rich gabbro (eldorose; analysis 7, p. 43). This rock is dark green to nearly black and millimeter-grained. The microscope shows the fabric to be seriate porphyroid, crystals of augite as much as 7 millimeters across, with a few of plagioclase of corresponding size, lying in a fine-grained groundmass of other minerals. The constituents are augite, plagioclase, biotite, magnetite, and apatite, and all are sufficiently abundant to be designated as major rather than minor. The augite is in pale-green, nonpleochroic grains which show extinction angles as great as 45°; it incloses some crystals of magnetite and biotite and a very few of apatite. The plagioclase forms euhedral to subhedral grains corresponding in size to those of augite. It shows pronounced zonal structure, but its exact position in the plagioclase series was not determinable in the section studied. It incloses small crystals of augite, biotite, and magnetite. The remaining constituents (biotite, magnetite, and apatite) are in smaller crystals which, except where they occur as inclusions, as noted above, form a matrix for the augite and plagioclase. The rock shows twice as much apatite in the norm as No. 6 in the table on page 43 and more than three times as much as No. 5. Magnetite is notably more abundant than in any of the other rocks thus far described.

The norm of this rock as computed by H. S. Washington is as follows:

Orthoclase	13.62	F=26.41	Sal, 32.65
Anorthite	12.79		
Leucite	2.83	L= 6.24	
Nephelite	3.41		
Diopside	11.99	P+O=29.69	Fem, 65.17
Olivine	17.70		
Magnetite	23.90	M=28.76	
Ilmenite	4.86		
Apatite	6.72	A= 6.72	

$\frac{\text{Sal}}{\text{Fem}}=\frac{32.65}{65.17}$, Class ″IV, dofemane.

$\frac{\text{P+O}}{\text{M}}=\frac{29.69}{28.76}$, order 3, sverigare.

$\frac{\text{P}}{\text{O}}=\frac{11.99}{17.70}$, section 3(4), uteiare (new name).

$\frac{\text{MgO+FeO}}{\text{CaO}''}=\frac{404}{130}$, rang 2, eldorase (new name).

$\frac{\text{MgO}}{\text{FeO}}=\frac{197}{207}$, subrang 3, eldorose (new name).

Formula, ″IV.3.3(4).2.3.

For the section to which this rock belongs the writer proposes the name uteiare, from Ute Mountain, about 3 miles south of Eldora, and for the rang and subrang the names eldorase and eldorose, respectively, from the town of Eldora, 2½ miles south of Caribou.

Rocks still richer in magnetite belong to two distinct types, one composed essentially of magnetite, olivine, and augite and the other of magnetite and augite. Both occur within the same ore body, but their relation to each other could not be determined in the field because of the close similarity in megascopic appearance of the two types.

The magnetite-olivine type is represented by a specimen collected half a mile south of Caribou; its petrographic description is as follows:

Magnetite peridotite (cardinalose; analysis 8, p. 43). This is a dark-gray rock, semimetallic in appearance from the abundance of magnetite, which stands out prominently in relief on weathered faces. The microscope shows augite, olivine (mainly altered to serpentine), and magnetite as the principal constituents. The augite, pale green and nonpleochroic, forms euhedral to subhedral grains from 0. 3 to 3 millimeters in diameter. It shows incipient alteration to hornblende. Olivine is about equal to augite in abundance and forms subhedral grains from 0.3 to 1.0 millimeter in diameter. It is now mainly altered to serpentine, which accounts for the high percentage of combined water in the analysis. Some magnetite grains are inclosed by olivine or by augite, but most of the magnetite forms a matrix between the olivine and augite grains. With the exception of the magnetite inclusions the order of crystallization was (1) olivine, (2) augite, (3) magnetite.

The norm of this rock as calculated by H. S. Washington is as follows:

Albite	1. 57	F= 8. 52	Sal, 8. 52
Anorthite	6. 95		
Diopside	21. 03	P+O=50. 72	Fem, 87. 44
Olivine	29. 69		
Magnetite	31. 55	M=36. 72	
Ilmenite	5. 17		

$\frac{\text{Sal}}{\text{Fem}}=\frac{8.52}{87.44}$, Class V'', perfemane.

$\frac{\text{P+O}}{\text{M}}=\frac{50.72}{36.72}$, order ''3, rhodare.

$\frac{\text{P}}{\text{O}}=\frac{21.03}{29.69}$, section 3'', bouldiare (new name).

$\frac{\text{MgO+FeO}}{\text{CaO}''}=\frac{668}{96}$, rang (1)2, cardinalase (new name).

$\frac{\text{MgO}}{\text{FeO}}=\frac{450}{218}$, subrang 2'', cardinalose (new name).

Formula, V''.''3.3''.(1)2.2''.

For the section to which this rock belongs the name "bouldiare" is proposed, from Boulder County; for the rang and subrang the names "cardinalase" and "cardinalose," respectively, are proposed, from Cardinal station, 2 miles southeast of Caribou.

The second type of iron ore is exemplified by a specimen from the body of ore half a mile south of Caribou, described below.

Magnetite pyroxenite.—This rock is similar in megascopic appearance to the magnetite peridotite of analysis 8 (p. 43). The microscope shows that its principal constituent is augite (extinction angles as great as 45°) in euhedral to subhedral grains showing some alteration to hornblende. The remainder of the rock is magnetite, mainly intersertal between the augite grains, though a few small grains are inclosed by augite. Apatite is absent.

Another magnetite pyroxenite from the body of iron ore just northwest of Caribou is identical with this one in every respect except that it contains a fair abundance of apatite.

No analyses were made of the magnetite pyroxenite collected by the writer, but Jennings [1] has published an analysis of ore of this type which is given as No. 9 in the table on page 43. The minerals present he determined by microscopic study to be the following, the percentages being calculated from the analysis:

Ilmenite	8. 50
Magnetite	67. 25
Apatite	. 18
Spinel	6. 70
Diopside [2]	16. 89

From Jennings's analysis the writer has calculated the norm of this rock as follows:

Anorthite	16. 65	F=16. 65	Sal, 17.25
Nephelite	. 57	L= . 57	
Åkermanite	. 29	O= 5. 17	Fem, 82.17
Olivine	4. 88		
Magnetite	64. 73	M=76. 66	
Ilmenite	8. 51		
(Mg, Fe)O	3. 42		
Apatite	. 34	A= . 34	

$\frac{\text{Sal}}{\text{Fem}}=\frac{17.25}{82.17}$, Class IV, dofemane.

$\frac{\text{O}}{\text{M}}=\frac{5.17}{76.66}$, order ''5, cordillare (new name).

$\frac{\text{H}}{\text{T}}=\frac{68.15}{8.51}$, section 1(2), cordilliare (new name).

$\frac{\text{MgO+FeO}}{\text{CaO}''}=\frac{480}{7}$, rang 1, pomerase (new name).

$\frac{\text{MgO}}{\text{FeO}}=\frac{129}{351}$, subrang 4, pomerose (new name).

Formula, IV.''5.1(2).1.4.

For the order and section to which this rock belongs the writer proposes the names cordillare and cordilliare, respectively, from the Cordillera, or great mountain system of this

[1] Jennings, E. P., op. cit., p. 23.
[2] Augite according to Bastin's studies.

region. For the rang and subrang the names "pomerase" and "pomerose" are proposed, from Pomeroy Mountain, just north of Caribou.

NATURE OF THE DIFFERENTIATION.

It has been well established, principally through the researches of Vogt[1] and of Kemp,[2] that the titaniferous iron ores are almost exclusively products of magmatic differentiation. It has further been shown by Vogt[1] that in most of the 500 or so known occurrences of titaniferous iron ores the parent rock was a gabbro or norite or rarely an augite or nephelite syenite. The amount of silica in the parent rock is generally between 48 and 54 per cent, more rarely between 54 and 56 per cent. Vogt[3] believes that in the somewhat metamorphosed deposits of the Rödsand-Erzfeldes in Norway he can trace the process of magmatic differentiation from a granitic parent magma into a gabbroid magma and finally into the iron ores. The Caribou deposits show a somewhat analogous mode of occurrence, in which a parent magma of monzonitic character (51.43 to 56.64 per cent SiO_2 and 0.76 to 0.94 per cent TiO_2) has differentiated into gabbroid rocks (30.47 to 44.66 per cent SiO_2 and 1.41 to 2.56 per cent TiO_2), and these into the iron ores. In the majority of described occurrences of such ores the TiO_2 content of the parent rock is from 0.3 to 1.0 per cent, but that of the derived iron ore does not generally fall below 4 or 5 per cent and in many deposits exceeds 15 per cent.

FIGURE 2.—Titaniferous iron ore from Caribou (after E. P. Jennings). Dark areas are magnetite and ilmenite; light areas are augite.

In the Caribou ores evidences of origin by magmatic differentiation are found (1) in the general form and situation of the bodies of gabbro and iron ore which are irregular bodies lying wholly within the monzonite stocks; (2) in observed transitions from iron ore to gabbro and from gabbro to monzonite, an evidence whose validity is not annulled by the presence in a few places of sharp contacts between these different rock types; (3) in the consistent character of the variations in chemical composition, as shown in the diagram on the opposite page; (4) in the mineralogic gradation traceable from one rock type to another, notable features being the marked uniformity in the optical characters of the augite in all the rocks and the presence of olivine not only in certain iron ores but in certain of the gabbros and monzonites as well.

Jennings[4] regarded the iron ores as differentiations at depth from the monzonite magma (which he termed orthoclase-biotite gabbro), the differentiation products having later been intruded into their present position. The writer's observations indicate that they are in part differentiations in place.

A feature of especial interest in this deposit is the dual character of the differentiation, which produced within the same gabbro body masses of iron ore consisting solely of magnetite, ilmenite, and augite (fig. 2), and others carrying abundant olivine. This feature is shown in the diagram forming figure 3. The tendency for differentiation to proceed along two lines, one of which leads to rocks very rich in magnesia, is apparent even in the more felsic rocks of the Caribou district, for some of the monzonites are olivine-bearing; strictly, therefore, the broken lines in figure 3 should probably extend farther to the left. The process appears to be somewhat unusual or at least has not hitherto been described. Vogt[5] noted in certain Norwegian deposits two correlative lines of differentiation, but they led not to two

[1] Beyschlag, F., Krusch, P., and Vogt, J. H. L., Die Lagerstätten der nutzbaren Mineralien und Gesteine, vol. 1, pp. 247-253, 1910. Also Vogt, J. H. L., Zeitschr. prakt. Geologie, vol. 8, pp. 233-235, 1900.

[2] Kemp, J. F., A brief review of the titaniferous magnetites: Columbia School of Mines Quart., vol. 20, pp. 323-356; vol. 21, pp. 56-65, 1899.

[3] Vogt, J. H. L., Zeitschr. prakt. Geologie, vol. 18, p. 65, 1910.

[4] Jennings, E. P., op. cit., pp. 24-25

[5] Vogt, J. H. L., Zeitschr. prakt. Geologie, vol. 8, pp. 234-235, 1900.

types of iron ore but to spinel-bearing iron ores along one line and to olivine gabbros and peridotites very poor in iron oxides along the other line.

Minor chemical features worthy of mention are the small percentage of sulphur, increasing slightly toward the iron-ore end of the series, the presence of small amounts of cobalt but no nickel in some of the rocks, and the absence of chromium in all that were tested for this metal.

Specimens of lean iron ore from Caribou are shown in Plate XI, *B* and *C*.

DIKE ROCKS NEAR NEDERLAND.

The area between Caribou, Nederland, and Phoenix contains a profusion of dikes of prevailing easterly trend, of types not found elsewhere in the region. They include hornblende monzonite porphyries, hornblende and biotite andesites, and hornblende and biotite diorites, many of the latter being very dark colored. The distribution of the different types is shown on Plate I (in pocket). These various dikes are not wholly contemporaneous, for at a number of places diorite dikes were observed to cut those of andesite. Nevertheless, it seems probable that the age differences are not very great and that the dikes of all the types were differentiated from a common parent magma of monzonitic composition, as explained on page 38. These dikes appear to take the place in the Nederland area of the monzonite dikes so common in other parts of the region.

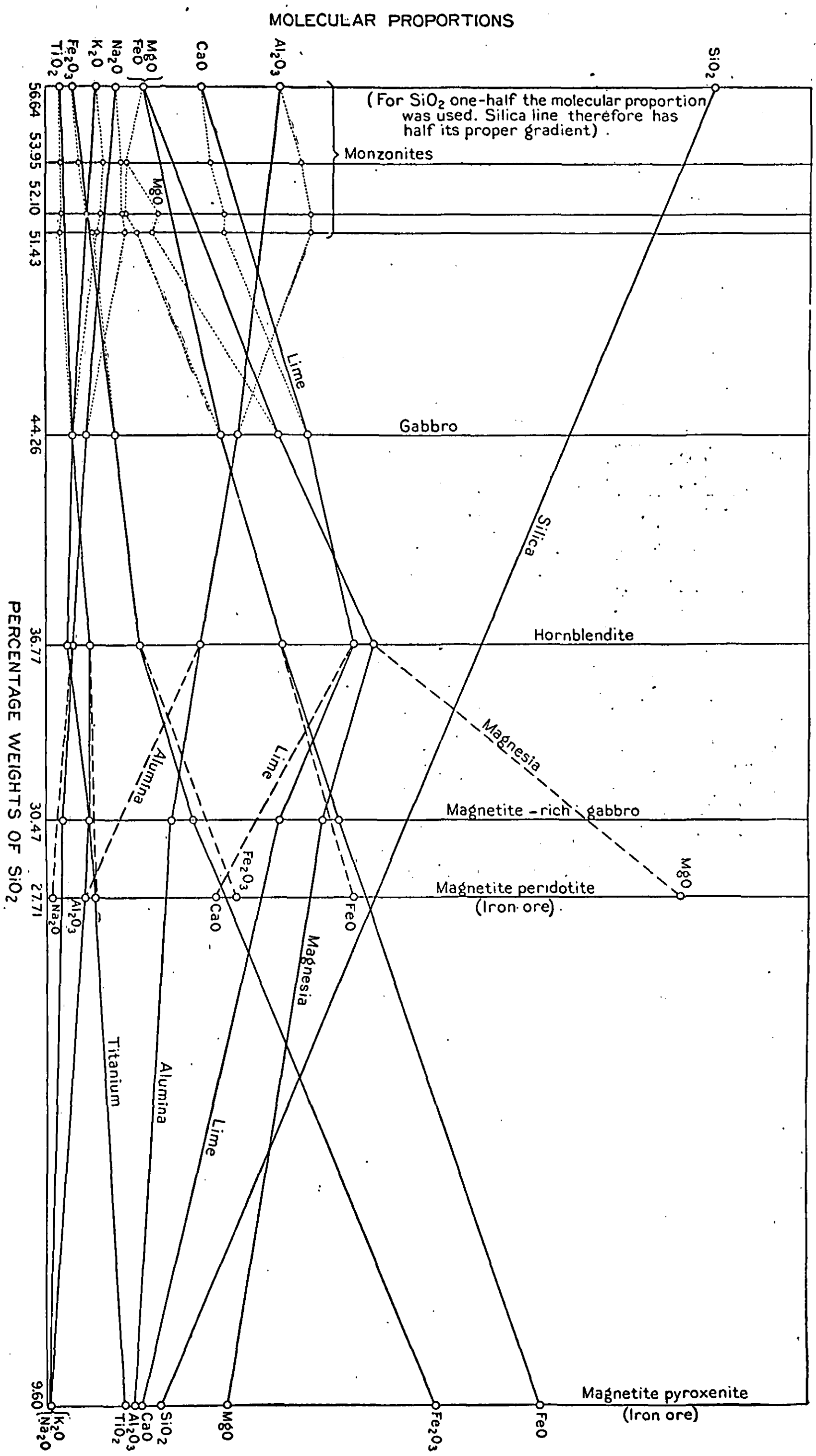


FIGURE 3.—Diagram illustrating the chemical relations of stock rocks near Caribou.

HORNBLENDE MONZONITE PORPHYRY.

General character.—The distinguishing characteristic of the hornblende monzonite porphyry is the great abundance of green hornblende phenocrysts, which in places attain a length of 12 millimeters, though commonly under 7 millimeters. In fresh specimens these dark-green hornblendes lie in a fine-grained (aphanitic) groundmass which is dark-greenish gray, so that they are not conspicuous; in somewhat weathered specimens, on the other hand, the groundmass weathers lighter gray and the hornblende phenocrysts, remaining dark, become very conspicuous. Feldspar phenocrysts are practically absent.

Distribution.—About ten dikes of hornblende monzonite porphyry were observed, all in the northeastern part of the region, between Eldora, Caribou, Nederland, and Rollinsville. Their precise position is shown on Plate I.

Features in detail.—One of the freshest specimens of this rock came from the slope of Eldorado Mountain, about three-fourths of a mile east of Eldora, and may be regarded as typical for most of these dikes. It shows a greenish-gray aphanitic groundmass in which lie abundant prisms of nearly black hornblende, a few of them 12 millimeters in length. No feldspar phenocrysts were certainly recognized. Under the microscope the phenocrysts of green pleochroic hornblende show partial alteration to chlorite and calcite. The groundmass consists mainly of minute feldspar laths, many of which are plainly lower than balsam in index of refraction and do not show polysynthetic twinning; they are probably orthoclase. Other feldspars of the groundmass are above balsam in index of refraction, show polysynthetic twinning, and are evidently plagioclase. Small grains of magnetite which are very abundant in the groundmass probably cause its dark color. Secondary calcite is also abundant in the groundmass, usually in small grains but locally in irregular masses 1 to 2 millimeters across. A little quartz associated with the calcite is probably also secondary. There are a few small apatite prisms.

A phase of the hornblende monzonite porphyry which differs from the common type in carrying fairly numerous phenocrysts of feldspar crops out along the small valley between Hicks Gulch and Coon Trail Creek. It is dark gray on fresh exposures and shows abundant phenocrysts of hornblende and less abundant phenocrysts of feldspar as much as 5 millimeters across. The feldspar phenocrysts are plagioclase, apparently andesine. The hornblende phenocrysts show little alteration, but have much less perfect crystal outlines than in most of the hornblende monzonite porphyries. The groundmass appears gray and aphanitic in the hand specimen but under the microscope is seen to be coarser than in most of the rocks of this group; it is composed of laths of plagioclase having a greater index than balsam, orthoclase, and abundant biotite. Secondary carbonate is also abundant in the groundmass. The rock may be termed a hornblende-biotite monzonite porphyry.

Age and relations.—The hornblende monzonite porphyries have not been observed to intersect any other rocks among the later intrusives of the region. One dike southeast of Caribou has been traced continuously into the Caribou stock of monzonite; for this reason and from the more general considerations outlined on page 38, these rocks are believed to be contemporaneous with the neighboring monzonite stocks and therefore probably of Tertiary age.

HORNBLENDE AND BIOTITE ANDESITE.

General character.—The hornblende and biotite andesites are medium-coarse rocks that are dark gray when fresh and buff or nearly white on weathering. Many variations were noted, from rocks so crowded with phenocrysts that they are almost granitic in appearance through others with only scattered phenocrysts into felsitic phases which can be identified as belonging to this rock type only because gradation has been traced in a few places. The constituent original minerals are plagioclase, either hornblende or biotite, or both, and small amounts of magnetite and apatite. Every gradation is traceable from phases in which hornblende is the predominant iron-bearing mineral into phases in which biotite is predominant.

These rocks occur exclusively as dikes, the greater number of which are too much weathered at their outcrops to yield good material for microscopic study.

Distribution.—The andesite dikes are confined to the area near Nederland, Caribou, and Eldora, where they are much more numerous than the dikes of hornblende monzonite porphyry. Their general trend is nearly due east.

Features in detail.—Most of the andesites are typically porphyritic, the phenocrysts being feldspar and either hornblende or biotite or both. The feldspar phenocrysts, so far as could be determined, are all plagioclase and are usually under 3 millimeters in diameter though locally reaching 6 millimeters. Usually their exact character is masked by alteration products, but in two slides their composition was determined as $Ab_{65}An_{35}$ (andesine). The hornblende phenocrysts are rarely fresh, some of them being altered to biotite and others to an association of epidote, calcite, and chlorite. Though usually much smaller, some in a dike near the Jasper mine, in Hicks Gulch, were 2 centimeters long and 5 or 6 millimeters in diameter. Some of the biotite phenocrysts are fresh, but many are altered to a mixture of muscovite, biotite, and iron oxide. They range from 1 to 3 millimeters in diameter. The groundmass is finely microgranular and consists of an aggregate of altered feldspar of indeterminate species, locally with some hornblende and secondary sericite and calcite. Magnetite is abundant in small grains and apatite in small short prisms.

One of the freshest specimens collected was obtained from a dike about half a mile northeast of Eldora and shows both hornblende and biotite. Megascopically this rock is gray in general tone and shows light-gray stubby prisms of feldspar averaging 2 to 3 millimeters in length, a few phenocrysts of biotite as much as 2 millimeters across, and lath-shaped phenocrysts of what appears to be altered hornblende reaching 4 millimeters in length. The phenocrysts are so closely crowded that the groundmass is very inconspicuous. The microscope shows that the feldspar phenocrysts are plagioclase of the average composition $Ab_{65}An_{35}$ (andesine), though they show some zonal structure. They are partly altered, sericite and calcite having been developed. The phenocrysts of biotite are practically unaltered. Some aggregates of small plates of biotite and grains of calcite in the groundmass are irregular in outline, but others have the prismatic form and six-sided cross section characteristic of hornblende. It is probable that they represent the alteration products of this mineral. The groundmass is a microgranular aggregate of unstriated feldspar, probably orthoclase, a little quartz, and secondary calcite and sericite. Grains that were originally magnetite are now largely altered to hematite.

Age and relations.—At several places the andesites were observed to be cut by dikes of diorite, as described on page 52, but no exposures showing their relations to the later intrusive rocks of other types were noted. For the reasons already outlined on page 38 the andesites are believed to have been derived by processes of magmatic differentiation from the monzonite magmas of this region and, like the monzonites, to be of Tertiary age.

HORNBLENDE AND BIOTITE DIORITES.

General character.—The hornblende and biotite diorites, which are dark gray to nearly black on fresh surfaces, have as principal constituents plagioclase, hornblende, biotite, magnetite, and their alteration products. Some varieties are porphyritic and others massive. In the porphyritic varieties the prominent phenocrysts may be feldspar, biotite, or rarely hornblende. Orthoclase was not observed, and the plagioclase is in general more calcic than in the andesites. The iron-bearing minerals are more abundant than in the andesites, and the rocks are correspondingly darker in color. They occur exclusively as dikes.

Distribution.—The diorite dikes are confined to the region north of Nederland and between that town and Caribou. Two dikes recognized on the surface are shown on Plate I, and a number of others are cut in the Boulder County and Alton tunnels.

Features in detail.—A diorite porphyry having conspicuous phenocrysts of feldspar crops out about 1¾ miles northwest of Nederland, along the northern road leading to the Boulder County mine. Greenish-gray feldspar phenocrysts from 2 to 3 millimeters across are scattered in moderate abundance through a nearly black aphanitic groundmass. Under the microscope the feldspar phenocrysts were determined to have a composition about $Ab_{25}An_{75}$ (bytownite). No quartz or orthoclase was recognized. The groundmass shows laths of plagioclase (well above balsam in index of refraction) disposed in all directions, very abundant biotite and magnetite, and much secondary calcite and chlorite.

A representative of the varieties in which biotite is the most conspicuous mineral in the hand specimen is exposed in the Boulder County tunnel about 725 feet from the portal. This rock is nearly black on fresh surfaces and shows a profusion of crystals of various sizes, the largest 6 millimeters across. The texture is porphyroid rather than porphyritic, as there is every gradation from the large biotite crystals to those that are very minute. The microscope shows that biotite is the most abundant constituent. The other minerals are plagioclase feldspar (well above balsam in index), magnetite in small grains, and abundant secondary calcite. The rock contains a little quartz, which is probably secondary.

The freshest specimen of the highly hornblendic type of the diorite came from a 6-inch to 1-foot dike in the Boulder County tunnel. This dike is cut by the Boulder County vein about 200 feet east of the line of the tunnel. It is a very dark gray aphanitic rock which under the microscope shows green hornblende as its principal constituent. This mineral forms laths of diverse size and orientation, the spaces between which are occupied by plagioclase feldspar of a high index of refraction and by abundant grains of magnetite. Small, stubby phenocrysts of plagioclase occur sparingly, but they are partly sericitized and their exact composition can not be determined. The metasomatic alterations which have affected this rock close to the vein are described on page 111.

Age and relations.—The highly micaceous varieties of the diorites, like that last described, are shown at several points in the Boulder County tunnel to be later than hornblende-biotite andesite dikes. Where dikes of these two types intersect the andesites show no change in texture near the contact, whereas the diorites become finer grained and nonporphyritic within one-fourth or one-half inch of the "frozen" contacts. The diorites are, however, older than the Boulder County vein, which distinctly cuts them, in places with "frozen" contacts. Like the other younger intrusive rocks, the diorites and diorite porphyries are believed to be of Tertiary age. The grounds for this belief have already been stated (p. 38).

BOSTONITE AND BOSTONITE PORPHYRY.

GENERAL CHARACTER.

The bostonites of the Central City quadrangle are gray to lilac-colored or reddish-brown, very fine grained (microcrystalline) rocks composed predominantly of alkali feldspar with only small amounts of quartz. Varieties having phenocrysts of alkali or alkali-calcic feldspar or of pyroxene, or both, are termed bostonite porphyry.

DISTRIBUTION.

These rocks occur mainly as dikes, which exceptionally expand into lens-shaped masses an eighth of a mile or so across. Some of the dikes are of extraordinary lengths, one being traceable continuously from the Topeka mine, near Russell Gulch, northwestward for 4½ miles. The distribution of the bostonite dikes between the camps of Russell Gulch and Nevadaville is noteworthy, for they radiate from a center near the Topeka mine in much the fashion that nerves radiate from a ganglion. Expansions of the dikes into narrow stocks occur 1 mile southeast of Dumont and 1½ miles north of Lawson.

The bostonite and bostonite porphyries are confined mainly to those parts of the surveyed area lying southeast of Mammoth Gulch and east of Empire.

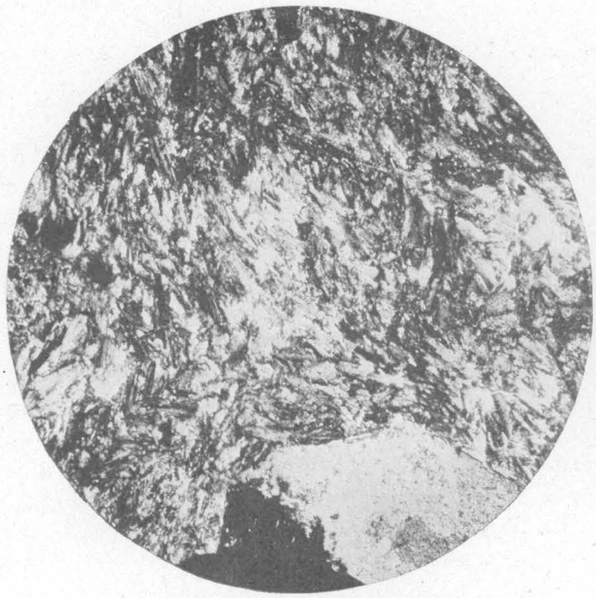
Ball[1] describes bostonites occurring in the northern part of the adjacent Georgetown quadrangle; there also they attain greater lengths than the Tertiary (?) dikes of any other type.

FEATURES IN DETAIL.

Though not always distinguishable from certain monzonite porphyries without microscopic study, most of the bostonite porphyries may be readily recognized because of their pinkish, lilac-colored, or reddish-brown body or groundmass through which are scattered pearl-gray or salmon-colored phenocrysts of feldspar, commonly under 5 millimeters in length, though a few are as long as 1 or even 2 centimeters. Some varieties contain green prisms of pyroxene or its alteration products as much as 5 millimeters in length. Ball noted some 2.5 millimeters long in dikes in the Georgetown quadrangle. Penetration twins in which the individuals join each other at angles of 60° are not uncommon.

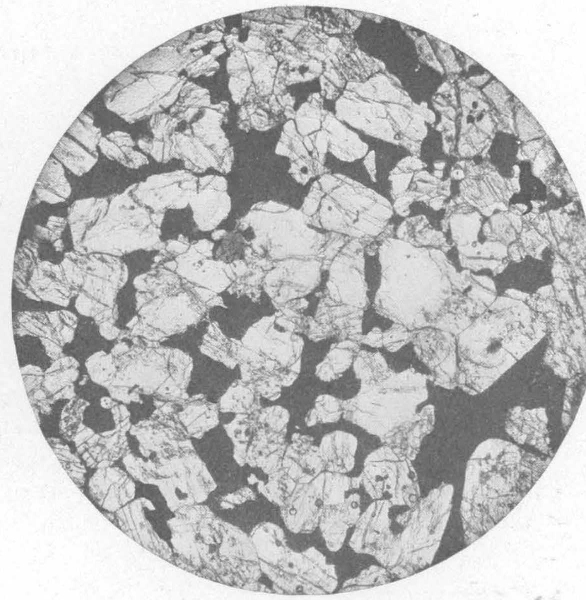
The nonpyroxenic bostonite porphyries are not readily differentiated without the aid of the microscope from certain monzonite porphyries of the region between Apex, Perigo, and Phoenix, which have a pinkish groundmass, but microscopic examination of the monzonites shows that the groundmass is granular rather than trachytic, as in the bostonites. In most of the bostonite porphyries the phenocrysts are widely scattered, and many of them

[1] Ball, S. H., op. cit., p. 78.



A. BOSTONITE PORPHYRY FROM A POINT NEAR IDAHO SPRINGS, SHOWING CHARACTERISTIC TRACHYTOID TEXTURE.

In certain areas of rounded outline quartz poikilitically embeds the feldspars. Enlarged.

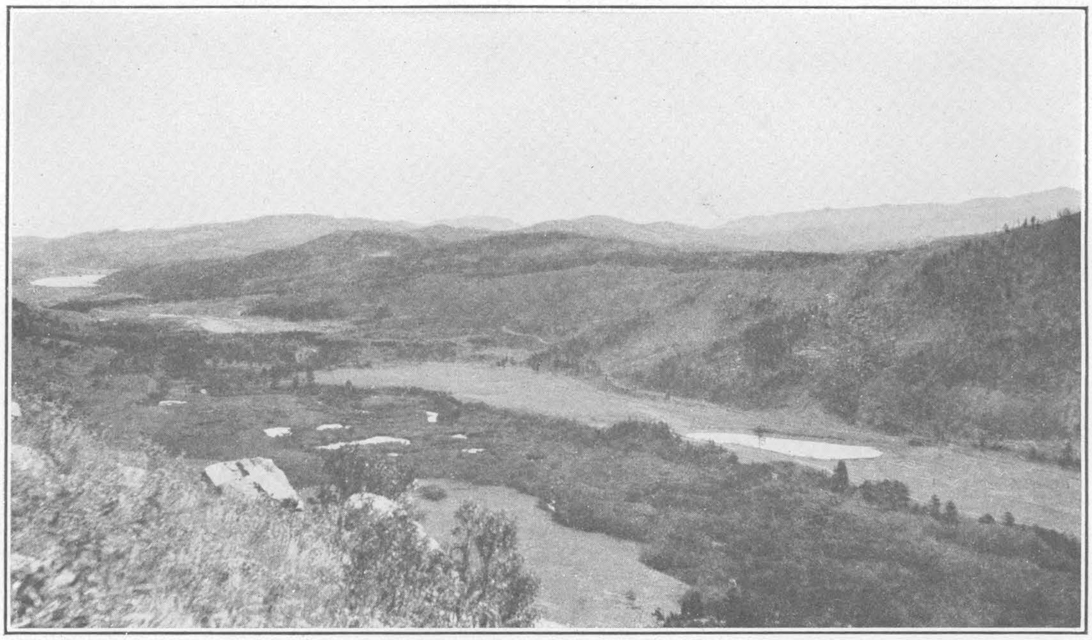


B. LEAN IRON ORE FROM CARIBOU, SHOWING MAGNETITE AND ILMENITE AND AUGITE.

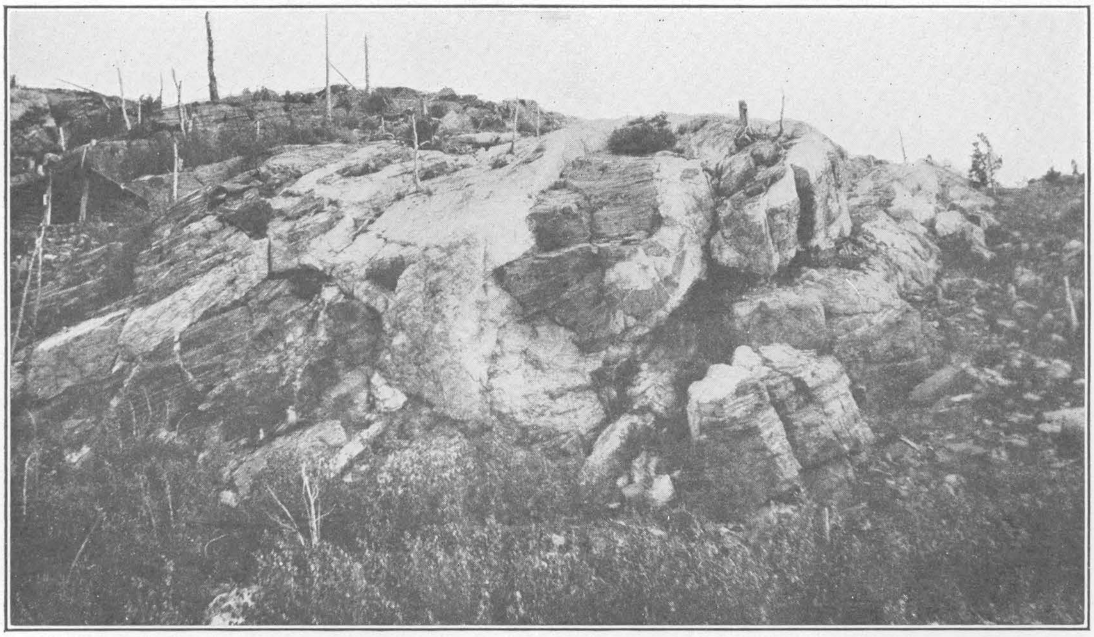
Black areas are magnetite and ilmenite; gray areas are augite. Enlarged 16 diameters.

C. LEAN IRON ORE FROM CARIBOU, SHOWING MAGNETITE AND ILMENITE, AUGITE, AND SERPENTINE.

Black areas are magnetite and ilmenite, white areas are serpentine formed by the alteration of olivine; some unaltered olivine remains and is gray. Enlarged 29 diameters.



A. OUTWASH PLAIN OF LATER GLACIAL EPOCH IN VALLEY OF MIDDLE BOULDER CREEK BETWEEN ELDORA AND NEDERLAND, LOOKING EASTWARD.



B. HORNBLENDE SCHIST OF IDAHO SPRINGS FORMATION INTRUDED BY PEGMATITE NEAR ELDORA.

show rhombic outlines. The nonporphyritic bostonites when fresh are usually recognizable by their lilac or reddish-brown color, but where altered by surface weathering or by mineralizing solutions they are usually bleached buff and can not then be distinguished without microscopic examination from fine-grained monzonites.

Under the microscope the bostonites and the groundmass of the bostonite porphyries exhibit a characteristic trachytic or trachytoid texture not observed in any of the monzonites. (See Pl. XI, *A*.) This texture is produced by thin tabular crystals of feldspar 0.05 to 0.5 millimeter in length, which in some places are oriented in all directions but elsewhere are in subparallel arrangement indicative of flowing movement during cooling. These crystals are soda-potash feldspar (anorthoclase) and between them are irregular grains of orthoclase. Quartz is present in the groundmass of some specimens and partly or wholly embeds a number of anorthoclase crystals. The feldspar phenocrysts may all be anorthoclase, or some may be anorthoclase and some orthoclase or oligoclase. Phenocrysts of salmon-colored feldspar from one of the freshest specimens were crushed and examined microscopically. The index of refraction determined by the immersion method lay between 1.52 and 1.53. The angle determined on cleavage plates parallel to 010 between the plane of the optic axes and the cleavage 001 ranged from 4° to 9°. These properties positively identify the feldspar as anorthoclase. Scattered prismatic phenocrysts, usually under 5 millimeters in length, are green pyroxene or its alteration products (hornblende or chlorite with calcite and magnetite).

By sericitization, through the influence of mineralizing solutions, bostonite becomes greenish white; through calcitization and kaolinization it bleaches; and through hydration of its iron-bearing minerals it takes on various shades of yellow and brownish red.

An analysis of bostonite from the Red Lyon lode, near Idaho Springs, is given by Spurr and Garrey,[1] but the position of the rock in the American quantitative system was not calculated by them. The analysis is repeated below, and from it the norm has been calculated.

[1] U. S. Geol. Survey Prof. Paper 14, p. 149, 1903.

Analysis of bostonite from Red Lyon lode, Idaho Springs district, Colo.

[W. T. Schaller, analyst.]

SiO_2	67.41	CO_2	0.56
Al_2O_3	16.23	P_2O_5	.05
Fe_2O_3	.85	SO_3	None.
FeO	1.14	Cl	None.
MgO	.15	S	Trace.
CaO	.14	MnO	.16
Na_2O	3.95	BaO	Trace.
K_2O	7.19	SrO	None.
H_2O-	.67	Li_2O	None.
H_2O+	.88		
TiO_2	.16		99.65
ZrO_2	.11		

Norm of bostonite from Red Lyon lode.

Quartz	15.42	Q=15.42	Sal, 94.31
Zircon	.18	Z= .18	
Corundum	1.53	C= 1.53	
Orthoclase	42.81	F=77.18	
Albite	33.54		
Anorthite	.83		
Ilmenite	.30	M= 1.46	Fem, 3.18
Magnetite	1.16		
Hypersthene:			
Iron metasilicate	1.32	P= 1.72	
Magnesium silicate	.40		
H_2O, CO_2, and P_2O_5 not included in norm			2.16
			99.65

$\frac{Sal}{Fem}=\frac{94.31}{3.18}$, Class I, persalane.

$\frac{Q+F}{CZ}=\frac{92.60}{1.71}$, Subclass I, persalone.

$\frac{Q}{F}=\frac{15.42}{77.18}$, order 4′, brittanare.

$\frac{K_2O'+Na_2O'}{CaO'}=\frac{141}{3}$, rang 1, liparase.

$\frac{K_2O'}{Na_2O'}=\frac{77}{64}$, subrang 3, liparose.

Formula, $I._I.4'.1.3$.

ORIGIN AND RELATION TO OTHER ROCKS.

The bostonites and bostonite porphyries are intrusive in all the pre-Cambrian rocks of the quadrangle. For the reasons given on page 38 it is thought probable that they came from the same magmatic source as the monzonites and monzonite porphyries and, like them, are of Tertiary age.

Mesozoic rocks which, like the bostonite analyzed, fall in the subrang liparose of the quantitative system occur in the Leadville and Silver Cliff districts and at Nathrop and have been described by Cross, and similar rocks were collected by E. B. Mathews in the Pikes Peak region.[2] Although no genetic connection can be assumed between these

[2] U. S. Geol. Survey Prof. Paper 63, p. 134, 1908.

occurrences of liparose, magmas of liparose composition were evidently not uncommon among the Mesozoic intrusives and effusives of Colorado.

BASALT PORPHYRY.

A single dike of typical basalt porphyry 4 feet in width was cut in the Freeland tunnel, near Dumont, at a distance of about 3,185 feet from the portal. It is unlike any dike found elsewhere in the quadrangle. The rock is nearly black, fine grained, and blotched with a few round areas of calcite that give it an amygdaloidal appearance. It is made up of augite, biotite, calcic plagioclase, magnetite, and secondary calcite and serpentine. The phenocrysts are pseudomorphs of calcite and serpentine after olivine, the characteristic structure and crystal outline of which are preserved. The groundmass is a very finely crystalline aggregate composed predominantly of augite, with brown biotite, magnetite, and calcic plagioclase in lesser amounts and smaller crystals. All the minerals of the groundmass are euhedral or subhedral, and the feldspar serves as a matrix for the iron-bearing minerals. With the exception of the olivine alteration the rock is perfectly fresh. There are a few small calcite amygdules.

GRANITE PORPHYRY.

GENERAL CHARACTER.

Three small dikes of porphyry just north of Idaho Springs (see Pl. VI, in pocket) differ from any of the other porphyries of the region in having a granular groundmass whose component grains are of unusual coarseness, so that even to the unaided eye the groundmass appears distinctly granular. These rocks are pale pinkish and show sparsely scattered phenocrysts of quartz and feldspar; the entire rock consists mainly of these two minerals.

DISTRIBUTION.

The granite porphyry was noted only as three small dikes cropping out a short distance northwest of Virginia Butte, on the ridge forming the west wall of Virginia Canyon. It is not certain that this rock corresponds to the granite porphyry of the western part of the Georgetown quadrangle, described by Ball.[1]

[1] Ball, S. H., op. cit., pp. 75-77.

FEATURES IN DETAIL.

The granite porphyries to the unaided eye show a finely crystalline groundmass of granular appearance and pale-pink color Through this are sparsely scattered phenocrysts of gray and pink feldspar under 3 millimeters in diameter and phenocrysts of light-gray quartz nearly 1 centimeter in diameter and usually somewhat irregular in outline.

The microscope shows that the groundmass is a granular aggregate of quartz and orthoclase in anhedral crystals, the feldspar slightly predominating in amount. Some plagioclase, apparently albite, is perthitically intergrown with the orthoclase. Much less abundant than either quartz or feldspar are very small flakes of biotite and grains of magnetite. These iron-bearing minerals are not recognizable to the unaided eye. The rock contains also a few small prisms of apatite.

AGE AND RELATIONS.

The granite porphyry dikes bear the same intrusive relation to the pre-Cambrian rocks as the neighboring monzonite and bostonite dikes. They were not observed in contact with any of the other porphyries, but it is considered probable that they belong to the same general period of igneous intrusion and are therefore probably Tertiary.

ALKALI SYENITE PORPHYRY.

GENERAL CHARACTER.

The alkali syenite porphyry, which is not widely distributed, varies considerably in appearance from place to place, but the most abundant facies is a light bluish-gray, coarsely porphyritic rock carrying phenocrysts of pyroxene, brownish garnet, and vitreous-looking gray feldspar.

DISTRIBUTION.

This rock occurs as a small stock having a surface diameter of 0.15 mile on the south side of Clear Creek, east of the mouth of Soda Creek. The syenite intrudes the pre-Cambrian rocks, inclosing near its border numerous fragments of the Idaho Springs formation. A dike of somewhat similar rock 0.2 mile long and 8 feet wide occurs southeast of the main mass; it strikes northwest and dips 60° NE.

FEATURES IN DETAIL.

An abbreviation of Ball's description of these porphyries[1] is given below.

The most conspicuous phenocrysts are greenish-black crystals of ægirite-augite as much as 3 millimeters in length and generally fresh. Many of them show zonal structure, and although some are partial crystals, others are little more than rounded grains. Less abundant than pyroxene are phenocrysts of brownish-black garnet with metallic luster, reaching 1 centimeter in diameter. The garnet appears dark brown under the microscope and shows faint zonal growth; it is probably melanite. Some of its larger crystals inclose phenocrysts of other minerals. Less conspicuous, but more abundant than either pyroxene or garnet, are phenocrysts of whitish-gray feldspar, mostly anorthoclase, although a few are orthoclase. They range from 3 to 15 millimeters in length. Small crystals of titanite, magnetite, and apatite are accessory. In one slide a few small crystals of zircon and biotite were seen.

The groundmass in most places is subordinate in quantity to the phenocrysts. It is microgranitic in texture and is made up of irregular masses of anorthoclase and some orthoclase, with a little quartz in some specimens.

Fluorite is present in irregular ramifying areas in the groundmass and in small areas flecking feldspar or ægirite-augite. It was probably introduced after the solidification of the rock, possibly by gases, and in part fills cavities between the minerals and in part replaces them. Analcite occurs in similar small areas, which are, however, more largely confined to the groundmass. As it occurs in thin sections of very fresh rocks, it is probably an original mineral, although it may be of secondary origin. The small percentage of SO_3 in the chemical analysis indicates the presence of haüynite or nosean, although neither mineral was recognized in the thin sections.

An analysis of a specimen typical of the commoner phases of the alkali syenite is given below, and its position in the American quantitative system is shown also.

[1] Ball, S. H., op. cit., pp. 82–83.

Analysis of alkali syenite (laurvikose) from south side of Clear Creek, near Soda Creek.

[George Steiger, analyst.]

SiO_2	60.30	ZrO_2	0.01
Al_2O_3	18.12	CO_2	None.
Fe_2O_3	2.45	P_2O_3	.25
FeO	1.25	SO_3	.06
MgO	.28	F	None.
CaO	3.89	S	None.
Na_2O	5.83	MnO	.12
K_2O	5.01	BaO	.26
H_2O-	.75		
H_2O+	.77		99.90
TiO_2	.55		

Norm of alkali syenite from south side of Clear Creek.

Quartz	1.02	Q= 1.02	Sal, 88.08
Orthoclase	29.47	F= 87.06	
Albite	49.25		
Anorthite	8.34		
Apatite	.34	A= .34	Fem, 9.96
Ilmenite	1.06	M= 4.40	
Magnetite	3.02		
Hematite	.32		
Wollastonite	3.71	P= 5.22	
Diopside	1.51		
H_2O, ZrO_2, and SO_3 not included in norm			1.59
			99.63

$\frac{Sal}{Fem}=\frac{88.08}{9.96}$, Class I, persalane.

$\frac{Q+F}{C+Z}=\frac{88.08}{0}$, Subclass I, persalone.

$\frac{Q}{F}=\frac{1.02}{87.06}$, order 5, canadare.

$\frac{K_2O'+Na_2O'}{CaO'}=\frac{147}{30}$, rang ′2, pulaskase.

$\frac{K_2O'}{Na_2O'}=\frac{53}{94}$, subrang ′4, laurvikose.

Formula, $I._{I}.5.'2.'4$.

AGE AND RELATIONS.

Concerning the age of the alkali syenite Spurr and Garrey[2] say:

> The rock is typically very fresh. Very near or at the contact of these syenite intrusions carbonated springs issue, some of which are hot and others cold. From the fresh character of the rocks, their lack of connection with ore deposits, and their association with the only hot springs in the region, it is very likely that the alkali syenites are the youngest of the Tertiary intrusives.

The syenite is believed by Spurr and Garrey to be younger than the ore deposits, but the evidence for this belief is presumptive and not conclusive, as in the case of the biotite latite.

In brief, the alkali syenite may, on the general grounds stated on page 38, be regarded as

[2] Spurr, J. E., and Garrey, G. H., op. cit., p. 135.

probably of Tertiary age and probably though not certainly slightly younger than most of the other supposed Tertiary intrusives.

A number of trachytes and andesites from the Rosita Hills [1] and the Pikes Peak region in Colorado, described by Cross, fall close to this rock in the quantitative classification. Most of these rocks are believed by Cross to be of early Tertiary age.

BIOTITE LATITE.

GENERAL CHARACTER.

Rocks of identical composition are termed "monzonite" or "latite," according as the groundmass was originally crystalline or glassy. The biotite latites of the Central City and Georgetown quadrangles consist of plagioclase, orthoclase, and biotite, in places with a little hornblende, embedded in a groundmass that was originally glassy or partly so. They are gray to light-brown rocks in which small phenocrysts of fresh-appearing biotite are common. They have been noted only as short dikes from 5 to 10 feet in width.

DISTRIBUTION.

Within the area covered by this report biotite latite has been seen only in the Stanley mine workings, near Idaho Springs. In the adjacent Georgetown quadrangle they are confined to the valleys of Chicago and West Chicago creeks. All have a general northeast trend and appear to lie along a single line or zone of intrusion. The biotite latite of the Stanley mine has not been observed at the surface.

FEATURES IN DETAIL.

In most of these rocks the groundmass equals or exceeds the phenocrysts in abundance. Most of the feldspar phenocrysts are from 1 to 5 millimeters in diameter and those of biotite usually from 0.5 to 1 millimeter, though a few are as large as 1 centimeter. The phenocrysts, named in the order of abundance, are orthoclase, biotite, and oligoclase. The biotite phenocrysts are very thin. Under the microscope the groundmass is found to be mainly a clear light-brown glass, in places slightly devitrified. In it are lath-shaped microlites of plagioclase, tabular orthoclase, and biotite. Flow structure is present in some specimens, notably in those from the borders of dikes, and some of the phenocrysts have been fractured during the flowage. The accessory minerals present, named in the order of abundance, are magnetite, apatite, and zircon. The rock constituents are remarkably fresh compared with those of most of the other "porphyries."

An analysis of biotite latite from the valley of Chicago Creek was published in the report on the Georgetown quadrangle,[2] but the position of the rock in the quantitative system was not calculated. The analysis is repeated below, the position of the rock in the quantitative system is calculated, and the new name freelandose is proposed for it. This name is derived from Freeland, the name of a mining camp in the Georgetown quadrangle not far from the places where these rocks have been found.

Analysis of biotite latite (freelandose) from Chicago Creek, Georgetown quadrangle.

[W. T. Schaller, analyst.]

SiO_2	66.44	CO_2	0.67
Al_2O_3	14.98	P_2O_5	.11
Fe_2O_3	1.57	SO_3	None.
FeO	.43	Cl	Trace?
MgO	.18	S	.02
CaO	2.47	MnO	.16
Na_2O	1.12	BaO	.11
K_2O	3.32	SrO	Trace?
H_2O-	4.60	Li_2O	None.
H_2O+	4.06		
TiO_2	.20		100.42
ZrO_2	.01		

Norm of biotite latite from Chicago Creek.

Quartz	42.06	Q=42.06	Sal, 87.93	
Corundum	5.30	C= 5.30		
Orthoclase	19.46	F=40.57		
Albite	9.43			
Anorthite	11.68			
Apatite	.34	A= .34	Fem, 3.09	
Ilmenite	.46	M= 2.35		
Magnetite	.93			
Hematite	.96			
Hypersthene	.40	P= .40		
H_2O, CO_2, S, and ZrO_2 not included in norm				9.36
				100.38

$\frac{Sal}{Fem}=\frac{87.93}{3.09}$, Class I, persalane.

$\frac{Q+F}{C}=\frac{82.63}{5.30}$, Subclass I, persalone.

$\frac{Q}{F}=\frac{42.06}{40.57}$, order 3, columbare.

$\frac{K_2O'+Na_2O'}{CaO'}=\frac{53}{42}$, rang 3, riesenase.

$\frac{K_2O'}{Na_2O'}=\frac{35}{18}$, subrang 2′, freelandose (new name).

Formula, I.I.3.3.2′.

[1] Cross, Whitman, Geology of Silver Cliff and the Rosita Hills, Colo.: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 2, pp. 273, 324, 1896. See also U. S. Geol. Survey Prof. Paper 14, p. 201, 1903.

[2] U. S. Geol. Survey Prof. Paper 63, p. 134, 1908.

AGE AND RELATIONS.

The biotite latites are believed by Spurr and Garrey[1] to have been intruded later than most of the other porphyries of the Georgetown quadrangle and later than the mineralization. At the junction of Chicago and West Chicago creeks latite incloses a few rounded fragments of quartz monzonite from 4 to 6 inches in diameter, and in the Stanley mine it incloses fragments of bostonite porphyry and of ore.

In having a glassy groundmass the rock contrasts strongly with the holocrystalline bostonite, with which it is closely associated, and the inference appears justified that it was intruded under different conditions admitting of more rapid cooling.

Though the biotite latite was clearly intruded later than the monzonites and bostonites its exact age can not be stated. Upon the broad grounds outlined on page 8 it may be provisionally regarded as Tertiary.

The close approach of this rock in the American classification to riesenose (formula I.I.3.3.3) from Leadville [2] and from Silver Cliff,[3] of supposed Tertiary age, shows that magmas of this composition were not uncommon among the late Mesozoic effusives of Colorado.

TERTIARY (?) TERRACE GRAVELS.

In the vicinity of Idaho Springs there are small amounts of cemented gravels, whose upper surface, though somewhat irregular, stands on the average about 180 feet above Clear Creek. Within the area covered by Plate VI these gravels form a short, narrow bench just northwest of the mouth of Gilson Gulch and a longer bench on the south side of Clear Creek, opposite the western part of the town of Idaho Springs. They occur most extensively, however, just south of the area covered by this report and are described by Spurr and Garrey [4] as follows:

> In the southeast angle formed by the union of Soda Creek with Clear Creek this terrace is underlain by a bench of bedrock which in few places reaches the surface, being usually covered with a river deposit averaging 40 feet in thickness. The lower 20 feet of this deposit consists of large rounded bowlders, gravel, and sand; the upper portion is composed of finer gravels and silts capped by aerial talus or silt having an average thickness of 6 feet.

This portion of the deposits was formerly extensively worked for gold with profitable results.

The narrow bench near the mouth of Gilson Gulch

> is a horizontal or slightly sloping shelf or ledge of coarse conglomerate and soft sandstone or granitic arkose, similar in character to the placer deposits on the other side of the valley. This fairly well indurated conglomerate, which is composed chiefly of rounded masses of gneiss and granite but also contains some rounded pebbles of porphyry * * * is plastered unconformably upon the rather steep gneiss walls of the valley at this point. Through this conglomerate, and to a less extent in the underlying gneiss, are veins (fissure fillings) of calcite.

The largest bowlders observed in these gravels are 5 feet in diameter. The degree of consolidation is indicated by the fact that on the south side of Clear Creek untimbered drifts excavated 40 or 50 years ago can still be traversed for considerable distances.

The high-terrace gravels at Idaho Springs rise more than 150 feet above the gravels of the later (Wisconsin) glacial valley train. Since their deposition Clear Creek has excavated, near Idaho Springs, a channel at least 160 feet deep in the bedrock. The altitude of the gravels and the depth of this canyon, much greater than any other known to have been excavated in this region wholly subsequent to the earlier (pre-Wisconsin) glaciation, make it probable that the gravels are older than the glacial epoch. They are classed as probably late Tertiary.

QUATERNARY DEPOSITS.

GENERAL FEATURES.

The Quaternary deposits of the Central City quadrangle include (1) glacial till and associated glacio-fluviatile deposits formed at two stages of Pleistocene glaciation, (2) débris sheets, (3) recent alluvium, and (4) talus. The last three are shown under the same symbol on the geologic map (Pl. I, in pocket).

GLACIATION.

GENERAL CONDITIONS.

During the Pleistocene or glacial epoch the entire northern half of the continent of North America was covered by a great ice sheet which moved outward from centers of accumulation in eastern, central, and western Canada.

[1] U. S. Geol. Survey Prof. Paper 63, pp. 81, 130, 344, 1908.
[2] Cross, Whitman, Petrography of the Leadville district: U. S. Geol. Survey Mon. 12, pp. 330-332, 1886. See also U. S. Geol. Survey Prof. Paper 14, p. 138, 1903.
[3] Cross, Whitman, and Eakins, L. G., A new occurrence of ptilolite: Am. Jour. Sci., 3d ser., vol. 44, p. 101, 1892. See also U. S. Geol. Survey Prof. Paper 14, p. 138, 1903.
[4] Spurr, J. E., and Garrey, G. H., op. cit., p. 313.

In western North America this great mass of ice extended only a short distance south of the present boundary between the United States and Canada, but local glaciers of the alpine or valley type were developed in most of the higher mountain ranges as far south as central New Mexico and the San Francisco Mountains of Arizona. A few glaciers exist at the present time near some of the higher peaks of the Cordilleran mountain ranges of the western United States, but they are insignificant in extent compared with their predecessors of the glacial epoch. The history of glacial time is very complex, for there were several stages of ice advance alternating with interglacial stages. In Colorado the Front Range was more or less generally glaciated in its higher portions, but the details of this glaciation have been studied only in the Georgetown and Central City quadrangles. There, as in most of the other western mountain ranges where the subject has been studied in detail, the glacial drift is referable to two or more stages of glaciation, somewhat widely separated in time.

EARLIER OR PRE-WISCONSIN GLACIAL STAGE.

Glaciers.—Within the Georgetown quadrangle and those portions of the Central City quadrangle that have been studied in detail glaciers of the earlier or pre-Wisconsin stage headed in the Continental Divide and moved eastward and northeastward down the valleys of the west and south forks of Clear Creek to a point not far east of Dumont. In these valleys the earlier glacial deposits extend farther down the valley and higher up the valley walls than those of the later or Wisconsin glacial stage. It is noteworthy that the Mount Evans region, in the Georgetown quadrangle, which was an area of considerable accumulation for glaciers of the later stage, apparently did not give rise to notable glaciers during the earlier stage. In the northeastern part of the Central City quadrangle evidences of the earlier glaciation have not been noted, although deposits made by the later glaciers are abundant.

From the differences in distribution of the glaciers of the two stages, it may be inferred that the conditions of accumulation were notably different. The nature of these differences is conjectural, but they were probably not topographic, because the amount of erosion between the two glacial stages appears to have been small.

At the west border of the Central City quadrangle the Clear Creek glacier appears to have extended to an altitude of about 11,000 feet; its front, 8½ miles farther east, near Dumont, descended to an altitude of about 7,850 feet; the slope of the ice surface in this distance, therefore, averaged about 370 feet to the mile. The most easterly remnants of the older drift are erratic blocks of granite at an altitude of 8,300 feet in the first gulch northeast of the junction of Mill and Clear creeks. Along Clear Creek itself traces of older drift were noted 500 feet downstream from the mouth of the Freeland tunnel, where rounded bowlders extend 75 feet above the wagon road.

Till deposits.—The till of the pre-Wisconsin glaciers—the material transported in, on, or beneath the ice—occurs in irregular remnants whose form and position in the valley of Clear Creek is shown on Plate I. The typical glacial topography which this till once exhibited has been largely destroyed by erosion, the surface as a rule being well drained and free from ponds or bogs. The glacial origin of the material is, however, apparent from its topographic position, its incoherence, its heterogeneity in size and character, and the presence of typical glacial striæ, especially on porphyry bowlders. The bowlders lying on the surface are roughened by weathering and somewhat decomposed, and the till is oxidized to depths varying from 3 to 15 feet.

The extent of stream erosion since the deposition of the older till is well shown in the valley of Silver Creek, south of Lawson. This creek, according to Ball[1] has cut since the early glaciation a canyon 3,000 feet long, 100 feet in average depth, and 250 feet wide at the top. At one place the upper 85 feet is cut in till and the lower 15 feet in the Idaho Springs formation and pegmatite. This amount of cutting is in marked contrast with that exhibited by streams of comparable size traversing the later till. (See p. 59.)

Outwash deposits.—No gravel deposits were noted that could be certainly identified as outwash from the glaciers of the earlier stage. Such deposits, which were doubtless abundant at one time in the valley of Clear Creek between

[1] Ball, S. H., op. cit., p. 86.

Dumont and Idaho Springs, have apparently been entirely removed or reworked by subsequent stream erosion.

LATER OR WISCONSIN GLACIAL STAGE.

Glaciers.—Glaciers of the later stage, believed to have been contemporaneous with the Wisconsin stage of the continental ice sheet, occupied the upper valleys of Clear Creek, Mill Creek, Fall River, Silver Creek, South Boulder Creek, Middle Boulder Creek, North Fork of Middle Boulder Creek, and North Boulder Creek. The distribution of these till deposits is shown on Plate I. The lowest altitude reached by these glaciers was about 8,200 feet at the front of the Clear Creek glacier, which extended to Lawson. The largest of the glaciers were those of Clear Creek and Middle Boulder Creek.

Glacial erosion.—The geologic surveys that form the basis of this report did not extend into the upper portions of many of the glaciated valleys where sculpturing by the ice was most active. Some glacial erosion was noted at the headwaters of Silver Creek, near Alice, but the Alice glacier was small and correspondingly weak. The steep rock walls near Eldora have undoubtedly been scoured vigorously by the glacier that occupied that valley. Elsewhere within the glaciated areas the predominant process was deposition rather than erosion.

Till deposits.—The till deposits of the later or Wisconsin glacial stage, in marked contrast to those of the earlier or pre-Wisconsin stage, have been modified only to a slight extent by later erosion and exhibit in many places the irregular and poorly drained surfaces characteristic of glacial topography. Lakes in basins formed wholly or partly by till are common only near Alice and south of Eldora; the largest is Lake Eldora, or Peterson Lake, which lies between a wall of schist on the north and a wall of till on the south. Distinct differentiation of the till deposits into terminal and lateral moraines is generally impossible, but on the south side of South Boulder Creek, from a point a little above Baltimore nearly to Tolland, Mr. Hill observed a well-marked lateral moraine. One of the best-defined terminal moraines is that which crosses Mill Creek at an altitude of about 9,650 feet. The front of this moraine is steep and about 300 feet high.

Among the bowlders and cobbles granite, pegmatite, granite gneiss, and porphyry predominate, the less resistant schist of the Idaho Springs formation being comparatively rare. The surface bowlders of the later till are little weathered or decomposed, and the body of the till is practically unoxidized. Postglacial erosion reached a maximum along the streams of large volume, such as Clear Creek, along which Ball [1] noted a postglacial channel southwest of Georgetown, 1,000 feet long and 30 feet deep, in the pre-Cambrian rocks. In other localities the erosion has been slight; Mill Creek, for example, breaks over the summit of the terminal moraine in a narrow cut about 30 feet deep and then cascades down over the outer slope in a number of small bowlder-filled channels, which unite just below the moraine into a single good-sized stream.

Outwash deposits.—Deposits of bowlders and gravel made by streams fed by the melting ice are present in practically all the glacial valleys. The most extensive are the narrow valley trains that occupy portions of the valley floors below the terminal moraines. The longest of these valley trains occupies Clear Creek valley and extends, with a few interruptions, from a point near Lawson to a point a short distance below Idaho Springs. Its altitude at Lawson is about 8,140 feet and at Idaho Springs about 7,540 feet, its average slope between these two places being therefore a little over 80 feet to the mile, or about the gradient of the present stream. At Idaho Springs the Wisconsin glacial gravels rise about 20 feet above the present flood plain of Clear Creek and form the terrace upon which most of the town is built. The materials of the valley trains are commonly well rounded.

In the valley of North Boulder Creek the outwash from the melting Wisconsin glacier was not confined to a narrow valley but spread over a considerable area, forming an outwash apron that skirts the moraine, sloping gently away from it, and merges into the recent alluvium.

Near Empire and from 1 to 2½ miles southwest of Nederland outwash plains have been formed during the retreat of the ice, back of the terminal moraines. The appearance of the Nederland plains is shown in Plate XII, *A*. In it are two small lakes that presumably mark the places where blocks of ice were left behind in

[1] Ball, S. H., op. cit., p. 86.

the glacial retreat and by their subsequent melting produced depressions that are now filled with water. A lake of similar character occurs in a smaller outwash plain near Tolland.

The glacial outwash has in some places yielded gold in paying quantities, as discussed on page 120.

AGE AND RELATIONS OF THE GLACIAL STAGES.

The considerable surface oxidation of the earlier or pre-Wisconsin till and the destruction by erosion of the features typical of morainal topography present so marked a contrast to the slight postglacial changes in the later or Wisconsin till that it is a necessary conclusion that the interval between the two stages was of long duration, probably much longer than the time which has elapsed since the later or Wisconsin stage. This conclusion is in entire harmony with the conclusions of Salisbury in regard to the relative ages of the earlier and later till in the Bighorn Mountains, in Wyoming,[1] and with those of Atwood for the San Juan Mountains of Colorado [2] and the Uinta and Wasatch mountains of Utah.[3] Both stages of glaciation occurred during Pleistocene time.

PLEISTOCENE (?) TERRACE GRAVELS.

Two gravel terraces, whose upper surfaces stood 55 and 25 feet, respectively, above the level of the present streams, were noted by Ball [4] along the lower 2.2 miles of Chicago Creek and along Clear Creek near the mouth of Chicago Creek, just outside the area covered by this report. The age of these terraces is uncertain. Ball states that the 55-foot terrace may be of glacial or preglacial age. The 25-foot terrace stands only a short distance above the late glacial valley train and may have been formed in early glacial or interglacial time.

DÉBRIS SHEETS.

In gently sloping portions of a number of valleys which have not been affected by glaciation and in which stream erosion has not been vigorous, deposits of angular, unassorted, and somewhat decayed fragments of the bordering and underlying rocks have accumulated in sufficient thickness to mask the hard-rock formations completely. Such deposits are found in Elk Park (west of Apex), at Pecks Flat, north of Mount Pisgah, near The Queens Chair (north of Central City), in Pleasant Valley, and at a number of other localities. They appear to have been formed by the disintegration of the bedrock under the action of frost, temperature changes, etc., and the gradual downhill creep of the disintegrated material under the influence of gravity aided by wetting and drying, freezing and thawing, and other processes. In the accumulation of the typical débris sheets stream erosion has played an insignificant part. There is, however, a gradation from typical sheet deposits of débris into stream alluvium, and both are shown on the maps (Pls. I and VI) under the same symbol. The thickness of the débris sheets can be determined only where they have been penetrated by mine workings. Near The Queens Chair, north of Central City, a shaft 20 feet deep is wholly in débris. In a few places, as near The Queens Chair, where the débris is composed principally of porphyry, it has been cemented apparently by silica into a coherent rock.

Here and there, as noted on page 120, the débris sheets have yielded gold in paying quantities.

The débris sheets appear to have accumulated mainly in glacial and postglacial time, although the lower portions of some deposits may be older. They are still being formed.

RECENT ALLUVIUM.

Deposits of bowlders, gravel, and sand laid down by the present streams are found in nearly all the valleys, and those extensive enough to map have been shown on Plates I, III, and VI. The narrow strips of alluvium along the principal streams are broadened at intervals by fanlike contributions of alluvium from tributary gulches, as at the mouths of Georgia and Hoosac gulches, both of which contain only temporary streams. (See Pl. VI.) In some places, as at the mouth of Dry Gulch in Idaho Springs, these fans rest upon glacial outwash gravels of the Wisconsin stage.

The recent stream alluvium has in the past been an important source of placer gold. (See p. 120.)

[1] Salisbury, R. D., U. S. Geol. Survey Geol. Atlas, Cloud Peak-Fort McKinney folio (No. 142), p. 12, 1906.

[2] Atwood, W. W., Physiographic studies in the San Juan district of Colorado: Jour. Geology, vol. 19, p. 449, 1911.

[3] Atwood, W. W., Glaciation of the Uinta and Wasatch mountains: U. S. Geol. Survey Prof. Paper 61, p. 92.

[4] Ball, S. H., op. cit., p. 84.

TALUS.

Deposits of talus or fragmental rock material that has fallen at the base of steep rock slopes as a result of their disintegration through changes in temperature, the action of frost, and other processes, are most abundant in the higher portions of the region, which have not been surveyed geologically. Within the surveyed area they are abundant only in a few places, as at the base of the cliffs north of Alice and in parts of the valley of Clear Creek above Empire.

STRUCTURE.

The structural features of the Central City quadrangle are very complex, and many of them represent the cumulated effect of processes acting through long periods of geologic time. The processes that have produced the structural features are (1) widespread earth movements of compression and uplift and (2) igneous intrusion. The principal structural features developed through these processes are foliation, faults, and joints.

FOLIATION.

Under the term foliation are included both schistosity and gneissic structure. Foliation, in this region, is confined to the pre-Cambrian rocks and is in general best developed in the oldest and least developed in the youngest of these rocks. The physical character of the rock has also been a factor in controlling foliation, some rocks becoming more highly foliated than others under the influence of the same stresses.

The preponderant direction of foliation, especially in the southern part of the area surveyed, is northeast, as is indicated not only by direct measurements but also by the northeasterly elongation of many of the bodies of intrusive igneous rock, pegmatite, quartz diorite, and others. (See Pl. I.) From this prevailing trend there are many variations, foremost among which is a tendency for the lines of foliation to wrap around large masses of intrusive rocks. This tendency is particularly marked near the large masses of pre-Cambrian quartz monzonite in the Georgetown quadrangle.

The most highly foliated rocks of the region belong to the oldest formation, the Idaho Springs, which is probably sedimentary and into which all the igneous rocks of the quadrangle have been intruded. The foliation developed in most of these rocks is of the finely laminated type termed schistosity and described more at length on page 27. Its perfect development in the Idaho Springs rocks is due in part to the readiness with which fine argillaceous sediments, such as originally made up much of this formation, recrystallize under differential pressure, but also to the fact that they have been submitted to such pressures during more periods than any of the other rocks. The latter fact is shown by the occurrence in the next younger rock, the granite gneiss, of fragments of the Idaho Springs formation having well-developed schistosity. The granite gneiss characteristically shows a well-defined gneissic structure, though in a few places it is massive. The microscope shows that in both the granite gneiss and the schist of the Idaho Springs formation the foliated structure has been developed through recrystallization without fracturing. The change took place, therefore, under high pressure and was presumably accomplished while the rocks were deeply buried.

In contrast to the granite gneiss and the Idaho Springs formation, the quartz diorite, Silver Plume granite, and pegmatites are characteristically massive. Where they appear foliated this structure may be the result of close-spaced shearing or of flowage during crystallization. Some of the granite pegmatite is a phase of the granite gneiss intrusion, and the absence of foliation in such pegmatite must be interpreted as evidence of its superior resistance to recrystallization under pressure compared with the finer-grained phases of the intrusion. The fact that the Silver Plume granite locally contains angular fragments of granite gneiss exhibiting the usual degree of gneissic structure shows that the foliation of the gneiss was developed prior to the intrusion of the granite.

The stresses that developed the schistose structure in the rocks of the Idaho Springs formation flexed these rocks into a series of compressed folds. Small folds are recognizable here and there within the formation, but in the absence of distinctive beds that mark the same stratigraphic horizon over large areas, the larger features of this folding can not be worked out.

FAULTS AND JOINTS.

The great depth at which recrystallization with the development of foliation took place was incompatible with any considerable formation of faults and joints. These structural features were developed mainly during later periods, when erosion had removed great thicknesses of covering rocks. Some faulting undoubtedly accompanied the intrusion of the younger pre-Cambrian igneous rocks, for in places pegmatite and granite contacts follow straight sharp fractures that cross the foliation of the schist of the Idaho Springs formation or the granite gneiss, but most of the faulting took place at a later time. Some of it preceded and some followed the intrusion of the Tertiary (?) porphyries, and faulting is in progress even at the present day.

The faulting may plausibly be regarded as in the main an effect of the various land movements which since Cretaceous time have brought the region to its present elevated position; to a lesser degree it has resulted from the intrusion of the Tertiary (?) igneous rocks.

Two dominant directions of faulting are recognizable—northeast and northwest. The northeasterly faults are by far the most numerous and most extensive. Both sets dip steeply. These directions of faulting were established previous to or contemporaneous with the intrusion of the Tertiary (?) igneous rocks and influenced their distribution, as is clearly shown on the map (Pl. I). Later faulting along the same general lines displaced the porphyries and created channels for ore deposition. The northeasterly faults correspond in general trend with the foliation in the pre-Cambrian rocks, and in this concordance is to be found perhaps the reason for their overwhelming preponderance over the northwesterly faults. Except for the few faults that displace porphyry dikes in mine workings, it is impossible to obtain an estimate of the amount of movement along the fault planes. It is perfectly clear, however, that in most places the movement was small, for nowhere was it sufficient to cause noteworthy displacement of a geologic boundary as shown on the surface.

The northeasterly faults are of great economic importance, for along them nearly all the metalliferous veins have been deposited.

Joints are prominent chiefly in the regions of extensive faulting and in general are parallel to the faults.

IGNEOUS INTRUSION.

The most salient structural characteristic of the region is the intricate manner in which igneous rocks ranging from pre-Cambrian to probably Tertiary in age and from iron ores to quartz-rich pegmatites in composition have been intruded into the sedimentary Idaho Springs formation and into one another. The unraveling of this intricate association formed the principal problem in the geologic mapping, and even the large-scale maps suffice only to record a generalized picture of the true relations. Ball[1] illustrates this wonderful complexity in a striking manner with the statement that within a distance of 1 mile near Lawson six formations alternate 76 times, or at the rate of one alternation to 70 feet.

[1] Ball, S. H., op. cit., p. 91.

CHAPTER IV.—GEOLOGIC HISTORY.

PRE-CAMBRIAN TIME.

The geologic events of the Central City region that are recorded in its rocks began with the deposition in pre-Cambrian time, probably in marine waters, of great thicknesses of clays and of very minor amounts of sands, gravels, and marls, now represented by the Idaho Springs formation. The position and size of the land masses which furnished these sediments and the character of their rocks are unknown, but from the character of the Idaho Springs rocks it may be inferred that the waters in which the sediments were deposited were not deep and that conditions favorable for limestone deposition rarely held sway. During long periods of time these incoherent deposits became buried to a great depth beneath other deposits, were consolidated to shales, sandstones, conglomerates, and limestones, and eventually were closely folded and recrystallized under the influence of compressive stresses and converted into the biotite schists, quartzites, conglomerates, and crystalline limestones that now make up the Idaho Springs formation. The stresses that produced this metamorphism operated at great depth and possibly during several periods. Whether this metamorphism far below the surface was accompanied by mountain building at the surface is unknown; certainly the present mountain range is comparatively young and in no way connected with these very ancient processes.

Subsequent to this metamorphism but still in pre-Cambrian time came the intrusion of a few broad dikes of quartz diorite grading into hornblendite, in the main parallel to the schistosity of the Idaho Springs formation. After that were intruded in the Georgetown quadrangle, large masses of monzonite and still later, in both the Georgetown and Central City quadrangles, bodies of granite, now represented by the stocks and injected bands and lenses of granite gneiss and associated pegmatite. Solutions emanating from the granite intrusives produced some contact metamorphism in parts of the Idaho Springs formation adjacent to or inclosed by them, converting biotite schist into hornblende schist and crystalline limestone into lime-silicate rocks. The intrusion of these granitic rocks took place at great depths and was followed by a renewal of comprehensive stresses which imparted to them a foliated structure and metamorphosed still further the rocks of the Idaho Springs formation. This metamorphism was, however, much less severe than the earlier metamorphism.

Later in pre-Cambrian time were intruded great batholiths of quartz monzonite, not found within the area covered by this survey but occupying large areas in the Georgetown quadrangle. Then followed the intrusion of the Rosalie granite of the Georgetown quadrangle and the Silver Plume granite of the Georgetown and Central City quadrangles, with their various dioritic and pegmatitic facies. These rocks, like the earlier granitic and monzonitic intrusives, produced locally some slight contact metamorphism of the rocks of the Idaho Springs formation.

There are reasons for believing that at the time of these later intrusions the section of the earth's crust now exposed at the surface was less deeply buried than in the earlier periods when regional metamorphism developed foliated structure. Evidence for this belief is found in the fact that the later intrusions fractured the inclosing rocks somewhat more than the earlier intrusions. If this belief is warranted it must be supposed that erosion was in progress in this region even in pre-Cambrian time—that is, that parts of the region were land—a conclusion that receives support from the reported occurrence of pre-Cambrian effusive igneous rocks in certain parts of the Front Range.[1]

PALEOZOIC TIME.

Whatever may be the facts in regard to erosion in pre-Cambrian time, it is certain that very extensive erosion had taken place in the region now occupied by the Front Range before the end of the Cambrian period, for metamorphosed quartzites and conglomerates of prob-

[1] Darton, N. H., Blackwelder, Eliot, and Siebenthal, C. E., U. S. Geol. Survey Geol. Atlas, Laramie-Sherman folio (No. 173), p. 3, 1910.

able Upper Cambrian age, containing pebbles of the foliated rocks, lie in erosional unconformity upon the pre-Cambrian crystalline complex at several places along the east flank of the range.[1] That parts of the region were land in Carboniferous time is shown by the fact that near Golden and Boulder the Fountain formation,[2] of Pennsylvanian age, rests in erosional unconformity upon the pre-Cambrian rocks. Ball [3] found what appeared to be remnants of the Fountain formation in the Georgetown quadrangle, and if his identification was correct portions of the region now comprised in the Georgetown and Central City quadrangles were covered by the sea during part of Pennsylvanian time.

Although the Paleozoic history of the region is therefore only imperfectly known, it is probable that both erosion and sedimentation were in progress and that the former far overbalanced the latter, the net effect being to bring the particular pre-Cambrian rocks which are now exposed for geologic study much closer to the surface.

MESOZOIC TIME.

Of the history of the region in early Mesozoic time little is known. That certain parts of the area now occupied by the Front Range were land during portions of this time is shown by the fact that in Middle Park,[4] on the west flank of the range, and apparently also at Breckinridge [5] the Dakota sandstone, of Upper Cretaceous age, lies in erosional unconformity upon the pre-Cambrian crystalline complex.

The Cretaceous seems in general to have been a period of submergence over most of the province. It can not be positively affirmed that the Cretaceous seas covered the Central City and Georgetown quadrangles, but it is highly probable that they did, for, as pointed out by Darton,[6] the late Cretaceous sediments now exposed along the east flank of the range do not become coarser nearer the mountains.

[1] Cross, Whitman, U. S. Geol. Survey Geol. Atlas, Pikes Peak folio (No. 7), 1894. Richardson, G. B., U. S. Geol. Survey Geol. Atlas, Castle Rock folio (No. 198), 1916.

[2] Fenneman, N. M., Geology of the Boulder district, Colo.: U. S. Geol. Survey Bull. 265, pp. 22–23, 54–56, 1905. Emmons, S. F., Cross, Whitman, and Eldridge, G. H., Geology of the Denver Basin in Colorado: U. S. Geol. Survey Mon. 27, pp. 91–92, 1896.

[3] Ball, S. H., op. cit., pp. 66–67.

[4] Hayden, F. V., Geological and geographical atlas of Colorado, 2d ed., sheet 12, U. S. Geol. and Geog. Survey Terr., 1881.

[5] Ransome, F. L., Geology and ore deposits of the Breckenridge district, Colo.: U. S. Geol. Survey Prof. Paper 75, pp. 30–38, 1911.

[6] Darton, N. H., U. S. Geol. Survey Geol. Atlas, Laramie-Sherman folio (No. 173), p. 13, 1910.

CENOZOIC TIME.

It has been shown that land areas existed in the region now occupied by the Front Range, even in pre-Cambrian time. Although the geologic evidence is not sufficient to justify the statement that these lands never assumed the aspect of mountains, the scarcity of coarse sediments in most of the Paleozoic and Mesozoic formations that flank the range seems in general to point to the opposite condition—that is, only moderate relief. The movements that produced the Rocky Mountain uplift began in or just before Tertiary time and were the result of compression along east-west lines. The growth of the range, however, has not resulted from a single simple compressive movement but is the net effect of several such movements separated by periods of quiescence and modified by volcanism, and some movement may still be in progress. The earlier movements appear in general to have been of greater magnitude than the later. Although some faulting took place in the region even in pre-Cambrian time it produced little deformation until the beginning of the mountain-building uplifts; the fractures formed by these uplifts were followed by many of the Tertiary(?) intrusions.

Just after the early periods of mountain growth, in late Cretaceous or early Tertiary time, volcanism, for the first time since the pre-Cambrian, again assumed importance. Masses of igneous material were intruded as dikes and stocks in the pre-Cambrian formations and in places issued at the surface, as is shown by the flows and tuffs intercalated with the sediments of the Denver formation in the Denver Basin [7] and with the Dawson arkose of the Castle Rock region.[8] The typical dike form and fine grain of many of these late Cretaceous or early Tertiary intrusions is in marked contrast to the lenticular form and coarse grain of many of the pre-Cambrian intrusions and indicates that they were formed much nearer to the surface.

The intrusion of the igneous rocks was followed almost immediately by the development throughout the region of a large number of faults of small displacement, many of which subsequently became the sites of ore deposition. The cause of this faulting is not apparent, but it was more widespread than any be-

[7] Emmons, S. F., Cross, Whitman, and Eldridge, G. H., op. cit., p. 210.

[8] Richardson, G. B., U. S. Geol. Survey Geol. Atlas, Castle Rock folio (No. 198), p. 9, 1916.

fore or since. The formation of the ore deposits appears to have been intimately related both to this faulting and to the Tertiary (?) volcanism. Magmatic differentiation within one of the monzonite stocks during its crystallization produced the titaniferous iron ores of Caribou, and the solutions that ascended along fracture zones and deposited the gold and silver ores of this region are believed to have come from the deeper parts of the igneous magmas after the higher parts had solidified. The few porphyry dikes that are later than the mineralization may be regarded as marking the last stages of volcanism in this region.

With the dying out of the late Cretaceous or early Tertiary volcanism began a long period of uninterrupted erosion, during which the Cretaceous sediments and late Cretaceous or early Tertiary volcanic rocks that probably covered the surface in early Tertiary times were completely removed and considerable thicknesses of the underlying pre-Cambrian rocks were also worn away. Large portions of the mountain province were subdued to a gently sloping peneplain, upon which the higher mountains stood as unreduced monadnocks. (See Pl. IX, p. 20.) Portions of the ore deposits and the intrusive "porphyries" that had been buried were laid bare by erosion, and the ore deposits were subjected to oxidation and downward enrichment through the influence of the atmosphere and meteoric waters. These alterations have been going on continuously up to the present day.

The next important event in the geologic history appears to have been the renewal of uplift in late Tertiary time. This uplift was intermittent, but its general effect was to stimulate the streams to renewed activity, developing gorges in the old plateau surface and heightening the escarpment between the plains and mountain tracts.

In Pleistocene time climatic changes at two distinct periods led to the development of glaciers of the alpine type, which accumulated in the higher parts of the range and moved for several miles down the larger valleys. With reverse climatic changes the glaciers disappeared and the conditions which exist to-day were initiated.

PART II.—GENERAL FEATURES OF THE ECONOMIC GEOLOGY.

By Edson S. Bastin.

Chapter V.—HISTORY OF MINING.

In romantic interest and as a record of human achievement in the face of great difficulties and privations, the story of the discovery and early development of the mineral wealth of this region can hardly be surpassed by any other chapter in the history of the "winning of the West." If in the brief account that follows the personality of these pioneers is lost in the story of their practical achievements, it is because the pen of a novelist rather than a geologist is required to depict the human side of the story.

The writer is indebted to publications by Rickard,[1] Fossett,[2] and Hall,[3] for most of the facts here presented.

In the summer of 1849 a party of seven Georgians were taking a herd of thoroughbred horses across the continent to California. Reaching the mountains too late in the fall to effect a safe crossing with their stock, they established a winter camp at the junction of Cherry Creek and Platte River, on the present site of the city of Denver, and during the fall occupied themselves in prospecting the gravels along Cherry Creek, but they did not penetrate into the mountain canyons for fear of the Indians. Gold in quantities sufficient to awaken their hopes was found at several places, particularly at a point 16 miles upstream. With the arrival of spring they proceeded to California, where for several years they engaged in mining, but in 1857 they sold out their interests in California and returned to Georgia. Before separating it was agreed among several of them that in the near future they would form a prospecting party to go to the Rocky Mountains and search for gold. In May, 1858, the original seven and four others met in St. Louis, and in August they reached the present site of Denver, where they established a camp and began prospecting. According to Rickard, one of these parties followed Boulder Creek up to the forks, finding small amounts of gold. Another party proceeded across the ridges to Fall River and Spring Gulch. They did not descend into the valley of North Clear Creek at that time but crossed Quartz Hill and found rich gravel at Russell Gulch, named after its discoverer, W. Green Russell. As it was too near winter to begin mining, the prospectors returned to their camp at Cherry Creek. Six of the party went east to obtain provisions, returning in the spring of 1859.

By the fall of 1858 rumors of the gold discoveries had reached eastern Kansas. The East and especially the Middle West was still suffering from the effects of the financial panic of 1857, and this fact undoubtedly accounted in a measure for the enthusiasm with which any plan that promised to revive fallen fortunes was received. Prospectors in large numbers traveled to the new gold field, which became generally known as the Pikes Peak field. The town at the mouth of Cherry Creek, on the present site of Denver, was named Auralia, and there in 1858 wintered a considerable number of people disappointed at the small findings of gold in that vicinity and ready to stampede to any field of new discovery. At the foot of the mountains, where now stands the town of Golden, three prospectors camped for the winter. One of these men, George A. Jackson, a native of Missouri, penetrated into the mountains during the winter of 1858 and discovered the hot soda springs near the present site of the town of Idaho Springs, and shortly afterward, on January 7, 1859, he washed fine gold from the gravels bordering Chicago Creek near its mouth. A monument now marks the site of his discovery. The news of Jackson's find and the

[1] Rickard, T. A., The development of Colorado's mining industry: Am. Inst. Min. Eng. Trans., vol. 26, pp. 834 et seq., 1897.

[2] Fossett, Frank, Colorado, 1879.

[3] Hall, Frank, History of the State of Colorado, 4 vols., 1889–1895.

display of his gold at Auralia, where he offered it in payment for tools and supplies, precipitated a rush of prospectors to the mountains and resulted in the spring of 1859 in the discovery of gold at many other places. Among those who joined in this rush was John Hamilton Gregory, a native of Georgia, who followed up North Clear Creek. On May 6 Gregory made the first lode discovery in the Rockies, on the lode that bears his name (on Gregory No. 5 claim), between the present sites of Blackhawk and Central City. Other prospectors coming up North Clear Creek soon learned of his discovery, and the news spread and occasioned another rush, many hastening across the hills from Cherry Creek and from the Jackson "diggings," on South Clear Creek. Gregory sold his two claims for $21,000 in the summer of 1859 and soon afterward left the district.

In June, 1859, shortly after Gregory's discovery, A. D. Gambell discovered gold in Gamble Gulch in the Perigo region, and prospectors from the Jackson and Gregory diggings, spreading over the country in all directions, made many other discoveries at Twelve-mile, Gold Hill (12 miles west of Boulder), and other places.

Early in June, 1859, W. Green Russell, a member of the original party of Georgians, had commenced washing gold in the gulch that bears his name. According to Hollister,[1] "A week's work with six men yielded 76 ounces of gold. Others had taken claims above and below him, and toward the end of September there were 891 men at work in the gulch." By July 1 about 100 sluices were at work in the vicinity of Gregory's discovery, and yields of $100 to $400 for a day's work were not uncommon. Certain lodes averaged $100 a day for months at a time.

Thus was initiated the first period of mining in Colorado. The subsequent history of the district is too complex to be followed here in detail, but attention may be drawn to a few of its salient events. The discovery of other valuable lodes followed fast upon that of the Gregory lode. On May 15, 1859, the Bates lode was uncovered, and on May 25 the Gunnell, Kansas, and Burroughs. The Bobtail was discovered in June. On June 8, 1859, the miners at the "Gregory diggings" (Blackhawk) met in mass meeting and framed and adopted resolutions defining the boundaries of the district and the conditions under which claims could be taken and held. One of the resolutions provided that lode claims were to be 100 feet long and 50 feet wide, and "creek" or placer claims were to extend 100 feet up or down the gulch and from wall to wall. These provisions remained in force until the enactment of the Federal mining act of May 10, 1872. Subsequent meetings on July 9 and 16, 1859, organized a provisional local government.

In spite of warnings issued through the eastern newspapers by Horace Greeley and other eastern men who had visited the Gregory district in 1859, a second stampede to the district, larger than the first, took place in the summer of 1860. During the early part of summer immigrants bound for the new gold field arrived on the present site of Denver at the rate of 100 a day. The diggings became overcrowded and many hardships resulted. In that year the existing mining laws for the Gregory district were codified and amplified. The integrity of the local laws within each mining district was upheld by one of the first acts of the Territorial legislature of Colorado, in 1861, and further supported by an act of Congress, approved July 26, 1866. This act contained the first statement of the famous "apex law."

On February 26, 1861, the region, which had up to this time formed a part of the Territory of Kansas, was organized by act of Congress as the Territory of Colorado and William Gilpin was appointed governor.

All the veins of the region were gold bearing in their surface-oxidized portions, and it was not until mining had been extended to the underlying sulphide-bearing ores that some of the veins were found to be rich in silver. The first discoveries of silver ore appear to have been made in 1864 by men from the Empire district. They uncovered the Belmont vein, on McClellan Mountain, which afterward yielded large amounts of rich silver ore. In 1865 and 1866 there was a rush to the Georgetown district, and a large number of rich silver veins were discovered. In 1869 the rich silver ores of the Caribou or Grand Island district, in Boulder County, were discovered. The silver veins of Silver Hill, near Blackhawk, were not discovered until 1877 or 1878.

A notable stimulus was given to the development of mining by the completion of the

[1] Hollister, O. J., The mines of Colorado, pp. 71-72, 1867.

Union Pacific Railroad to Cheyenne in 1867, and particularly by the completion in the summer of 1870 of the Denver Pacific line between Denver and Cheyenne. In August of the same year the Kansas Pacific Railroad reached Denver, making two rail connections with the East. In 1870 the narrow-gage railroad was completed from Denver to Golden, and in 1872 it was extended to Blackhawk, and in 1873 to Floyd Hill, on South Clear Creek.

During the early years, when mining was confined to the gravels and to the gossans of the veins and the ores obtained were soft and free milling, they could be cheaply mined and amalgamated with the aid only of such simple devices as sluices, cradles, arrastres, and crude stamp mills. As mining progressed and depths of 50 to 100 feet were attained on the veins, the oxidized ore began to give way to sulphide ores, which could not be treated profitably by such simple methods. With deeper development, too, the handling of water in the mines became a more and more serious problem. For these reasons and because of financial ills consequent upon overcapitalization of many properties the period between 1864 and 1868 was one of depression in the mining industry, which was only slowly alleviated as progress was made in the treatment of the sulphide ores.

The further history of mining in the region is so intimately bound up with the progress in ore concentration and smelting that the reader is referred to the discussion of this development in the chapter on ore treatment (pp. 153–171). One event, however, of especial importance was the completion in 1887 of the Gilpin County tramway with 24-inch gage to serve the mines of Blackhawk, Central City, and Russell Gulch. About $100,000 of local capital was invested in this enterprise.

For the history of some of the smaller camps of the region the reader is referred to the detailed descriptions in Part III.

The claims shown on Plates V and VIII (in pocket) are given in the subjoined finding lists.

Finding list of claims shown on map of Central City and vicinity (Pl. V).

Arranged by coordinates.

A–I.	1.	Barnacle.
A–II.	1.	Quartz Valley placer.
A–V.	1.	Silver Mug.
	2.	Bill.
	3.	Mesa.
A–VI.	1.	Del Monte.
	2.	Zuni.
	3.	Yule.
	4.	Vendome.
	5.	Mystic.
	6.	Hawkeye.
	7.	Galton.
	8.	Gardner Extension.
	9.	Porphyry.
	10.	No Name.
	11.	Indiana Extension.
	12.	Gold Coin.
	13.	Heloe.
	14.	Silver Coin.
A–VII.	1.	Torrent.
	2.	Siren.
	3.	Orient.
	4.	Ivanhoe.
	5.	Empire.
	6.	Leontine.
	7.	Soden Extension.
	8.	Neptune.
	9.	Keystone.
	10.	Vermilion.
	11.	Leonidas.
	12.	Jupiter.
A–VII.	13.	Gem.
	14.	Wood.
A–VIII.	1.	Ward.
	2.	Howard.
	3.	Gibraltar.
	4.	Pure Gold.
	5.	May.
	6.	Quaker City.
	7.	Song.
	8.	Golden Wing.
	9.	Grace.
	10.	Spring.
	11.	Golden Dollar.
	12.	West Delaware.
	13.	Shamrock.
	14.	Dean Richmond.
	15.	Florence D.
	16.	Maldar.
	17.	Monte Christo.
	18.	Prompt Pay.
	19.	Union.
	20.	Randolph Extension.
	21.	Air Line.
	22.	Hazard.
A–IX.	1.	Triton.
	2.	North Fairfield.
	3.	Dayton.
	4.	Fairfield.
	5.	South Fairfield.
	6.	Isle Royal.
	7.	Jupiter.
A–IX.	8.	St. Clair.
	9.	Belmont.
	10.	Springdale.
	11.	Montana.
	12.	Shamrock II.
	13.	Celtic.
	14.	Bremen.
	15.	Osoeze.
	16.	Ruby.
	17.	Ethlyn.
	18.	Alta Monte.
	19.	Morning Star.
	20.	Denbigh.
	21.	Tarquin.
A–X.	1.	Bronco.
	5.	Bryant.
	3.	Westchester.
	4.	McKee.
	5.	Grisley.
	6.	Bob Laurie.
	7.	Rajah.
	8.	Slavonic.
	9.	Camper Down.
	10.	Nagle.
	11.	Thunderbolt.
	12.	John L. Emerson.
	13.	Asteroid.
	14.	White Cloud.
	15.	Golden Star.
	16.	President Hayes.
	17.	Phoenix.

Finding list of claims shown on map of Central City and vicinity—Continued.

Arranged by coordinates—Continued.

A–X. 18. Summit.
19. Legal Tender.
20. Sam Lee.
21. Oregon.

B–II. 1. Belle.
2. Chicago.

B–III. 1. Defender.
2. Dictator.

B–IV. 1. Rara Avis Extension.
2. Chief.
3. "S."

B–V. 1. George.
2. "B."
3. "A."
4. Herbert.
5. Defender.
6. Puritan.
7. Vigilant.
8. Shafts.
9. Suffolk.
10. Kate Kearney.
11. Salpiro.
12. Irving.
13. Skelton.
14. Essex No. 2.
15. Amberson & Warren.
16. Hubert Fork.
17. Hubert Extension.

B–VI. 1. Oranoake.
2. Oranoake Extension.
3. Hickory.
4. Geraldine.
5. Salvator.
6. Kansas.
7. Northrop.
8. Big Moon.
9. American Flag.
10. Indiana.
11. Keystone.
12. Express.
13. Symonds.
14. Cooper.
15. Powell.
16. Flack.

B–VII. 1. Sun.
2. Octavia Rachel.
3. Soden.
4. Mineral.
5. Ina.
6. Olympia.
7. Griffin.
8. Badger.
9. Courtland.
10. Caledonia.
11. Pyrenees.
12. Pyrenees Extension.
13. Boston.
14. French.
15. Gunn.
16. Delmonico.

B–VIII. 1. Boston.
2. French.
3. North Eclipse.
4. Charter Oak.
5. Gem.
6. Ezra White.
7. Capitol.
8. Day Spring.
9. Capitol Prize.
10. Jefferson (1011).
11. Jefferson (768)
12. Delaware (460 A).
13. Delaware mill site (460 B).
14. Randolph.
15. Eldorado.
16. Portage.
17. Mollie Newcombe.
18. Arlington (5875).
19. Conemara.
20. Morrell.
21. Topeka.
22. Stewart.
23. Blanche M.

B–IX. 1. Cooper.
2. Orion.
3. Gomer.
4. Pittsburg.
5. Pendleton.
6. Phoenix.
7. Preston.
8. Peale.
9. Congressional.
10. Senatorial.
11. Russell.
12. Gomer No. 2.
13. Homestake.
14. Free Coinage.

B–X. 1. Tonight.
2. West Pewabic.
3. Federal.
4. Becky Sharp.
5. Rubber.
6. Rocky Mountain Terror.
7. Munson.
8. Warfield.
9. Robert Fulton.
10. Gladstone.
11. Iron West.
12. Pawtucket.
13. "84."
14. Legal Tender.
15. Livingstone.
16. North.
17. Venus.
18. "93."
19. Golden Cloud.
20. Nashville.
21. Columbia.
22. Acra.

C–I. 1. Quartz Valley placer.
2. Janitor.

C–II. 1. Francis.

C–III. 1. Spur Daisy.
2. Monitor.
3. Cemetery.
4. Boodle.
5. Louis.
6. Garden No. 2.
7. Garden.

C–IV. 1. Bullion No. 2.
2. Bullion No. 6.
3. Rara Avis.
4. J. P. Whitney.
5. Senate.
6. Independence.
7. Ready Cash.
8. Fissure.

C–V. 1. Essex.
2. Bertie.
3. Dover.
4. Concrete.
5. Champion.
6. Balen.
7. Golden Treasure.
8. Bird.
9. Jay Eye See.
10. Motto.
11. Humboldt.
12. Parole.
13. Hubert.
14. Jones.
15. Genuine.
16. Membrino.

C–VI. 1. Axtell.
2. Douglas.
3. American Flag.
4. Kansas No. 4.
5. Kansas mill site (91 B).
6. Kansas (91).
7. Mill site 619 B.
8. Ute.
9. Irish Flag.
10. Monitor.
11. Burroughs.
12. Truran.
13. Grand River.
14. Randell Extension.
15. Providence.
16. Hidden Treasure.
17. Hidden Treasure No. 2.
18. California.
19. Gardner.
20. Annie.
21. Berkley.
22. Flack (664).
23. E. Flack (929).
24. Flack (65).
25. Mercer County.

Finding list of claims shown on map of Central City and vicinity—Continued.

Arranged by coordinates—Continued.

C-VI. 26. Mercer County Extension.
27. Badger State.
28. Rhode Island.
29. Kent County.
30. Maraposa.
31. Barker.
32. Governor Adams.
33. Kansas (87).
34. Kansas (67).
35. Camp Grove (86).
36. Mill site 111 B.
37. Mill site 210.
38. Mill site 350 B.

C-VII. 1. Sugar Tit.
2. New Pikes Peak.
3. Mitchell.
4. Belcher.
5. German.
6. Last Chance.
7. Burro.
8. Lizzie S.
9. Ingomar.
10. Dexter.
11. Alps.
12. Mackie.
13. Tigress.
14. Shaw.
15. Telephone.
16. Ethan Allen.
17. Winslow.
18. Kirk.
19. Polar Star.
20. Blagden.
21. Effie.
22. Day Spring Extension.
23. Willowdale.
24. Calhoun (837).
25. Bouvier.
26. Ninette.

C-VIII. 1. Wood.
2. Day Spring Extension.
3. Calhoun (231).
4. Mayflower.
5. Calhoun (837).
6. Fremont.
7. Gold King.
8. Mill site 247.
9. Quartz Mill.
10. Leavenworth.
11. Bon Ton.
12. Paola.
13. Topeka.
14. Gold Ring.
15. Wyandotte.
16. Topeka (518).
17. Topeka (100).
18. East Leavenworth.
19. Harrison.
20. Ruby.

C-VIII. 21. Defiance.
22. Ohio.
23. Bench.
24. Rockford.
25. Perrin.
26. Hogan.
27. Hill House.
28. West Wyandotte.

C-IX. 1. Nelson.
2. Russell Pride.
3. Denver.
4. Lutz Extension.
5. Rist placer.
6. Placer (858).
7. Wautauga.
8. Wautauga Extension.
9. Phillips.
10. Crœsus Extension.
11. Crœsus.
12. Minnesota.
13. Incidental.
14. Rosebud.
15. Major.
16. Pogue.
17. Advalorem.
18. Oldtown.
19. Margaret.
20. Clayton's Dream.
21. Success.
22. Lotus.
23. Hot Time.
24. Wash Kash.

C-X. 1. Mill site 180.
2. Becky Sharp.
3. Federal.
4. Pewabic (125).
5. Pewabic (560).
6. Richardson.
7. Bobtail.
8. Iron.
9. Bangor.
10. Cecilia.
11. Mars.
12. Bloomfield.
13. Danforth.
14. Montclair.
15. Fannie.
16. J. L.
17. Victor.
18. Hail Storm.
19. Esmeralda.
20. Virginia.
21. Togo.
22. Grasshopper.
23. Ida.

D-I. 1. Norton.
2. Harrison.

D-II. 1. General Logan.
2. West Keystone.
3. Only Boy.

D-II. 4. Bon Ton.
5. A. M.
6. Idea.

D-III. 1. Gold.
2. Two Sisters.
3. Maggie M.
4. Pacific.
5. Claire-Marie.
6. Carroll.
7. Little Chief.
8. Hamilton.
9. Storm King.
10. Iowa.
11. Lilly Rose.
12. Alva Adams.
13. Prospector.
14. Lake Superior.

D-IV. 1. Congress.
2. Wood.
3. Kohinoor No. 2.
4. Columbia Avenue.
5. Gold Bug.
6. Arlington.
7. Eureka.
8. Baby Ruth.
9. Marine.
10. Carrie G.
11. Hydrant.
12. Grand Army.
13. Fagan.

D-V. 1. Retriever.
2. Wheeler.
3. Herman.
4. Josephine.
5. Kriegbaum.
6. Silent King.
7. North Star.
8. Slaughter House.
9. Prize.
10. Iron Rock.
11. Prize Extension.
12. Seuderberg.
13. Buena Vista.
14. Cymbra.
15. Ashtabula.
16. Newfoundland.
17. Newfoundland No. 2.
18. Sunflower.
19. Mayflower.
20. Ashtabula-Ahay.
21. Dyke.
22. Windsor.
23. Jones.
24. Post Hole.
25. Levis mill site.
26. Avondale.

D-VI. 1. Mill site 88 B.
2. Mill site 160 B.
3. Sullivan.
4. Kansas (610).

Finding list of claims shown on map of Central City and vicinity—Continued.

Arranged by coordinates—Continued.

D-VI. 5. Monroe (643).
6. Monroe (8420).
7. Monroe (195).
8. Buckeye.
9. New Chicago.
10. Jay Gould.
11. Welcome.
12. Burroughs (262).
13. Burroughs (176).
14. Baker.
15. Gold Retort.
16. Oakland.
17. Climax.
18. Little Pittsburg.
19. Big Bone.
20. Hannibal.
21. Edinborough.
22. Jan Joan.
23. Gardner.
24. Extenuate.
25. Rhoderick Dhu.
26. Confidence.
27. Illinois.
28. Mollie Gibson.
29. Ingalls.
30. Bell.
31. Pratt.
32. Egyptian.
33. Protection.
34. Modoc.
35. Mill site 101 B.

D-VII. 1. Pikes Peak Extension.
2. Scandia.
3. Jessie.
4. Blythe.
5. North.
6. East Calhoun (11130).
7. Calhoun.
8. Telegraph.
9. Mercury.
10. "K."
11. Monadnoc.
12. East Harsh Extension.
13. East Calhoun (7319).
14. West Cuno.

D-VIII. 1. Swiss Home.
2. New Home.
3. Home.
4. George Deemster.
5. Gopher.
6. Canton.
7. Harsh.
8. Maud S. (6351).
9. Overland.
10. Michigan Boy.
11. Holland.
12. Columbus.
13. Free American.
14. Liberty.
15. Yukon.
16. Anglo-Saxon.
17. Niagara.
18. C. H. Smith placer.
19. Yuma.
20. Victoria mill site (5568).

D-IX. 1. Royal.
2. Louisiana.
3. Bengal.
4. Guion.
5. Anchor.
6. Lutz.
7. I X L.
8. Lucky Boy.
9. Lilian.
10. Waterloo.
11. Wellington No. 5.
12. Wellington No. 4.
13. "83."
14. Wellington No. 3.
15. Pewabic.
16. Wellington.

D-X. 1. Iron Duke.
2. West Wellington.
3. Compeer.
4. Wellington No. 7.
5. Wellington No. 8.
6. Bonny Bell.
7. Clifton Bell.
8. Bert.
9. Liberty Bell.
10. Blue Bell.
11. Old Guard.
12. Olga.
13. Lottie.
14. Paris.
15. Gold Dollar.

E-I. 1. Onandaga Chief.
2. Carmichel.

E-II. 1. Gold Cup.
2. Montezuma.
3. Buckeye.
4. Bullion (9607).
5. Bullion (459).
6. East Keystone.
7. Delight.
8. Easton.
9. Ravenswood.
10. Colorado Girl.
11. Keystone.

E-III. 1. Tiger.
2. Cedar.
3. R. H. D.
4. Polar Star.
5. Irene.
6. Harkaway.
7. Gulnare.
8. Minnesota.
9. Burlington.
10. Iowa.
11. Freiberg.
12. Oro.

E-IV. 1. Little Mack.
2. Humboldt.
3. Thurman.
4. I. X. L.
5. Cameron.
6. Montrose.
7. Buckley.
8. Gunnell No. 2.
9. Gunnell (71).
10. Nominee.
11. Silent Queen.
12. James Henry.
13. Gunnell mill site 473.
14. Gunnell (470).
15. Mount Lincoln.

E-V. 1. Backsheesh.
2. Reno.
3. High Grade.
4. Straub.
5. East Nevada.
6. St. Louis Extension.
7. Mill site 52.
8. Stub Tail.
9. Belcher.
10. Lyman.
11. Di Vernon.
12. Kansas.
13. Alger.
14. Isabella.
15. Mill site 151.
16. Old Rice.
17. Vanderbilt.
18. Lewis.
19. New York.
20. Columbia.
21. Argo.
22. Cork.
23. Corydon.

E-VI. 1. Fourth of July.
2. Thomas Freeman.
3. Columbia (657).
4. Columbia (567).
5. Missouri.
6. Harlem.
7. Vidette.
8. Copper Bottom.
9. Interocean.
10. Hecla.
11. Barnes.
12. Sylvania.
13. Gauntlet.
14. Quaker Lane.
15. Times.
16. Mat France.
17. Big Thunder.
18. Hayes & Wheeler.
19. Continental.
20. Mill site 155B.
21. Pocahontas.
22. Woodbury.
23. Aunt Jennie.
24. Gibson (70).

Finding list of claims shown on map of Central City and vicinity—Continued.

Arranged by coordinates—Continued.

E-VI. 25. Mill site 70 B.
26. Walhala.
27. Register.
28. Climax.
29. Burroughs.
30. Gibson (562).
31. Independence.

E-VII. 1. Hubert.
2. Scottish Chief.
3. Loma.
4. Aunt Jennie.
5. Straughton.
6. Skelly.
7. Great Mammoth.
8. Mill site 59 B.
9. Harrisburg.
10. Gold Bug.
11. Tropic.
12. White Pine.
13. Merrimac.
14. Free Coinage.
15. Diedrick.
16. Maud S.
17. Blue Ridge.
18. Queen Bee.
19. Gold King.
20. Cuno.
21. Gettysburgh.
22. C. H.

E-VIII. 1. Gold Run.
2. Gold Coin.
3. Peck.
4. Center.
5. Organ.
6. Emma.
7. Pine Ridge.
8. Cataract.
9. Russell Gulch.
10. Autocrat.
11. Centennial.
12. Ipavia.
13. Cissler.
14. Whistler.
15. Retriever.
16. Gaston.
17. Defender.
18. Little Jennie.

E-IX. 1. Niagara No. 2.
2. Guion.
3. Star of the West.
4. Missouri.
5. Ridge.
6. Japan.
7. Sunshine.
8. Bengal.
9. Lizzie.
10. Henry Paul placer.
11. Homeguard.
12. Wellington No. 10.
13. Wellington No. 1.
14. East Wellington.
15. Compensation.
16. Wellington Side.
17. West Wellington.
18. London.
19. Two-Forty.

E-X. 1. Compeer.
2. Wellington No. 6.
3. Wellington No. 9.
4. London.
5. Paris.
6. Russell Bell.
7. Central Bell.
8. Daisy Bell.
9. Two-Forty.
10. Junius.
11. Apis.
12. Panurge.
13. Actæón.
14. Osoeze.
15. Geoffrey.

F-I. 1. Dick Wilson.
2. Ben Crenshaw No. 2.
3. Ben Crenshaw.

F-II. 1. Central.
2. Ontario.
3. Gundy.
4. Tucker mill site (216).
5. Tucker Extension.
6. Starling.
7. Cliff.

F-III. 1. Cliff Extension.
2. Doc Beers.
3. Lulu Bowen.
4. Castle Rock.
5. Robert G. Ingersoll.
6. Mill site 440 B.
7. George W. Ellery.
8. Black Quartz.
9. Herbert Spencer.
10. R. P. Ranney (435).
11. R. P. Ranney (94).
12. Louis Napoleon.
13. Arapahoe.

F-IV. 1. Troublesome.
2. Review.
3. Castro.
4. Triangle.
5. Winnebago.
6. Winnebago Extension.
7. Huddleston.
8. National Bank.
9. Teller House.
10. Grand Gift.
11. Mechanics.
12. Gunnell (449).
13. Sapphire.
14. John Hay.
15. Jackson.
16. St. Louis No. 2.
17. Tremont.
18. West St. Louis.
19. Butler-St. Louis.
20. St. Louis.

F-V. 1. Holman.
2. Pleasant View No. 2.
3. Satisfaction.
4. Mountain Lion.
5. Gilpin County.
6. East Boston.
7. Isabel.
8. Cœur d'Alene.
9. Wilber.
10. Pierce.
11. Pierce-Galena.
12. Esperanza.
13. Cora H.
14. Mill site 114 B.
15. Quartz Hill tunnel No. 3.
16. Quartz Hill tunnel No. 6.
17. Minnesota.
18. Ouray.
19. Mill site 143 B.
20. Adaline.

F-VI. 1. Elizabethan.
2. Baxter and Crispin.
3. Hunter Extension.
4. Eldorado.
5. National.
6. Durango.
7. Mammoth West.
8. Summit.
9. Mountain.
10. Pride.
11. Vanderbilt.
12. Aspen.
13. Curran.
14. Grand Junction.
15. Baby B.
16. Texas.
17. Baby A.
18. Times.
19. Mat France.
20. Wright.
21. South Brooklyn.
22. Mill site 410 B.

F-VII. 1. Lincoln.
2. Gladstone.
3. Firenzi.
4. Wells.
5. British.
6. Nugget.
7. Old Dougherty.
8. Imperial.
9. Theodore.
10. Come and see.
11. Thornton.
12. Sunshine.
13. Sunnyside.
14. Reichstag.
15. Prize Baby.

F-VIII. 1. Aurora.
2. West Alva Adams.

Finding list of claims shown on map of Central City and vicinity—Continued.

Arranged by coordinates—Continued.

F-VIII.
3. Extension.
4. S. C. Booth.
5. Pocahontas.
6. Eleventh Hour.
7. Independence.
8. East Centennial.
9. Beacon of the West.
10. Marathon.
11. Eliminator.
12. North Saratoga.
13. Decatur Extension.
14. Lorah.
15. Saratoga tunnel No. 1 West.
16. Congress.
17. Gaston (369).
18. Saratoga West.
19. West Saratoga.
20. Vindicator.

F-IX.
1. Exterminator.
2. Waltham.
3. Timbuctoo.
4. Rover.
5. Henry Paul placer.
6. Pewabic No. 4.
7. Pewabic No. 3.
8. Helmer.
9. Banner No. 2.
10. New House.
11. Maine.
12. Peton.
13. West Hazeltine.
14. Quandry.

F-X.
1. Trentina.
2. Elizbone.
3. Margaret.
4. Old Jordan.
5. Church placer.
6. Searle.
7. Aduddell.
8. Poor Luck.

G-I.
1. Wheeler mill site (382).
2. Tunnel Lode No. 1.
3. Bonanza tunnel No. 28.
4. Bonanza tunnel No. 27.
5. Bonanza tunnel No. 26.
6. Bonanza tunnel No. 25.
7. Bonanza tunnel No. 24.
8. Bonanza tunnel No. 23.
9. Bonanza tunnel No. 22.
10. Bonanza tunnel No. 21.

G-II.
1. Bonanza tunnel No. 20.
2. Bonanza tunnel No. 19.
3. Bonanza tunnel No. 18.
4. Bonanza tunnel No. 17.
5. Bonanza tunnel No. 16.
6. Bonanza tunnel No. 15.
7. Bonanza tunnel No. 14.
8. Bonanza tunnel No. 13.
9. Bonanza tunnel No. 12.
10. Bonanza tunnel No. 11.
11. Bonanza tunnel No. 10.
12. Bonanza tunnel No. 9.
13. Sans Souci.
14. Mountain and Plain.
15. Mountain Club.

G-III.
1. Allie.
2. Security.
3. Black Hawk.
4. Alonzo Fernals.
5. Greenside.
6. First Centennial.
7. East Centennial.
8. General.
9. Dewey.
10. Center.
11. Golden Gate.
12. Queen of the West.
13. Virginia.
14. Huddleston.
15. Maryland.
16. Bonanza tunnel No. 8.
17. Bonanza tunnel No. 7.
18. Bonanza tunnel No. 6.
19. Virginia Extension.
20. Bonanza tunnel No. 5.
21. Bonanza tunnel No. 4.
22. Mill site 240 B.
23. Mill site 384 B.
24. Robert Emmet.
25. Tennel & Belden.

G-IV.
1. St. Louis No. 3.
2. Road Jr.
3. Bueno.
4. Comstock.
5. Clipper.
6. Freedom.
7. Sterling.
8. Rialto.
9. Dillon.
10. Lottie.

G-V.
1. U. S. M. (424).
2. Bugher.
3. Bull of the Woods.
4. Gregory No. 2.
5. Maine.
6. Number One.
7. Hamlet.
8. Kip.
9. Union.
10. Mountain City.
11. Tierney.
12. Epizootic.
13. McCallister.
14. Old Bullion.
15. Homer.
16. Brighton.
17. Brooklyn Eagle.
18. Waterberry.
19. West Michigan.
20. Rhine.
21. Schiller.
22. McAdams.
23. Mosell.
24. Ontonagon.
25. Mill site 53.
26. Calhoun.

G-VI.
1. Mammoth.
2. McAdams.
3. Mammoth Side.
4. Chicago.
5. West Michigan.
6. Republic-Gregory.
7. West Gregory.
8. Cashier.
9. Montana.
10. Lake View.
11. Mountain Rose.
12. Poole.
13. Protection.
14. Good Luck.
15. Empress.
16. Sapsfield.

G-VII.
1. Hamburg.
2. Gold King.
3. Eagle.
4. Mountain.
5. Jasper.
6. Iowa.
7. Bismarck.
8. Gladstone.
9. Augustin.
10. Notice.
11. Baldwin.
12. Little Etta.
13. Blaine.
14. Mattie May.

G-VIII.
1. Alva Adams.
2. Baltimore.
3. Decatur.
4. Saratoga tunnel No. 1 East.
5. East Saratoga.
6. Saratoga.
7. West Chase.
8. Pandora.
9. Chase No. 2.
10. Mammoth.

G-IX.
1. Helmer.
2. Mill site 148 B.
3. Mill site 147 B.
4. Hazeltine.
5. Henry Paul placer.
6. Church placer.
7. Paul.

G-X.
1. Howard.
2. Kokomo.
3. Klondike.
4. Texas.
5. Lost Float.
6. Bimetallic.

H-I.
1. L. C. Rockwell.
2. Brittle Silver.

Finding list of claims shown on map of Central City and vicinity—Continued.

Arranged by coordinates—Continued.

H-I. 3. Juno.
4. Kimber Fullerton mill site.
5. Arrigni mill site.
6. Mill site 185 B.
H-II. 1. Kinney tunnel.
2. Dumas.
3. Howard.
4. Queens County.
5. Mary Ella.
6. Oliver.
7. Discovery of Virginia.
8, 9. Brack Hollow.
H-III. 1. Mill site 272 A.
2. Maryland.
3. Mill site 272 B.
4. Bonanza tunnel No. 3.
5. Bonanza tunnel No. 2.
6. Ætna.
7. Mill site 241 B.
8. Alabama.
9. Road of Elephant.
10. Mill site 385 B.
11. Ninety-Four.
12. Enterprise.
13. South Bend.
14. Surprise.
H-IV. 1. Somes.
2. Billings (200).
3. Billings (168).
4. Prospector.
5. Smith.
6. Wain.
7. Whiteside.
8. Ontonagon.
9. Gregory (879).
10. Levitt.
11. Eliott.
12. Union.
13. Saxon.
14. Vulcan.
15. Gettysburgh.
16. Topeka.
17. Bates.
18. Kitty.
19. Hope No. 2.
20. Next President.
H-V. 1. Hartford.
2. Dump.
3. Mill site 212.
4. Atlantic.
5. O'Neil.
6. Pennsylvania.
7. Golden Crossing.
8. Morning Star.
9. Parole.
10. Mammoth (366).
11. Puzzle
12. Fisk.
13. Cook No. 2.
14. Washington.
H-V. 15. Branch.
16. Orion.
17. Cook (97).
H-VI. 1. Treasury.
2. Allie.
3. King Solomon.
4. Gold Brick.
5. Humboldt.
6. Golden Fleece.
7. Duchess.
8. Katie.
9. Morning Red.
10. Double Eagle.
11. Golden Eagle.
12. Evening Star.
H-VII. 1. Hoff Garten.
2. Seeker-Finder.
3. Lone Tree.
4. Golden Quick.
5. Notaway Belle.
6. Sub-Treasury.
7. Independence.
8. Notaway (136).
9. Homestake.
10. Golden Wedge.
11. Notaway (735).
12. Buffalo.
13. Meeker.
14. Little Raven.
15. Eighty-Niner.
16. Cecil.
17. Notaway (328).
18. Hidee.
H-VIII. 1. Argo.
2. La Place.
3. Big Wampum.
4. Tiger.
5. Nebula.
6. Mohonga.
7. S. P. Chase.
8. Sanger.
9. Bosen Plume.
10. Princess Louise.
11. Minnehaha.
12. New Brunswick.
13. Herschel.
14. War Dance.
15. G. A. S. No. 4.
16. Partner Newcomb.
17. G. A. S. No. 5.
18. Golden.
19. Silver Dollar.
20. Powers.
H-IX. 1. Martin.
2. Conjunction.
3. White Rock.
4. Paul.
5. Kokomo.
6. East Hazeltine.
7. Hammon.
8. Yellow Girl.
H-IX. 9. Ohio.
10. Golden Ridge.
11. Klondike.
12. Texas.
H-X. 1. Mystery.
2. Fate.
3. Golden Ridge.
4. Glascow.
5. Little Annie.
6. McFarlane.
7. Rob Roy.
8. Palo Alto.
9. Silver Ledge.
I-I. 1. St. Louis.
2. Nil Desperandum.
3. Mayflower.
4. Susquehanna.
5. Wheel of Fortune.
6. Little Willie.
I-II. 1. Mill site 221 B.
2. Elsinore.
3. Cyclops.
4. Mammoth Silver.
5. Brack Hollow.
6. Dallas.
7. Mountain mill site.
8. Peru.
9. Julia.
10. Fannie.
11. St. James.
12. Paul Jones.
13. East Star.
14. Slice.
15. Pocahontas.
I-III. 1. Tippecanoe.
2. Powhatan.
3. Freedom.
4. Smith.
5. Extension of Bates.
6. Carbonate.
7. Little Giant.
I-IV. 1. Bates mill site.
2. O. M.
3. P. M.
4. Democrat.
5. A. M.
6. Gregory (267).
7. Gregory Extension.
8. Gregory (373).
9. Mill site 2378.
10. Mill site 186 B.
11. Mill site 128 B.
12. Sleepy Hollow.
13. Blyth.
14. Sioux City.
15. Americus.
I-V. 1. Lizzie.
2. Ground Hog.
3. Broadway.
4. Bobtail (489).
5. Mollie Stark.

Finding list of claims shown on map of Central City and vicinity—Continued.

Arranged by coordinates—Continued.

Arranged alphabetically.

Finding list of claims shown on map of Central City and vicinity—Continued.

Arranged alphabetically—Continued.

Bonanza tunnel No. 10. G–II: 11.
Bonanza tunnel No. 11. G–II: 10.
Bonanza tunnel No. 12. G–II: 9.
Bonanza tunnel No. 13. G–II: 8.
Bonanza tunnel No. 14. G–II: 7.
Bonanza tunnel No. 15. G–II: 6.
Bonanza tunnel No. 16. G–II: 5.
Bonanza tunnel No. 17. G–II: 4.
Bonanza tunnel No. 18. G–II: 3.
Bonanza tunnel No. 19. G–II: 2.
Bonanza tunnel No. 20. G–II: 1.
Bonanza tunnel No. 21. G–I: 10.
Bonanza tunnel No. 22. G–I: 9.
Bonanza tunnel No. 23. G–I: 8.
Bonanza tunnel No. 24. G–I: 7.
Bonanza tunnel No. 25. G–I: 6.
Bonanza tunnel No. 26. G–I: 5.
Bonanza tunnel No. 27. G–I: 4.
Bonanza tunnel No. 28. G–I: 3.
Bonny Bell. D–X: 6.
Bon Ton. C–VIII: 11; D–II: 4.
Boodle. C–III: 4.
Bosen Plume. H–VIII: 9.
Boston. B–VII: 13; B–VIII: 1.
Boston Boy. I–VIII: 4.
Bouvier. C–VII: 25.
Brack Hollow. H–II: 8; H–II: 9; I–II: 5.
Branch. H–V: 15.
Bremen. A–IX: 14.
Broadway. I–V: 3.
Bronco. A–X: 1.
Brooklyn Eagle. G–V: 17.
Brighton. G–V: 16.
British. F–VII: 5.
Brittle Silver. H–I: 2.
Bryant. A–X: 2.
Buckeye. E–II: 3; D–VI: 8.
Buckley. E–IV: 7.
Buena Vista. D–V: 13.
Bueno. G–IV: 3.
Buffalo. H–VII: 12.
Bugher. G–V: 2.
Bullion (459). E–II: 5.
Bullion (9607). E–II: 4.
Bullion No. 2. C–IV: 1.
Bullion No. 6. C–IV: 2.
Bull of the Woods. G–V: 3.
Bunker Hill. I–VIII: 17.
Burlington. E–III: 9.
Burro. C–VII: 7.
Burroughs. E–VI: 29; C–VI: 11.
Burroughs (176). D–VI: 13.
Burroughs (262). D–VI: 12.
Butler-St. Louis. F–IV: 19.

Caledonia. B–VII: 10.
Caledonia No. 2. I–VII: 14.
Calhoun. D–VII: 7; G–V: 26.
Calhoun (837). C–VII: 24; C–VIII: 5.
Calhoun (231). C–VIII: 3.
California. C–VI: 18.
Calumet & Hecla. I–VII: 12.
Calumet & Hecla No. 2. I–VII: 11.
Cameron. E–IV: 5.
Camper Down. A–X: 9.
Camp Grove (86). C–VI: 35.
Canton. D–VIII: 6.
Capitol. B–VIII: 7.
Capitol Prize. B–VIII: 9.
Carbonate. I–III: 6.
Carmichel. E–I: 2.
Carr. I–VI: 11.
Carrie G. D–IV: 10.
Carroll. D–III: 6.
Cashier. G–VI: 8.
Castle Rock. F–III: 4.
Castro. F–IV: 3.
Cataract. E–VIII: 8.
Cecil. H–VII: 16.
Cecilia. C–X: 10.
Cedar. E–III: 2.
Celtic. A–IX: 13.
Cemetery. C–III: 3.
Centennial. E–VIII: 11.
Center. E–VIII: 4; G–III: 10.
Central. F–II: 1.
Central Bell. E–X: 7.
C. H. E–VII: 22.
Champion. C–V: 5.
Charter Oak. B–VIII: 4.
Chase No. 2. G–VIII: 9
Chicago. B–II: 2; G–VI: 4.
Chief. B–IV: 2.
C. H. Smith placer. D–VIII: 18.
Church placer. F–X: 5; G–IX: 6.
Cissler. E–VIII: 13.
Claire-Marie. D–III: 5.
Clayton's Dream. C–IX: 20.
Cliff. F–II: 7.
Cliff Extension. F–III: 1.
Clifton Bell. D–X: 7.
Climax. E–VI: 28; D–VI: 17.
Clipper. G–IV: 5.
Cœur d'Alene. F–V: 8.
Colorado Girl. E–II: 10.
Columbia. E–V: 20; B–X: 21.
Columbia (657). E–VI: 3.
Columbia (567). E–VI: 4.
Columbia Avenue. D–IV: 4.
Columbus. D–VIII: 12.
Come and see. F–VII: 10.
Compeer. D–X: 3; E–X: 1.
Compensation. E–IX: 15.
Comstock. G–IV: 4.
Concrete. C–V: 4.
Conemara. B–VIII: 19.
Confidence. D–VI: 26.
Congress. D–IV: 1; F–VIII: 16.
Congressional. B–IX: 9.
Conjunction. I–VIII: 16; H–IX: 2.
Continental. E–VI: 19.
Cook (97). H–V: 17.
Cook No. 2. H–V: 13.
Cooper. B–IX: 1; B–VI: 14.
Copper Bottom. E–VI: 8.
Cora H. F–V: 13.
Cork. E–V: 22.
Corydon. E–V: 23.
Cotton. I–V: 9.
Courtland. B–VII: 9.
Crœsus. C–IX: 11.
Crœsus Extension. C–IX: 10.
Cuno. E–VII: 20.
Curran. F–VI: 13.
Cyclops. I–II: 3.
Cymbra. D–V: 14.

Daisy Bell. E–X: 8.
Dale. I–VII: 2.
Dallas. I–II: 6.
Danforth. C–X: 13.
Day Spring. B–VIII: 8.
Day Spring Extension. C–VII: 22; C–VIII: 2.
Dayton. A–IX: 3.
Decatur. G–VIII: 3.
Decatur Extension. F–VIII: 13.
Defender. B–III: 1; B–V: 5; E–VIII: 17.
Defiance. C–VIII: 21.
Delaware (460 A). B–VIII: 12.
Delaware mill site 460 B. B–VIII: 13.
Delight. E–II: 7.
Delmonico. B–VII: 16.
Del Monte. A–VI: 1.
Democrat. I–IV: 4.
Denbigh. A–IX: 20.
Denmark. I–V: 12.
Denver. C–IX: 3.
Dewey. G–III: 9.
Dexter. C–VII: 10.
Dick Wilson. F–I: 1.
Dictator. E–III: 2.
Diedrick. B–VII: 15.
Dillon. G–IV: 9.
Discovery of Virginia. H–II: 7.
Di Vernon. E–V: 11.
Doc Beers. F–III: 2.
Double Eagle. H–VI: 10.
Douglas. C–VI: 2.
Dover. C–V: 3.
Duchess. H–VI: 7.
Dumas. H–II: 2.
Dump. H–V: 2.
Durango. F–VI: 6.
Dyke. D–V: 21.

Finding list of claims shown on map of Central City and vicinity—Continued.

Arranged alphabetically—Continued.

Eagle. G–VII: 3.
East Boston. F–V: 6.
East Calhoun (7319). D–VII: 13.
East Calhoun (11130). D–VII: 6.
East Centennial. G–III: 7; F–VIII: 8.
East Flack (929). C–VI: 23.
East Harsh Extension. D–VII: 12.
East Hazeltine. H–IX: 6.
East Keystone. E–II: 6.
East Leavenworth. C–VIII: 18.
East Nevada. E–V: 5.
Easton. E–II: 8.
East Saratoga. G–VIII: 5.
East Star. I–II: 13.
East Wellington. E–IX: 14.
Edinborough. D–VI: 21.
Effie. C–VII: 21.
Egyptian. D–VI: 32.
Eighty-Four. B–X: 13.
Eighty-Niner. H–VII: 15.
Eighty-Three. D–IX: 13.
Eldorado. F–VI: 4; B–VIII: 15.
Eleventh Hour. F–VIII: 6.
Eliminator. F–VIII: 11.
Eliott. H–IV: 11.
Elizabeth. I–VII: 8.
Elizabethan. F–VI: 1.
Elizbone. F–X: 2.
Elsinore. I–II: 2.
Emma. E–VIII: 6.
Empire. A–VII: 5.
Empress. G–VI: 15.
Enterprise. H–III: 12.
Epizootic. G–V: 12.
Esmeralda. C–X: 19.
Esperanza. F–V: 12.
Essex. C–V: 1.
Essex No. 2. B–V: 14.
Ethan Allen. C–VII: 16.
Ethlyn. A–IX: 17.
Eureka. D–IV: 7.
Evelyn. I–VII: 9.
Evening Star. H–VI: 12.
Express. B–VI: 12.
Extension. F–VIII: 3.
Extension of Bates. I–III: 5.
Extenuate. D–VI: 24.
Exterminator. F–IX: 1.
Ezra White. B–VIII: 6.

Fagan. D–IV: 13.
Fairfield. A–IX: 4.
Fannie. I–II: 10; C–X: 15.
Fate. H–X: 2.
Fay. I–VII: 5.
Federal B–X: 3; C–X: 3.
Firenzi. F–VII: 3.
First Centennial. G–III: 6.
Fisk. I–V: 8; H–V: 12.
Fissure. C–IV: 8.
Flack. B–VI: 16.
Flack (65). C–VI: 24.
Flack (664). C–VI: 22.
Florence D. A–VIII: 15.
Fourth of July. E–VI: 1.
Francis. C–II: 1.
Free American. D–VIII: 13.
Free Coinage. B–IX: 14; E–VII: 14.
Freedom. I–III: 3; G–IV: 6.
Freiberg. E–III: 11.
Fremont. C–VIII: 6.
French. B–VII: 14; B–VIII: 2.

Galton. A–VI: 7.
Garden. C–III: 7.
Garden No. 2. C–III: 6.
Gardner. C–VI: 19; D–VI: 23.
Gardner Extension. A–VI: 8.
G. A. S. No. 1. I–VIII: 13.
G. A. S. No. 2. I–VIII: 14.
G. A. S. No. 3. I–VIII: 5.
G. A. S. No. 4. H–VIII: 15.
G. A. S. No. 5. H–VIII: 17.
Gaston. E–VIII: 16.
Gaston (369). F–VIII: 17.
Gauntlet. E–VI: 13.
Gem. A–VII: 13; B–VIII: 5.
General. G–III: 8.
General Logan. D–II: 1.
Genuine. C–V: 15.
Geoffrey. E–X: 15.
George. B–V: 1.
George Deemster. D–VIII: 4.
George W. Ellery. F–III: 7.
Geraldine. B–VI: 4.
German. C–VII: 5.
Gettysburgh. E–VII: 21; H–IV: 15.
Gibraltar. A–VIII: 3.
Gibson (562). E–VI: 30.
Gibson (70). E–VI: 24.
Gilpin County. F–V: 5.
Gladstone. B–X: 10; F–VII: 2; G–VII: 8.
Glascow. H–X: 4.
Gold. D–III: 1.
Gold Brick. H–VI: 4.
Gold Bug. E–VII: 10; D–IV: 5.
Gold Coin. A–VI: 12; E–VIII: 2.
Gold Cup. E–II: 1.
Gold Dollar. D–X: 15.
Golden. H–VIII: 18.
Golden Cloud. B–X: 19.
Golden Crossing. H–V: 7.
Golden Dollar. A–VIII: 11.
Golden Eagle. H–VI: 11.
Golden Fleece. H–VI: 6.
Golden Gate. G–III: 11.
Golden Quick. H–VII: 4.
Golden Ridge. H–IX: 10; H–X: 3.
Golden Star. A–X: 15.
Golden Treasure. C–V: 7.
Golden Wedge. H–VII: 10.
Golden Wing. A–VIII: 8.
Gold King. G–VII: 2; C–VIII: 7; E–VII: 19.
Gold Retort. D–VI: 15.
Gold Ring. C–VIII: 14.
Gold Run. E–VIII: 1.
Gomer. B–IX: 3.
Gomer No. 2. B–IX: 12
Good Luck. G–VI: 14.
Gopher. D–VIII: 5.
Governor Adams. C–VI: 32.
Grace. A–VIII: 9.
Grand Army. D–IV: 12.
Grand Gift. F–IV: 10.
Grand Junction. F–VI: 14.
Grand River. C–VI: 13.
Grand View. J–VIII: 2.
Grasshopper. C–X: 22.
Great Mammoth. E–VII: 7.
Greenside. G–III: 5.
Gregory (879). H–IV: 9.
Gregory No. 2. G–V: 4.
Gregory (267). I–IV: 6.
Gregory (373). I–IV: 8.
Gregory Extension. I–IV: 7.
Griffin. B–VII: 7.
Grisley. A–X: 5.
Ground Hog. I–V: 2.
Guion. E–IX: 2; D–IX: 4.
Gulch. I–VII: 1.
Gulnare. E–III: 7.
Gundy. F–II: 3.
Gunn. B–VII: 15.
Gunnell No. 2. E–IV: 8.
Gunnell (71). E–IV: 9.
Gunnell (449.) F–IV: 12.
Gunnell (470). E–IV: 14.
Gunnell mill site 473. E–IV: 13.

Hail Storm. C–X: 18.
Hamburg. G–VII: 1.
Hamilton. D–III: 8.
Hamlet. G–V: 7.
Hammon. H–IX: 7.
Hampton. I–VIII: 11.
Hannibal. D–VI: 20.
Hard to Beat. I–VIII: 22.
Harkaway. E–III: 6.
Harlem. E–VI: 6.
Harrisburg. E–VII: 9.
Harrison. C–VIII: 19; D–I: 2.
Harsh. D–VIII: 7.
Hartford. H–V: 1.
Hawkeye. A–VI: 6.
Hayes and Wheeler. E–VI: 18.
Hazard. A–VIII: 22.
Hazeltine. G–IX: 4.
Hecla. E–VI: 10.

Finding list of claims shown on map of Central City and vicinity—Continued.

Arranged alphabetically—Continued.

Helen Gould. I-VII: 16.
Helmer. F-IX: 8; G-IX: 1.
Heloe. A-VI: 13.
Henry Paul placer. E-IX: 10; F-IX: 5; G-IX: 5.
Herbert. B-V: 4.
Herbert Spencer. F-III: 9.
Herman. D-V: 3.
Herschel. H-VIII: 13.
Hickory. B-VI: 3.
Hidden Treasure. C-VI: 16.
Hidden Treasure No. 2. C-VI: 17.
Hidee. H-VII: 18.
High Grade. E-V: 3.
Hill House. C-VIII: 27.
Hoff Garten. H-VII: 1.
Hogan. C-VIII: 26.
Holland. D-VIII: 11.
Holman. F-V: 1.
Home. D-VIII: 3.
Homeguard. E-IX: 11.
Homer. G-V: 15.
Homestake. B-IX: 13; H-VII, 9.
Hope No. 2. H-IV: 19.
Hot Time. C-IX: 23.
Howard. A-VIII: 2; H-II: 3; G-X: 1.
Hubert. E-VII: 1; C-V: 13.
Hubert Extension. B-V: 17.
Hubert Fork. B-V: 16.
Huddleston. F-IV: 7; G-III: 14.
Humboldt. C-V: 11; E-IV: 2; H-VI: 5.
Hunky Dory. I-VI: 4.
Hunter Extension. F-VI: 3.
Hydrant. D-IV: 11.

Ida. C-X: 23.
Idea. D-II: 6.
Illinois. D-VI: 27.
Imperial. F-VII: 8.
Ina. B-VII: 5.
Incidental. C-IX: 13.
Independence. E-VI: 31; C-IV: 6; F-VIII: 7; H-VII: 7.
Indiana. B-VI: 10.
Indiana Extension. A-VI: 11.
Ingalls. D-VI: 29.
Ingomar. C-VII: 9.
Interocean. E-VI: 9.
Iowa. E-III: 10; D-III: 10; G-VII: 6.
Ipavia. E-VIII: 12.
Irene. E-III: 5.
Iroquois. I-VIII: 15.
Irish Flag. C-VI: 9.
Iron. C-X: 8.
Iron Duke. D-X: 1.
Iron Rock. D-V: 10.
Iron West. B-X: 11.
Irving. B-V: 12.
Isabel. F-V: 7.
Isabella. E-V: 14.
Isle Royal. A-IX: 6.
Ivanhoe. A-VII: 4.
I. X. L. D-IX: 7; E-IV: 4.

Jackson. F-IV: 15.
James Henry. E-IV: 12.
Janitor. C-I: 2.
Jan Joan. D-VI: 22.
Japan. E-IX: 6.
Jasper. G-VII: 5.
Jay Eye See. C-V: 9.
Jay Gould. D-VI: 10.
Jefferson (768). B-VIII: 11.
Jefferson (1011). B-VIII: 10.
Jessie. D-VII: 3.
J. L. C-X: 16.
John Hay. F-IV: 14.
John L. Emerson. A-X: 12.
Jones. D-V: 23; C-V: 14.
Josephine. D-V: 4.
J. P. Whitney. C-IV: 4.
Julia. I-II: 9.
Junius. E-X: 10.
Juno. H-I: 3.
Jupiter. A-VII: 12; A-IX: 7.

"K." D-VII: 10.
Kansas. B-VI: 6; E-V: 12.
Kansas mill site (91 B). C-VI: 5.
Kansas No. 4. C-VI: 4.
Kansas (67). C-VI: 34.
Kansas (87). C-VI: 33.
Kansas (91). C-VI: 6.
Kansas (610). D-VI: 4.
Kate Kearney. B-V: 10.
Katie. H-VI: 8.
Kent County. C-VI: 29.
Keystone. A-VII: 9; B-VI: 11.
Kimber Fullerton mill site. H-I: 4.
King Solomon. H-VI: 3.
Kinney tunnel. H-II: 1.
Kip. G-V: 8.
Kirk. C-VII: 18.
Kitty. H-IV: 18.
Klondike. G-X: 3; H-IX: 11.
Kokomo. G-X: 2; H-IX: 5.
Kohinoor No. 2. D-IV: 3.
Kriegbaum. D-V: 5.

Lake Superior. D-III: 14.
Lake View. G-VI: 10.
La Place. H-VIII: 2.
Last Chance. C-VII: 6.
L. C. Rockwell. H-I: 1.
Leavenworth. C-VIII: 10.
Legal Tender. A-X: 19; B-X: 14.
Leonidas. A-VII: 11.
Leontine. A-VII: 6.
Levis mill site. D-V: 25.
Levitt. H-IV: 10.
Lewis. E-V: 18.
Liberty. D-VIII: 14.
Liberty Bell. D-X: 9.
Lilian. D-IX: 9.
Lilly Rose. D-III: 11.
Lincoln. F-VII: 1.
Little Annie. H-X: 5.
Little Chief. D-III: 7.
Little Etta. G-VII: 12.
Little Giant. I-III: 7.
Little Harvey. I-VI: 6.
Little Jennie. E-VIII: 18.
Little Mack. E-IV: 1.
Little Pittsburg. I-VI: 12; D-VI: 18.
Little Raven. H-VII: 14.
Little Willie. I-I: 6.
Lizzie. I-V: 1; I-VI: 1; E-IX: 9.
Lizzie S. C-VII: 8.
Livingstone. B-X: 15.
Loma. E-VII: 3.
London. E-IX: 18; E-X: 4.
Lone Tree. H-VII: 3.
Lorah. F-VIII: 14.
Lorillard. I-VIII: 8.
Lost Float. G-X: 5.
Lottie. D-X: 13; G-IV: 10.
Lotus. C-IX: 22.
Louis. C-III: 5.
Louisiana. D-IX: 2.
Louis Napoleon. F-III: 12.
Luckie Ducky. I-VI: 9.
Lucky Boy. D-IX: 8.
Lulu Bowen. F-III: 3.
Lutz. D-IX: 6.
Lutz Extension. C-IX: 4.
Lyman. E-V: 10.

McAdams. G-VI: 2; G-V: 22.
McCallister. G-V: 13.
Mackie. C-VII: 12.
Maggie M. D-III: 3.
Maine. F-IX: 11; G-V: 5.
Major. C-IX: 15.
Maldar. A-VIII: 16.
Mammoth. G-VI: 1; G-VIII: 10.
Mammoth (366). H-V: 10.
Mammoth Side. G-VI: 3.
Mammoth Silver. I-II: 4.
Mammoth West. F-VI: 7.
Manahan. I-V: 6.
Maraposa. C-VI: 30.
Marathon. F-VIII: 10.
Margaret. C-IX: 19; F-X: 3.
Marine. D-IV: 9.
Marks. I-VII: 6.
Mars. C-X: 11.
Martin. H-IX: 1; I-VIII: 21.
Mary Ella. H-II: 5.

Finding list of claims shown on map of Central City and vicinity—Continued.

Arranged alphabetically—Continued.

Maryland. G–III: 15; H–III: 2.
Mat France. E–VI: 16; F–VI: 19.
Mattie May. G–VII: 14.
May. A–VIII: 5.
Mayflower. C–VIII: 4; D–V: 19; I–I: 3; I–VIII: 19.
Maud S. E–VII: 16.
Maud S. (6351). D–VIII: 8.
Mechanics. F–IV: 11.
Meeker. H–VII: 13; I–VIII: 6.
Membrino. C–V: 16.
Mercer County. C–VI: 25.
Mercer County Extension. C–VI: 26.
Mercury. D–VII: 9.
Merrimac. E–VII: 13.
Michigan Boy. D–VIII: 10.
Mill site 52. E–V: 7.
Mill site 53. G–V: 25.
Mill site 59 B. E–VII: 8.
Mill site 70 B. E–VI: 25.
Mill site 88 B. D–VI: 1.
Mill site 101 B. D–VI: 35.
Mill site 111 B. C–VI: 36.
Mill site 114 B. F–V: 14.
Mill site 128 B. I–IV: 11.
Mill site 143 B. F–V: 19.
Mill site 147 B. G–IX: 3.
Mill site 148 B. G–IX: 2.
Mill site 151. E–V: 15.
Mill site 155 B. E–VI: 20.
Mill site 160 B. D–VI: 2.
Mill site 180. C–X: 1.
Mill site 185 B. H–I: 6.
Mill site 186 B. I–IV: 10.
Mill site 210. C–VI: 37.
Mill site 212. H–V: 3.
Mill site 221 B. I–II: 1.
Mill site 240 B. G–III: 22.
Mill site 241 B. H–III: 7.
Mill site 247. C–VIII: 8.
Mill site 272 A. H–III: 1.
Mill site 272 B. H–III: 3.
Mill site 350 B. C–VI: 38.
Mill site 384 B. G–III: 23.
Mill site 385 B. H–III: 10.
Mill site 410 B. F–VI: 22.
Mill site 440 B. F–III: 6.
Mill site 619 B. C–VI: 7.
Mill site 2378. I–IV: 9.
Mineral. B–VII: 4.
Minnehaha. H–VIII: 11.
Minnesota. C–IX: 12; E–III: 8; F–V: 17.
Missouri. E–VI: 5; E–IX: 4.
Mitchell. C–VII: 3.
Modoc. D–VI: 34.
Mohonga. H–VIII: 6.
Mollie Gibson. D–VI: 28.
Mollie Newcombe. B–VIII: 17.
Mollie Stark. I–V: 5.
Mollie Stark Extension. I–VI: 8.
Monadnoc. D–VII: 11.
Monitor. C–III: 2; C–VI: 10.
Monroe (195). D–VI: 7.
Monroe (643). D–VI: 5.
Monroe (8420). D–VI: 6.
Montana. A–IX: 11; G–VI: 9.
Montclair. C–X: 14.
Monte Christo. A–VIII: 17.
Montezuma. E–II: 2.
Montrose. E–IV: 6.
Morning Star. A–IX: 19; H–V: 8.
Morning Red. H–VI: 9.
Morrell. B–VIII: 20.
Morris. I–VII: 18.
Mosell. G–V: 23.
Motto. C–V: 10.
Mount Lincoln. E–IV: 15.
Mountain. F–VI: 9; G–VII: 4.
Mountain mill site. I–II: 7.
Mountain and Plain. G–II: 14.
Mountain City. G–V: 10.
Mountain Club. G–II: 15.
Mountain Lion. F–V: 4.
Mountain Rose. G–VI: 11.
Munson. B–X: 7.
Mystery. H–X: 1.
Mystic. A–VI: 5.

Nagle. A–X: 10.
Nashville. B–X: 20.
National. F–VI: 5.
National Bank. F–IV: 8.
Nebula. H–VIII: 5.
Nelson. C–IX: 1.
Nemeha. I–V: 10.
Neptune. A–VII: 8.
New Brunswick. H–VIII: 12.
New Chicago. D–VI: 9.
Newfoundland. D–V: 16.
Newfoundland No. 2. D–V: 17.
New Home. D–VIII: 2.
New House. F–IX: 10.
New Jersey. I–V: 7.
New Pikes Peak. C–VII: 2.
New York. E–V: 19.
Next President. H–IV: 20.
Niagara. D–VIII: 17.
Niagara No. 2. E–IX: 1.
Nil Desperandum. I–I: 2.
Ninety-Four. H–III: 11.
Ninety-Three. B–X: 18.
Nominee. E–IV: 10.
No Name. A–VI: 10.
Norton. D–I: 1.
North. B–X: 16; D–VII: 5.
North Eclipse. B–VIII: 3.
North Fairfield. A–IX: 2.
Northrop. B–VI: 7.
North Saratoga. F–VIII: 12.
North Star. D–V: 7.
Notaway (136). H–VII: 8.
Notaway (328). H–VII: 17.
Notaway (735). H–VII: 11.
Notaway Belle. H–VII: 5.
Notaway Extension. I–VI: 13.
Notice. G–VII: 10.
Nugget. F–VII: 6.
Number One. G–V: 6.

Oakland. D–VI: 16.
Octavia Rachel. B–VII: 2.
Ohio. C–VIII: 22; H–IX: 9.
Old Bullion. G–V: 14.
Old Dougherty. F–VII: 7.
Old Guard. D–X: 11.
Old Jordan. F–X: 4.
Old Rice. E–V: 16.
Oldtown. C–IX: 18.
Olga. D–X: 12.
Oliver. H–II: 6.
Olympia. B–VII: 6.
Onandaga Chief. E–I: 1.
O'Neil. H–V: 5.
Only Boy. D–II: 3.
Ontario. F–II: 2.
Ontonagon. G–V: 24; H–IV: 8.
O. M. I–IV: 2.
Oranoake. B–VI: 1.
Oranoake Extension. B–VI: 2.
Oregon. A–X: 21.
Organ. E–VIII: 5.
Orient. A–VII: 3.
Orion. B–IX: 2; H–V: 16.
Oro. E–III: 12.
Osoeze. A–IX: 15; E–X: 14.
Ouray. F–V: 18.
Overland. D–VIII: 9.

Pacific. D–III: 4.
Palo Alto. H–X: 8.
Pandora. G–VIII: 8.
Panurge. E–X: 12.
Paola. C–VIII: 12.
Paris. D–X: 14; E–X: 5.
Parole. C–V: 12; H–V: 9.
Partner Newcomb. H–VIII: 16.
Paul. G–IX: 7; H–IX; 4.
Paul Jones, I–II: 12.
Pawtucket. B–X: 12.
Peale. B–IX: 8.
Peck. E–VIII: 3.
Pendleton. B–IX: 5.
Pennsylvania. H–V: 6.
Perrin. C–VIII: 25.
Peru. I–II: 8.
Peton. F–IX: 12.

Finding list of claims shown on map of Central City and vicinity—Continued.

Arranged alphabetically—Continued.

Pewabic. D-IX: 15.
Pewabic (125). C-X: 4.
Pewabic (560). C-X: 5.
Pewabic No. 3. F-IX: 7.
Pewabic No. 4. F-IX: 6.
Phillips. C-IX: 9.
Phoenix. A-X: 17; B-IX: 6.
Pierce. F-V: 10.
Pierce-Galena. F-V: 11.
Pikes Peak Extension. D-VII: 1.
Pine Ridge. E-VIII: 7.
Pittsburg. B-IX: 4; I-VII: 10.
Pittsburg Extension. I-VII: 17.
Placer (858). C-IX: 6.
Pleasant View No. 2. F-V: 2.
P. M. I-IV: 3.
Pocahontas. E-VI: 21; F-VIII: 5; I-II: 15.
Pogue. C-IX: 16.
Polar Star. C-VII: 19; E-III: 4.
Poole. G-VI: 12.
Poor Luck. F-X: 8.
Porphyry. A-VI: 9.
Post Hole. D-V: 24.
Portage. B-VIII: 16.
Powell. B-VI: 15.
Powers. H-VIII: 20.
Powhatan. I-III: 2.
Pratt. D-VI: 31.
President Hayes. A-X: 16.
Preston. B-IX: 7.
Pride. F-VI: 10.
Princess Louise. H-VIII: 10.
Prize. D-V: 9.
Prize Baby. F-VII: 15.
Prize Extension. D-V: 11.
Prompt Pay. A-VIII: 18.
Prospector. D-III: 13; H-IV: 4.
Protection. D-VI: 33; G-VI-13.
Providence. C-VI: 15.
Pure Gold. A-VIII: 4.
Puritan. B-V: 6.
Puzzle. H-V: 11.
Pyrenees. B-VII: 11.
Pyrenees Extension. B-VII: 12.

Quaker City. A-VIII: 6.
Quaker Lane. E-VI: 14.
Quandry. F-IX: 14.
Quartz Hill tunnel No. 3. F-V: 15.
Quartz Hill tunnel No. 6. F-V: 16.
Quartz Mill. C-VIII: 9.
Quartz Valley placer. A-II: 1; C-I: 1.
Queen Bee. E-VII: 18.
Queen of the West. G-III: 12.
Queens County. H-II: 4.

Rainbow. I-VIII: 7.
Rajah. A-X: 7.
Randell Extension. C-VI: 14.
Randolph. B-VIII: 14.
Randolph Extension. A-VIII: 20.
Rara Avis. C-IV: 3.
Rara Avis Extension. B-IV: 1.
Ravenswood. E-II: 9.
Ready Cash. C-IV: 7.
Register. E-VI: 27.
Reichstag. F-VII: 14.
Reno. E-V: 2.
Republic-Gregory. G-VI: 6.
Retriever. D-V: 1; E-VIII: 15.
Review. F-IV: 2.
R. H. D. E-III: 3.
Rhine. G-V: 20.
Rhode Island. C-VI: 28.
Rhoderick Dhu. D-VI: 25.
Rialto. G-IV: 8.
Richardson. C-X: 6.
Ridge. E-IX: 5.
Rist Placer. C-IX: 5.
Road of Elephant. H-III: 9.
Road Jr. G-IV: 2.
Robert Emmet. G-III: 24.
Robert Fulton. B-X: 9.
Robert G. Ingersoll. F-III: 5.
Rob Roy. H-X: 7.
Rockford. C-VIII: 24.
Rocky Mountain Terror. B-X: 6.
Rosebud. C-IX: 14.
Rover. F-IX: 4.
Royal. D-IX: 1.
R. P. Ranney (94). F-III: 11.
R. P. Ranney (435). F-III: 10.
Rubber. B-X: 5.
Ruby. A-IX: 16; C-VIII: 20.
Russell. B-IX: 11.
Russell Bell. E-X: 6.
Russell Gulch. E-VIII: 9.
Russell Pride. C-IX: 2.

"S". B-IV: 3.
Salpiro. B-V: 11.
Salvator. B-VI: 5.
Sam Lee. A-X: 20.
Sanger. H-VIII: 8.
Sans Souci. G-II: 13.
Sapphire. F-IV: 13.
Sapsfield. G-VI: 16.
Saratoga. G-VIII: 6.
Saratoga tunnel No. 1 East. G-VIII: 4.
Saratoga tunnel No. 1 West. F-VIII: 15.
Saratoga West. F-VIII: 18.
Satisfaction. F-V: 3.
Saxon. H-IV: 13.
Scandia. D-VII: 2.
S. C. Booth. F-VIII: 4.
Schiller. G-V: 21.
Scottish Chief. E-VII: 2.
Searle. F-X: 6.
Security. G-III: 2.
Seeker-Finder. H-VII: 2.
Senate. C-IV: 5.
Senatorial. B-IX: 10.
Seuderberg. D-V: 12.
Shafts. B-V: 8.
Shamrock. A-VIII: 13.
Shamrock II. A-IX: 12.
Shaw. C-VII: 14.
Silent King. D-V: 6.
Silent Queen. E-IV: 11.
Silver Coin. A-VI: 14.
Silver Dollar. H-VIII: 19.
Silver Ledge. H-X: 9.
Silver Mug. A-V: 1.
Sioux City. I-IV: 14.
Siren. A-VII: 2.
Skelly. E-VII: 6.
Skelton. B-V: 13.
Slaughter House. D-V: 8.
Slavonic. A-X: 8.
Sleepy Hollow. I-IV: 12.
Slice. I-II: 14.
Smith. H-IV: 5; I-III: 4.
Soden. B-VII: 3.
Soden Extension. A-VII: 7.
Somes. H-IV: 1.
Song. A-VIII: 7.
South Bend. H-III: 13.
South Brooklyn. F-VI: 21.
South Fairfield. A-IX: 5.
S. P. Chase. H-VIII: 7.
Spring. A-VIII: 10.
Springdale. A-IX: 10.
Spur Daisy. C-III: 1.
St. Clair. A-IX: 8.
St. James. I-II: 11.
St. Louis. F-IV: 20; I-I: 1.
St. Louis No. 2. F-IV: 16.
St. Louis No. 3. G-IV: 1.
St. Louis Extension. E-V: 6.
Starling. F-II: 6.
Star of the West. E-IX: 3; I-VIII: 9.
Star Route. I-VII: 3; I-VIII: 3.
Sterling. G-IV: 7.
Stewart. B-VIII: 22.
Storm King. D-III: 9.
Straub. E-V: 4.
Straughton. E-VII: 5.
Stub Tail. E-V: 8.
Sub-Treasury. H-VII: 6.
Success. C-IX: 21; I-VIII: 2.
Suffolk. B-V: 9.
Sugar Tit. C-VII: 1.
Sullivan. D-VI: 3.
Summit. A-X: 18; F-VI: 8.

Finding list of claims shown on map of Central City and vicinity—Continued.

Arranged alphabetically—Continued.

Sun. B-VII: 1.
Sunflower. D-V: 18.
Sunnyside. F-VII: 13.
Sunshine. E-IX: 7; F-VII: 12.
Surprise. H-III: 14.
Susquehanna. I-I: 4.
Sutton. I-VII: 13.
Swiss Home. D-VIII: 1.
Sylvania. E-VI: 12.
Symonds. B-VI: 13.

Tarquin. A-IX: 21.
Telegraph. D-VII: 8.
Telephone. C-VII: 15.
Teller House. F-IV: 9.
Tennel & Belden. G-III: 25.
Texas. F-VI: 16; G-X: 4; H-IX: 12.
Theodore. F-VII: 9.
Thomas Freeman. E-VI: 2.
Thornton. F-VII: 11.
Thunderbolt. A-X: 11.
Thurman. E-IV: 3.
Tierney. G-V: 11.
Tiger. E-III: 1; H-VIII: 4.
Tigress. C-VII: 13.
Timbuctoo. F-IX: 3.
Times. E-VI: 15; F-VI: 18.
Tippecanoe. I-III: 1.
Togo. C-X: 21.
Tonight. B-X: 1.
Topeka. B-VIII: 21; C-VIII: 13; H-IV: 16.
Topeka (100). C-VIII: 17.
Topeka (518). C-VIII: 16.
Torrent. A-VII: 1.
Treasury. H-VI: 1.
Tremont. F-IV: 17.
Trentina. F-X: 1.
Triangle. F-IV: 4.
Triton. A-IX: 1.
Tropic. E-VII: 11.
Troublesome. F-IV: 1.
Truran. C-VI: 12.
Tucker Extension. F-II: 5.
Tucker mill site (216). F-II: 4.
Tunnel Lode No. 1. G-I: 2.
Two Sisters. D-III: 2.
Two-Forty. E-IX: 19; E-X: 9.

Uncle Sam. I-VIII: 1.
Unexpected. I-VI: 10.
Union. A-VIII: 19; G-V: 9; H-IV: 12.
U. S. M. (424). G-V: 1.
Ute. C-VI: 8.

Vanderbilt. F-VI: 11; E-V: 17.
Vendome. A-VI: 4.
Venus. B-X: 17.
Vermilion. A-VII: 10.
Victor. C-X: 17.
Victoria mill site (5568). D-VIII: 20.
Vidette. E-VI: 7.
Vigilant. B-V: 7.
Vindicator. F-VIII: 20.
Virginia. C-X: 20; G-III: 13.
Virginia Extension. G-III: 19.
Vulcan. H-IV: 14.

Wain. H-IV: 6.
Walhala. E-VI: 26.
Waltham. F-IX: 2.
Ward. A-VIII: 1.
War Dance. H-VIII: 14.
War Dance Extension. I-VIII: 20.
Warfield. B-X: 8.
Warwick. I-V: 11.
Washington. H-V: 14.
Washington Extension. I-VIII: 18.
Wash Kash. C-IX: 24.
Waterberry. G-V: 18.
Waterloo. D-IX: 10.
Wautauga. C-IX: 7.
Wautauga Extension. C-IX: 8.
Welcome. D-VI: 11.
Wellington. D-IX: 16.
Wellington No. 1. E-IX: 13.
Wellington No. 3. D-IX: 14.
Wellington No. 4. D-IX 12.
Wellington No. 5. D-IX: 11.
Wellington No. 6. E-X: 2.
Wellington No. 7. D-X: 4.
Wellington No. 8. D-X: 5.
Wellington No. 9. E-X: 3.
Wellington No. 10. E-IX: 12.
Wellington Side. E-IX: 16.
Wells. F-VII: 4.
West Alva Adams. F-VIII: 2.
West American Boy. I-VIII: 12.
West Chase. G-VIII: 7.
Westchester. A-X: 3.
West Cuno. D-VII: 14.
West Delaware. A-VIII: 12.
West Gregory. G-VI: 7.
West Hazeltine. F-IX: 13.
West Keystone. D-II: 2.
West Michigan. G-V: 19; G-VI: 5.
West Pewabic. B-X: 2.
West Saratoga. F-VIII: 19.
West St. Louis. F-IV: 18.
West Wellington. D-X: 2; E-IX: 17.
West Wyandotte. C-VIII: 28.
Wheel of Fortune. I-I: 5.
Wheeler. D-V: 2.
Wheeler mill site (382). G-I: 1.
Whistler. E-VIII: 14.
White Cloud. A-X: 14.
White Pine. E-VII: 12.
White Rock. H-IX: 3.
Whiteside. H-IV: 7.
Wilber. F-V: 9.
Williamsville. I-VI: 2.
Willowdale. C-VII: 23.
Windsor. D-V: 22.
Winnebago. F-IV: 5.
Winnebago Extension. F-IV: 6.
Winslow. C-VII:17.
Wood. A-VII: 14; C-VIII: 1; D-IV: 2.
Woodbury. E-VI: 22.
Wright. F-VI: 20.
Wyandotte. C-VIII: 15.

Yellow Girl. H-IX: 8.
Yukon. D-VIII: 15.
Yule. A-VI: 3.
Yuma. D-VIII: 19.

Zuni. A-VI: 2.

Finding list of claims shown on map of Idaho Springs and vicinity (Pl. VIII).

Arranged by coordinates.

A-I. 1. Standard.
2. Norma.
3. Dakota.
4. Reciprocity.
5. C. M. S.
6. Boston.
7. Satisfaction.
8. Yosemite (12040).

A-II. 1. Mandolina (Yosemite) (6591).
2. East Mandolina.
3. W. W. Kirby.
4. Parthenon.
5. Golden Gate.
6. Gondola.
7. Genesta.
8. Brunswick.
9. "X."
10. Kinda Extension.
11. John M. Osborne placer.
12. Lilly.

A-III. 1. Wano.
2. Annie.
3. Umbra.
4. Etruria.
5. Majestic.
6. Confidence.
7. Mugwump.
8. Lady Alice.
9. Teutonic.
10. Hilda.
11. June.
12. Jake Whitter.

Finding list of claims shown on map of Idaho Springs and vicinity—Continued.

Arranged by coordinates—Continued.

A-IV. 1. Photographer.
2. Big Five.
3. Big Bonanza.
4. Free Gold.
5. September.
6. Surprise.
7. Empress.
8. Gertrude.
9. Richard III.
10. Holly Extension.
11. Dubuque Extension.
12. John M. Osborn placer.

A-V. 1. Margaret M.
2. Iron Mask.
3. Guy W.
4. Klondike.
5. Harry.
6. Dubuque.
7. Bennett placer.
8. Hoosac placer.
9. Alpine mill site.
10. Miner mill site.
11. Miner.
12. East Coyote.
13. Milwaukee.
14. Clear Creek Belle.
15. Tough Nut.

A-VI. 1. Edna L.
2. Heine.
3. Willie.
4. Black Forest.
5. Antelope.
6. Anoka County.
7. Cook.
8. Golden Lina.
9. Little Alice.
10. Mount Vesuvius (998).

A-VII. 1. Mount Vesuvius (1062).
2. Mount Ætna.
3. Dewey.
4. Golden Gate.
5. Robert Emmett.
6. Maggie May.
7. Morning Star.

A-VIII. 1. Copp.
2. Squaw.
3. Star.
4. Edward.
5. Double Eagle.
6. Jim Corbett.
7. Jim Jeffries.
8. Fitz.
9. Rochester.
10. Edward mill site (422 B).

B-I. 1. Gertrude.
2. Big Lobster.
3. Maggie.
4. Minnie.
5. Mary.
6. Oriole.
7. Iowa.
8. Plymouth.
9. Yellowstone.
10. Sioux City.
11. Winlock.

B-II. 1. Saxony.
2. St. Louis.
3. St. Paul.
4. Bourbon.
5. Lucky Star.
6. Leyner.
7. Kinda.
8. Lucania.
9. U. P. R.
10. Campania.
11. Florence.
12. Good Hope.
13. Ballia.
14. Servia.
15. Tunnel.

B-III. 1. Wright.
2. Amazon.
3. Rhoderic Dhu.
4. Lipton.
5. Dewey.
6. A. H. R.
7. Colorado.
8. Ohio.
9. G. R.
10. S. S.
11. L. P.

B-IV. 1. King George.
2. U. G. W.
3. King Edward.
4. Emperor.
5. Little Giant.
6. Midnight.
7. German Tunnel No. 2.
8. July.
9. Gold Dollar.
10. Gold Bullion.
11. President.

B-V. 1. Uncle George.
2. Lizzie S.
3. Dover.
4. Lawrence L.
5. Dierdre.
6. Dubuque.
7. Tornado.
8. Annie.
9. Boston (Big Hit).
10. May Queen Tunnel.
11. May Queen Annex.
12. May Queen Side.
13. May Queen.
14. May Queen Cross.
15. Hoosac.

B-VI. 1. Robinson placer.
2. Rising Sun.
3. J. C.
4. William F. placer.
5. Oro placer.
6. Ellis & Stevens placer.

B-VII. 1. Annie.
2. Lincoln (5954).
3. South Lincoln.
4. Kunegunde.
5. Lincoln (655).
6. Lincoln (338).
7. Josephine.
8. Elliot & Barber.
9. Bellevue Extension.
10. Donna Juanita.
11. Donna Julia placer.

B-VIII. 1. Bellevue.
2. Idaho View.
3. Dolphanee.
4. Cardigan.
5. Manhattan.
6. York.
7. Cregar.
8. Stanley.
9. Folwell.

C-I. 1. Sam Lee.
2. Hauch Haus.
3. West Virginia.
4. Coring.
5. Scott.
6. Sister Mary.
7. Ada J.
8. Poutycymmer.
9. Lauttwits.
10. Boston Run.
11. Arizona.
12. Victor.
13. Oregon.
14. Vida.

C-II. 1. Pappoose.
2. Central.
3. Brooklyn.
4. City of Berlin.
5. City of Paris.
6. Hughes.
7. New York.
8. Levy.
9. Alaska.
10. Little Belle.
11. Telephone.
12. Champion.
13. Richmond.
14. Specie Payment Extension.
15. Nell Pitkin.

C-III. 1. Apex.
2. Welch.
3. Little Annie.
4. Big Chief.
5. Welch Boy.
6. Ffestinioc.
7. Mons.

Finding list of claims shown on map of Idaho Springs and vicinity—Continued.

Arranged by coordinates—Continued.

C-III. 8. Waverly.
9. Spear.
10. Congress.

C-IV. 1. W. R. D.
2. Congress tunnel.
3. German tunnel No. 1.
4. Annex.
5. Lucky Star.
6. Big Chief.
7. Young Chief.
8. Grouse.
9. Gloria Mundi.
10. Box.

C-V. 1. Coin.
2. Hoosac Extension.
3. Little Johnny.
4. McKinley.
5. Canasota.
6. Syracuse.
7. Maria Collins.

C-VI. 1. New York.
2. New Bedford.
3. Mab.
4. Wallace.
5. Oro Extension.
6. Columbia.
7. Oro.
8. Golden Nugget.
9. Mastodon.
10. Old Jink.
11. Monte Cristo.
12. Bonnie Belle.
13. Pennsylvania.
14. Smith placer.

C-VII. 1. Columbia.
2. King Cyrus.
3. Lost.
4. Maud Monroe.
5. Lea placer.
6. Bennett placer.
7. H. & W. placer.
8. Gladstone.
9. H. & W. placer.
10. Little Harry.
11. King.
12. Wana & Browdoin placer.
13. Dumont placer.
14. Whale (290).

C-VIII. 1. Pride of the West.
2. Powell.
3. Golden Link.
4. Battem.
5. Sun.
6. Columbine.
7. Enterprise.
8. Moon.
9. Star.
10. Bullion King No. 1.
11. Bullion King No. 2.

D-I. 1. Summit.
2. President Hayes.
3. Oregon.
4. Columbia.
5. Glennalla.
6. Knickerbocker.
7. Golden Star.
8. Castleton.
9. Williams.
10. Rio Grande.
11. German.
12. Equity.
13. Howard.
14. Crown Point & Virginia.
15. M. K. (17265).

D-II. 1. Hot Pot.
2. Sunshine.
3. Clarissa.
4. Nonpareil.
5. Mixsell Tunnel No. 1.
6. Phillips.
7. Lucas.
8. Enterprise.
9. Grover Cleveland.
10. Lilly.
11. Kohn.
12. East Young.
13. Beecher.
14. Little Annie Extension.
15. Mona Mine.
16. Steneck.
17. Specie Payment Extension East.
18. Trio.

D-III. 1. Bellevue.
2. Young.
3. Wolverine.
4. Governor.
5. Peralta.
6. Mountain Chief.
7. Specie Payment.
8. Rambo.
9. Cashier.
10. Hellen.
11. Gold Vault.
12. Revenue.

D-IV. 1. Emma.
2. Etta.
3. European.
4. Germany.
5. Cleopatra.
6. Madison.
7. Minneapolis.
8. Sherbrook.
9. Indianapolis.
10. Idalia.
11. Bald Eagle Extension.

D-V. 1. New Discovery.
2. Major Conger.
3. Little Johnny Extension.
4. Tom Boy.
5. Morning Star.
6. Virginia House.
7. Golden Treasure.
8. Transvaal.
9. Morning Star Extension.

D-VI. 1. General Funston.
2. Golden Edith.
3. Lily.
4. Gold Dust.
5. Tee Pee.
6. Bronaber.
7. Summit.
8. Loeber.
9. Ninnian.

D-VII. 1. Atlantic.
2. Dominion.
3. Rannell.
4. Little Mac.
5. Centennial.
6. Lulu.
7. Crockett.
8. Pogue.
9. Hukill (615).
10. Hukill (126).
11. Salisbury.
12. Eulalie.
13. Bullion.
14. Vivian placer.
15. Whale (850).
16. Mount Olive.
17. Wana & Browdoin placer.
18. Albany placer.
19. Graeff placer.

D-VIII. 1. Little Joker.
2. Bullion King.
3. Mayflower.
4. Lafayette.
5. Bullion King No. 3.
6. Bullion King No. 6.
7. Belle Extension.
8. Bullion King No. 4.
9. Bullion King No. 5.

E-I. 1. Twelve-Thirty.
2. Semel.
3. Ada.
4. Marshall.
5. Chipmunk.
6. Fairmont (988).

E-II. 1. Bantala.
2. Insulator.
3. Blue Bell.
4. Clarissa.
5. Mixsell Tunnel No. 2.
6. Belman.

Finding list of claims shown on map of Idaho Springs and vicinity—Continued.

Arranged by coordinates—Continued.

E–II. 7. Seigel.
8. Sylph.
9. Great Center Extension.
10. Diamond Joe.
11. Uncle Sam.

E–III. 1. Valverde.
2. Mono.
3. No Name.
4. Grandma.
5. Hills.
6. Laura.
7. Bald Eagle.
8. Lake West.
9. Swansea.
10. Margaret.
11. Surplus.
12. Anaconda.
13. Two Brothers.
14. Daniels.

E–IV. 1. Stella.
2. Kentuck West.
3. Lillie.
4. Lucy.
5. U. S.
6. Fanny.
7. Big Five.
8. Laura.
9. Nicholas.
10. Good-for-Nothing.

E–V. 1. Strong.
2. Not Forgotten.
3. Anon.
4. Star.
5. Fortune.
6. Little Comstock.
7. Fairmont (988).
8. Shafter (2280).
9. Jennie Lind No. 2.

E–VI. 1. Refugee.
2. Lillian K.
3. Great American.
4. Providence.
5. East Stanley.
6. Little Annabel.
7. Hannalulu.
8. East Hukill.
9. Edgar.
10. Union.
11. Virginia.
12. Fairmont (195 A).

E–VII. 1. Fairmont mill site (195 B).
2. G. & M.
3. Little Ella.
4. New Century.
5. Lucia.
6. Le Coup.
7. Ella.
8. Hyland.
9. Wedge.
10. Beauzy.
11. Coupon.
12. Cleopatra.
13. Little Mack.
14. Scalloway.
15. Aurum.

E–VIII. 1. Borealis.
2. Essex.
3. Collom mill site.
4. White placer.
5. Cooper placer.
6. Graeff placer.
7. Black Bear.
8. Intersection.
9. Jumbo.
10. Tunnel.

F–I. 1. T. M. Jr.
2. McDonald.
3. Pittsburg.
4. Nector.
5. Francis.
6. Mugosy.
7. Mountain No. 1.
8. Hail Storm.
9. Olga.
10. Lottie.

F–II. 1. Mountain No. 2.
2. Fairmont Extension.
3. Little Billie.
4. Newbridge.
5. Ace of Diamonds.
6. Mono Extension.
7. Quincy.
8. Lakeside.
9. Lake.

F–III. 1. Ben Franklin.
2. Little Belle.
3. Windsor Castle.
4. Tarifa.
5. Comstock Extension.
6. West Dove's Nest.
7. Rara Avis.
8. Kentuck.
9. Sunol.
10. Polaris mill site (11228 B).
11. Nansen.
12. Polaris.
13. Capricorn.

F–IV. 1. Valentine.
2. Erie.
3. Highlander.
4. Hudson.
5. European.
6. Hudson mill site (1131 B).
7. C. J.
8. Calvin.
9. Hortense.
10. Helen.
11. Mary.
12. Red Jacket.
13. Patten.
14. M. I. X.
15. Great Center.

F–V. 1. Perplexity.
2. Adrie.
3. Keystone.
4. Jenny Lind.
5. Ogden.
6. Jenny Lind No. 1.
7. Shafter (2280).
8. Big Chief.
9. Chief.
10. Christmas.
11. Golden Chief (15158).
12. Golden Chief No. 1 (17192).
13. Herstoral.
14. Crystal.
15. Edgar Union.
16. Carrie.

F–VI. 1. Protection.
2. Robson.
3. Bryan.
4. Carrie.
5. Humphrey.
6. Fulton.
7. Comstock.
8. Judge.
9. Coupon.
10. Mount Royal.
11. Little Chief.
12. Edgar No. 1.

F–VII. 1. Edith S.
2. Gertrude.
3. Lewis.
4. Hyland Extension.
5. Olive.
6. Leonard.
7. Harry.

F–VIII. 1. McMickle.
2. Queen.
3. Darragh placer.
4. Clear Creek.
5. Clear Creek placer.
6. Harwood.
7. Venwood.

G–I. 1. Thirty Cents.
2. Calcutta.
3. Sultan.
4. Mountain No. 10.
5. Mountain No. 9.
6. Mountain No. 8.
7. Mountain No. 7
8. Mountain No. 6.
9. Mountain No. 5.

G–II. 1. Mountain No. 4.
2. Mountain No. 3.
3. Aduddell.

Finding list of claims shown on map of Idaho Springs and vicinity—Continued.

Arranged by coordinates—Continued.

G–II. 4. Fontaine.
5. Tarik.
6. Lake.
7. East Lake.
8. Owatonna.
9. Jewell.
10. Atlantic.
11. Ashland.

G.–III. 1. Post.
2. W. P. R.
3. O'Conner.
4. Dove's Nest.
5. Comstock.
6. Silver Link.
7. Safe.
8. Peck.
9. Emma.
10. Lucerne Annex.
11. Second Lucerne.
12. Jenny Lind.
13. Lucerne.
14. Oetta.
15. Chester.
16. North Park.

G–IV. 1. Park.
2. Park Side.
3. Republican.
4. Martha.
5. Dederick.
6. Cash.
7. Sheldon Jackson Patten Extension.
8. S. P. Remington.
9. Ohio.
10. The Hartman.
11. Silver Cord.
12. Bullion.
13. Cornucopia.
14. Kangaroo.
15. Champion.
16. Boreas.
17. Argo.
18. Interocean.
19. Ethel.
20. East Shafter.

G–V. 1. Champion.
2. Modoc.
3. Dump.
4. Little Jonnie.
5. Crystal.
6. New Year.
7. Columbus.
8. Beaver.
9. Fulton Extension.
10. Edgar Extension.
11. Index.
12. Edgar No. 2.
13. Western.
14. Early Bird.
15. Old Proverb.
16. Rattler.

G–VI. 1. Shaw.
2. Nonpariel.

G–VII. 1. Newton.
2. Goodyear.
3. Sunnyside.
4. Quartermaster.

G–VIII. 1. Mancarrow placer.
2. Terril placer (Fulton Water Power).
3. Old Rackensack.
4. Ward.

H–I. 1. Geoffrey.
2. Amador.
3. Church placer.
4. Frontenac mill site (461 B).
5. Clifton.
6. Fontaine.
7. Frontenac.
8. Formosa.
9. Aduddell.
10. Good Luck.

H–II. 1. Tee Gee Aitch.
2. St. Vrain.
3. Swift.
4. Carcasonne.
5. Soudan.
6. Phonolite.
7. Minnie Moore.

H–III. 1. Lightning Streak.
2. Cricket.
3. Canton.
4. Lead Belt.
5. Hub.
6. James.
7. Competition.
8. West Santa Fe.
9. Main Trunk.
10. Brighton No. 2.
11. Little Star.
12. Summit.

H–IV. 1. Ticknor.
2. Crœsus.
3. Victor.
4. Amazon.
5. Peru.
6. Bride.
7. Fourth of July.
8. Little Emma.
9. Kangaroo No. 2.
10. Seaton.
11. Little Casino.
12. No. 2 Lode in Metropolitan Tunnel.
13. Fraction.
14. Tunnel Lode No. 3.
15. Beauty No. 2.
16. Tunnel Lode No. 1.
17. Total Eclipse.
18. Crockett Extension.

H–V. 1. Josephine.
2. Joseph A. Horn.
3. Boss.
4. Crockett.
5. Tigris.
6. Luther.
7. Crockett mill site (993 B).
8. Bell Tunnel.
9. Proverb.
10. Esmeralda.
11. France.

H–VI. 1. Clyde.

H–VIII. 1. Mount Pleasant.

I–I. 1. Searle.
2. Aduddell.
3. Poor Luck.
4. B. Poe.
5. Alice K.
6. Ronalds.
7. Kent.
8. Argo tunnel.
9. Argo tunnel No. 2.
10. Half and Half.
11. Elkhorn.
12. Albyn.

I–II. 1. Albatross.
2. No. 14758.
3. New Years Holiday.
4. Colorado Star.
5. Colfax.
6. Bertha.
7. Iowa.
8. Morning Star.
9. Minnie.
10. Arizona.
11. Little Ella.
12. Hope.
13. German American.

I–III. 1. Sun.
2. Moon.
3. Garden.
4. Golden Wedge.
5. Muff.
6. C. P. Minot.
7. Santa Fe.
8. White Metal.
9. Freeze Out.
10. Out Crop.
11. Belman.
12. Martial.
13. Freidar.
14. Max.
15. Gem Extension.
16. Gem.

I–IV. 1. Burlington.
2. Grand Trunk.
3. Grantham.
4. Trust.

Finding list of claims shown on map of Idaho Springs and vicinity—Continued.

Arranged by coordinates—Continued.

I–IV. 5. Boadicea.
6. Latimer.
7. Silver Horn.
8. Amy C.
9. C., B. & Q.
10. Tropic.
11. Seaton.
12. Queen City.
13. Sunny Side.
14. Casino Tunnel Lode No. 2.
15. Danube.
16. Silver Queen.
17. Tenwall.
18. Ottawa.
I–V. 1. Grand View.
2. Euphrates.
3. No Name mill site (14222 B).
4. Gleaner.
5. France Extension.
6. Isabelle Hedges.
7. Northern Light.
8. Borealis.
I–VI. 1. Treasure Vault.
2. Aurora.
3. Gold Quartz.
I–VII. 1. John Paul Jones.
I–VIII. 1. Graham placer.
2. Montague placer.
3. Richard placer.
J–I. 1. Elite.
2. Elk.
3. Champion.
4. Seminole.
5. Sullton 3.
6. Pay Rock.
7. Hartford.
8. Home.
9. North American.
10. Elk Valley.
11. Bi-Metallic.
J–II. 1. Half Moon.
2. Rochester.
3. Stump Tail.
4. Star.
5. William Penn.
6. North American.
7. Moosehead.
8. Earth.
9. Elkstail.
10. Cortelyou.
11. Hitchcock.
12. New Century.
J–III. 1. Bread Winner.
2. Nest Egg.
3. Exchequer.
4. J. J. W.
5. Rescue.
6. Shapleigh.
J–III. 7. Legal Tender.
8. Enid.
9. Oro Fino.
10. J. Warner.
J–IV. 1. Guy.
2. Mary F.
3. Washington.
4. Freighter Friend.
5. Franklin.
6. Florence.
7. Veto.
8. Congress.
9. Prince Henry.
10. Good Enough.
11. Dora.
12. Terrible.
13. Seaton Extension.
14. Seven-Twenty.
15. Trojan.
16. Dorina.
17. Silver Queen.
18. No Name.
19. Gleaner.
20. Bert.
21. Alpha.
22. Cass.
23. Frank E.
J–V. 1. Gleaner.
2. Harvest.
3. Orr.
4. Gold Leaf.
5. Golden Fleece.
6. Motor.
7. Harold.
8. Edgardine.
9. Gertrude.
10. Maud S.
11. St. Louis.
J–VII. 1. Chicago.
2. K. C.
J–VIII. 1. Martin.
2. Dunn placer.
3. Logan placer.
4. Doherty placer.
5. Lewis placer.
6. Sears placer.
K–I. 1. Verticle.
2. Reade Street.
3. Eclipse.
4. Old Fry.
5. Hattie Myrtle.
6. Free Coinage.
7. Horn Silver.
8. Elk Valley mill site (813 B).
9. New York.
10. Consolidated.
11. Sullton No. 2.
12. Moose.
13. Sullton No. 1.
K–I. 14. Syndicate.
K–II. 1. Root.
2. Taft.
3. Shaw.
4. Bonaparte.
5. Hilltop.
6. Governor.
7. Daisy.
8. Pine Tree.
K–III. 1. W. M. S.
2. Memphis.
3. Zozo.
4. Sunset.
5. Manhattan.
6. New York.
7. Brooklyn.
8. Minnekato.
9. Big Five.
10. Reno.
11. Galatea.
12. Little Blanche.
13. Wonderful.
14. Tom Kirby.
15. Doc Tray.
16. De Lesseps.
17. Gem Extension East.
18. Gold Finch.
19. Night Hawk Extension.
K–IV. 1. Dum Spiro Spero.
2. Summit.
3. Waterloo.
4. Seaton Extension.
5. South.
6. Joubert.
7. Connecting Link.
8. Magnet.
9. Bobby Burns.
10. Queen.
11. Queen mill site.
12. Franklin (87).
13. French Flag.
14. Freeman.
15. Potosi.
16. John H.
17. Golden Fleece.
18. Oscar.
19. Blind.
K–V. 1. Allen.
2. A. B. E.
3. Gold Leaf.
4. Fannie R.
K–VII. 1. Ellison placer.
K–VIII. 1. Argo.
2. Welch placer.
3. Ellison placer.
4. Silver Age placer.
5. Faivre placer.
6. Argo mill site.
L–II. 1. Home Run.
2. Soltaire.

Finding list of claims shown on map of Idaho Springs and vicinity—Continued.

Arranged by coordinates—Continued.

L-II. 3. Homestake.
4. Golden Reward.
5. King Dodo.
6. Ping Pong.
7. Wasp.
8. Black Duke.
9. Columbine.
10. Horse Shoe.

L-III. 1. Summit.
2. Pure Gold.
3. St. Joseph.
4. Alacoque.
5. Day Dawn.
6. Night Hawk.
7. Celestine.
8. Silver Gem.
9. Golden Wedge.
10. La Frank.

L-IV. 1. First Lode Vein.
2. Hanging.
3. Hudson.
4. Montana.
5. Tunnel.
6. Silver Age.
7. Ship Ahoy.
8. Silver Age Extension.
9. King.
10. Gold Medal.
11. Capon.
12. Artillery Man.
13. Silver Gem mill site.

L-V. 1. Mill site 6002 B.

L-VIII. 1. Rollins placer.

Arranged alphabetically.

A. B. E. K-V: 2.
Ace of Diamonds. F-II: 5.
Ada. E-I: 3.
Ada J. C-I: 7.
Adrie. F-V: 2.
Aduddell. G-II: 3; H-I: 9; I-I: 2.
A. H. R. B-III: 6.
Alacoque. L-III: 4.
Alaska. C-II: 9.
Albany placer. D-VII: 18.
Albatross. I-II: 1.
Albyn. I-I: 12.
Alice K. I-I: 5.
Allen. K-V: 1.
Alpha. J-IV: 21.
Alpine mill site. A-V: 9.
Amador. H-I: 2.
Amazon. B-III: 2; H-IV: 4.
Amy C. I-IV: 8.
Anaconda. E-III: 12.
Annex. C-IV: 4.
Annie. A-III: 2; B-V: 8; B-VII: 1.
Anoka County. A-VI: 6.
Anon. E-V: 3.
Antelope. A-VI: 5.
Apex. C-III: 1.
Argo. G-IV: 17; K-VIII: 1.
Argo mill site. K-VIII: 6.
Argo tunnel. I-I: 8.
Argo tunnel No. 2. I-I: 9.
Arizona. C-I: 11; I-II: 10.
Artillery Man. L-IV: 12.
Ashland. G-II: 11.
Atlantic. D-VII: 1; G-II: 10.
Aurora. I-VI: 2.
Aurum. E-VII: 15.

Bald Eagle. E-III: 7.
Bald Eagle Extension. D-IV: 11.
Ballia. B-II: 13.
Bantala. E-II: 1.
Battem. C-VIII: 4.
Beauty No. 2. H-IV: 15.
Beauzy. E-VII: 10.
Beaver. G-V: 8.
Beecher. D-II: 13.
Belle Extension. D-VIII: 7.
Bellevue. B-VIII: 1; D-III: 1.
Bellevue Extension. B-VII: 9.
Bell Tunnel. H-V: 8.
Belman. E-II: 6; I-III: 11.
Ben Franklin. F-III: 1.
Bennett placer. A-V: 7; C-VII: 6.
Bert. J-IV: 20.
Bertha. I-II: 6.
Big Bonanza. A-IV: 3.
Big Chief. C-III: 4; C-IV: 6; F-V: 8.
Big Five. A-IV: 2; E-IV: 7; K-III: 9.
Big Lobster. B-I: 2.
Bi-Metallic. J-I: 11.
Black Bear. E-VIII: 7.
Black Duke. L-II: 8.
Black Forest. A-VI: 4.
Blind. K-IV: 19.
Blue Bell. E-II: 3.
Boadicea. I-IV: 5.
Bobby Burns. K-IV: 9.
Bonnie Belle. C-VI: 12.
Bonaparte. K-II: 4.
Borealis. E-VIII: 1; I-V: 8.
Boreas. G-IV: 16.
Boss. H-V: 3.
Boston. A-I: 6.
Boston (Big Hit). B-V: 9.
Boston Run. C-I: 10.
Bourbon. B-II: 4.
Box. C-IV: 10.
B. Poe. I-I: 4.
Bread Winner. J-III: 1.
Bride. H-IV: 6.
Brighton No. 2. H-III: 10.
Bronaber. D-VI: 6.
Brooklyn. C-II: 3; K-III: 7.
Brunswick. A-II: 8.
Bryan. F-VI: 3.
Bullion. D-VII: 13; G-IV: 12.
Bullion King. D-VIII: 2.
Bullion King No. 1. C-VIII: 10.
Bullion King No. 2. C-VIII: 11.
Bullion King No. 3. D-VIII: 5.
Bullion King No. 4. D-VIII: 8.
Bullion King No. 5. D-VIII: 9.
Bullion King No. 6. D-VIII: 6.
Burlington. I-IV: 1.

Calcutta. G-I: 2.
Calvin. F-IV: 8.
Campania. B-II: 10.
Canasota. C-V: 5.
Canton. H-III: 3.
Capon. L-IV: 11.
Capricorn. F-III: 13.
Carcasonne. H-II: 4.
Cardigan. B-VIII: 4.
Carrie. F-V: 16; F-VI: 4.
Cash. G-IV: 6.
Cashier. D-III: 9.
Casino Tunnel Lode No. 2. I-IV: 14.
Cass. J-IV: 22.
Castleton. D-I: 8.
C., B. & Q. I-IV: 9.
Celestine. L-III: 7.
Centennial. D-VII: 5.
Central. C-II: 2.
Champion. C-II: 12; G-IV: 15; G-V: 1; J-I: 3.
Chester. G-III: 15.
Chicago. J-VII: 1.
Chief. F-V: 9.
Chipmunk. E-I: 5.
Christmas. F-V: 10.
Church placer. H-I: 3.
City of Berlin. C-II: 4.
City of Paris. C-II: 5.
C. J. F-IV: 7.
Clarissa. D-II: 3; E-II: 4.
Clear Creek. F-VIII: 4.
Clear Creek Belle. A-V: 14.
Clear Creek placer. F-VIII: 5.
Cleopatra. D-IV: 5; E-VII: 12.
Clifton. H-I: 5.
Clyde. H-VI: 1.
C. M. S. A-I: 5.
Coin. C-V: 1.
Colfax. I-II: 5.
Collom mill site. E-VIII: 3.
Colorado. B-III: 7.
Colorado Star. I-II: 4.
Columbia. C-VI: 6; C-VII: 1; D-I: 4.
Columbine. C-VIII: 6; L-II: 9.
Columbus. G-V: 7.
Competition. H-III: 7.
Comstock. F-VI: 7; G-III: 5.
Comstock Extension. F-III: 5.
Confidence. A-III: 6.

Finding list of claims shown on map of Idaho Springs and vicinity—Continued.

Arranged alphabetically—Continued.

Congress. C–III: 10; J–IV: 8.
Congress Tunnel. C–IV: 2.
Connecting Link. K–IV: 7.
Consolidated. K–I: 10.
Cook. A–VI: 7.
Cooper placer. E–VIII: 5.
Copp. A–VIII: 1.
Coring. C–I: 4.
Cortelyou. J–II: 10.
Cornucopia. G–IV: 13.
Coupon. E–VII: 11; F–VI: 9.
C. P. Minot. I–III: 6.
Cregar. B–VIII: 7.
Crœsus. H–IV: 2.
Cricket. H–III: 2.
Crockett. D–VII: 7; H–V: 4.
Crockett Extension. H–IV: 18.
Crockett mill site (993 B). H–V: 7.
Crown Point & Virginia. D–I: 14.
Crystal. F–V: 14; G–V: 5.

Daisy. K–II: 7.
Dakota. A–I: 3.
Daniels. E–III: 14.
Danube. I–IV: 15.
Darragh placer. F–VIII: 3.
Day Dawn. L–III: 5.
Dederick. G–IV: 5.
De Lesseps. K–III: 16.
Dewey. A–VII: 3; B–III: 5.
Diamond Joe. E–II: 10.
Dierdre. B–V: 5.
Doc Tray. K–III: 15.
Doherty placer. J–VIII: 4.
Dolphanee. B–VIII: 3.
Dominion. D–VII: 2.
Donna Juanita. B–VII: 10.
Donna Julia placer. B–VII: 11.
Dora. J–IV: 11.
Dorina. J–IV: 16.
Double Eagle. A–VIII: 5.
Dover. B–V: 3.
Dove's Nest. G–III: 4.
Dubuque. A–V: 6; B–V: 6.
Dubuque Extension. A–IV: 11.
Dumont placer. C–VII: 13.
Dump. G–V: 3.
Dum Spiro Spero. K–IV: 1.
Dunn placer. J–VIII: 2.

Early Bird. G–V: 14.
Earth. J–II: 8.
East Coyote. A–V: 12.
East Hukill. E–VI: 8.
East Lake. G–II: 7.
East Mandolina. A–II: 2.
East Shafter. G–IV: 20.
East Stanley. E–VI: 5.
East Young. D–II: 12.
Eclipse. K–I: 3.
Edgar. E–VI: 9.
Edgar No. 1. F–VI: 12.
Edgar No. 2. G–V: 12.
Edgardine. J–V: 8.
Edgar Extension. G–V: 10.
Edgar Union. F–V: 15.
Edith S. F–VII: 1.
Edna L. A–VI: 1.
Edward. A–VIII: 4.
Edward mill site (422 B). A–VIII: 10.
Elite. J–I: 1.
Elk. J–I: 2.
Elkhorn. I–I: 11.
Elkstail. J–II: 9.
Elk Valley. J–I: 10.
Elk Valley mill site (813 B). K–I: 8.
Ella. E–VII: 7.
Elliot & Barber, B–VII: 8.
Ellis & Stevens placer. B–VI: 6.
Ellison placer. K–VII: 1; K–VIII: 3.
Emma. D–IV: 1; G–III: 9.
Emperor. B–IV: 4.
Empress. A–IV: 7.
Enid. J–III: 8.
Enterprise. C–VIII: 7; D–I: 8.
Equity. D–I: 12.
Erie. F–IV: 2.
Esmeralda. H–V: 10.
Essex. E–VIII: 2.
Ethel. G–IV: 19.
Etruria. A–III: 4.
Etta. D–IV: 2.
Eulalie. D–VII: 12.
Euphrates. I–V: 2.
European. D–IV: 3; F–IV: 5.
Exchequer. J–III: 3.

Fairmont (988). E–I: 6; E–V: 7.
Fairmont (195 A). E–VI: 12.
Fairmont mill site (195 B). E–VII: 1.
Fairmont Extension. F–II: 2.
Faivre placer. K–VIII: 5.
Fannie R. K–V: 4.
Fanny. E–IV: 6.
Ffestinioc. C–III: 6.
First Lode Vein. L–IV: 1.
Fitz. A–VIII: 8.
Florence. B–II: 11; J–IV: 6.
Folwell. B–VIII: 9.
Fontaine. G–II: 4; H–I: 6.
Formosa. H–I: 8.
Fortune. E–V: 5.
Fourth of July. H–IV: 7.
Fraction. H–IV: 13.
France. H–V: 11.
France Extension. I–V: 5.
Francis. F–I: 5.
Frank E. J–IV: 23.
Franklin. J–IV: 5.
Franklin (87). K–IV: 12.
Free Coinage. K–I: 6.
Free Gold. A–IV: 4.
Freeman. K–IV: 14.
Freeze Out. I–III: 9.
Freidar. I–III: 13.
Freighter Friend. J–IV: 4.
French Flag. K–IV: 13.
Frontenac. H–I: 7.
Frontenac mill site (461 B). H–I: 4.
Fulton. F–VI: 6.
Fulton Extension. G–V: 9.

Galatea. K–III: 11.
G. & M. E–VII: 2.
Garden. I–III: 3.
Gem. I–III: 16.
Gem Extension. I–III: 15.
Gem Extension East. K–III: 17.
General Funston. D–VI: 1.
Genesta. A–II: 7.
Geoffrey. H–I: 1.
German. D–I: 11.
German American. I–II: 13.
German tunnel No. 1. C–IV: 3.
German tunnel No. 2. B–IV: 7.
Germany. D–IV: 4.
Gertrude. A–IV: 8; B–I: 1; F–VII: 2; J–V: 9.
Gladstone. C–VII: 8.
Gleaner. I–V: 4; J–IV: 19; J–V: 1.
Glennalla. D–I: 5.
Gloria Mundi. C–IV: 9.
Gold Bullion. B–IV: 10.
Gold Dollar. B–IV: 9.
Gold Dust. D–VI: 4.
Golden Chief (15158). F–V: 11.
Golden Chief No. 1 (17192). F–V: 12.
Golden Edith. D–VI: 2.
Golden Fleece. J–V: 5; K–IV: 17.
Golden Gate. A–II: 5; A–VII: 4.
Golden Lina. A–VI: 8.
Golden Link. C–VIII: 3.
Golden Nugget. C–VI: 8.
Golden Reward. L–II: 4.
Golden Star. D–I: 7.
Golden Treasure. D–V: 7.
Golden Wedge. L–III: 9; I–III: 4.
Gold Finch. K–III: 18.
Gold Leaf. J–V: 4; K–V: 3.
Gold Medal. L–IV: 10.
Gold Quartz. I–VI: 3.
Gold Vault. D–III: 11.
Gondola. A–II: 6.
Good Enough. J–IV: 10.
Good-for-Nothing. E–IV: 10.
Good Hope. B–II: 12.
Good Luck. H–I: 10.
Goodyear. G–VII: 2.
Governor. D–III: 4; K–II: 6.
G. R. B–III: 9.
Graeff placer. D–VII: 19; E–VIII: 6.
Graham placer. I–VIII: 1.
Grandma. E–III: 4.
Grand Trunk. I–IV: 2.

Finding list of claims shown on map of Idaho Springs and vicinity—Continued.

Arranged alphabetically—Continued.

Grand View. I–V: 1.
Grantham. I–IV: 3.
Great American. E–VI: 3.
Great Center. F–IV: 15.
Great Center Extension. E–II: 9.
Grouse. C–IV: 8.
Grover Cleveland. D–II: 9.
Guy. J–IV: 1.
Guy W. A–V: 3.

Hail Storm. F–I: 8.
Half and Half. I–I: 10.
Half Moon. J–II: 1.
H. & W. placer. C–VII: 7; C–VII: 9.
Hanging. L–IV: 2.
Hannalulu. E–VI: 7.
Harold. J–V: 7.
Harry. A–V: 5; F–VII: 7.
Hartford. J–I: 7.
Harvest. J–V: 2.
Harwood. F–VIII: 6.
Hattie Myrtle. K–I: 5.
Hauch Haus. C–I: 2.
Heine. A–VI: 2.
Helen. F–IV: 10.
Hellen. D–III: 10.
Herstoral. F–V: 13.
Hilda. A–III: 10.
Highlander. F–IV: 3.
Hills. E–III: 5.
Hilltop. K–II: 5.
Hitchcock. J–II: 11.
Holly Extension. A–IV: 10.
Home. J–I: 8.
Home Run. L–II: 1.
Homestake. L–II: 3.
Hoosac. B–V: 15.
Hoosac Extension. C–V: 2.
Hoosac placer. A–V: 8.
Hope. I–II: 12.
Horn Silver. K–I: 7.
Horse Shoe. L–II: 10.
Hortense. F–IV: 9.
Hot Pot. D–II: 1.
Howard. D–I: 13.
Hub. H–III: 5.
Hudson. F–IV: 4; L–IV: 3.
Hudson mill site (1131 B). F–IV: 6.
Hughes. C–II: 6.
Hukill (126). D–VII: 10.
Hukill (615). D–VII: 9.
Humphrey. F–VI: 5.
Hyland. E–VII: 8.
Hyland Extension. F–VII: 4.

Idaho View. B–VIII: 2.
Idalia. D–IV: 10.
Index. G–V: 11.
Indianapolis. D–IV: 9.
Insulator. E–II: 2.
Interocean. G–IV: 18.
Intersection. E–VIII: 8.
Iowa. B–I: 7; I–II: 7.
Iron Mask. A–V: 2.
Isabelle Hedges. I–V: 6.

Jake Whitter. A–III: 12.
James. H–III: 6.
J. C. B–VI: 3.
Jenny Lind. F–V: 4; G–III: 12.
Jenny Lind No. 1. F–V: 6.
Jenny Lind No. 2. E–V: 9.
Jewell. G–II: 9.
Jim Corbett. A–VIII: 6.
Jim Jeffries. A–VIII: 7.
J. J. W. J–III: 4.
John H. K–IV: 16.
John M. Osborne placer. A–II: 11; A–IV: 12.
John Paul Jones. I–VII: 1.
Joseph A. Horn. H–V: 2.
Josephine. B–VII: 7; H–V: 1.
Joubert. K–IV: 6.
Judge. F–VI: 8.
July. B–IV: 8.
Jumbo. E–VIII: 9.
June. A–III: 11.
J. Warner. J–III: 10.

Kangaroo. G–IV: 14.
Kangaroo No. 2. H–IV: 9.
K. C. J–VII: 2.
Kent. I–I: 7.
Kentuck. F–III: 8.
Kentuck West. E–IV: 2.
Keystone. F–V: 3.
Kinda. B–II: 7.
Kinda Extension. A–II: 10.
King. C–VII: 11; L–IV: 9.
King Cyrus. C–VII: 2.
King Dodo. L–II: 5.
King Edward. B–IV: 3.
King George. B–IV: 1.
Klondike. A–V: 4.
Knickerbocker. D–I: 6.
Kohn. D–II: 11.
Kunegunde. B–VII: 4.

Lady Alice. A–III: 8.
Lafayette. D–VIII: 4.
La Frank. L–III: 10.
Lake. G–II: 6; F–II: 9.
Lakeside. F–II: 8.
Lake West. E–III: 8.
Latimer. I–IV: 6.
Laura. E–III: 6; E–IV: 8.
Lauttwits. C–I: 9.
Lawrence L. B–V: 4.
Lead Belt. H–III: 4.
Lea placer. C–VII: 5.
Le Coup. E–VII: 6.
Legal Tender. J–III: 7.
Leonard. F–VII: 6.
Levy. C–II: 8.
Lewis. F–VII: 3.
Lewis placer. J–VIII: 5.
Leyner. B–II: 6.
Lightning Streak. H–III: 1.
Lillian K. E–VI: 2.
Lillie. E–IV: 3.
Lilly. A–II: 12; D–II: 10.
Lily. D–VI: 3.
Lincoln (338). B–VII: 6.
Lincoln (655). B–VII: 5.
Lincoln (5954). B–VII: 2.
Lipton. B–III: 4.
Little Alice. A–VI: 9.
Little Annabel. E–VI: 6.
Little Annie. C–III: 3.
Little Annie Extension. D–II: 14.
Little Belle. C–II: 10; F–III: 2.
Little Billie. F–II: 3.
Little Blanche. K–III: 12.
Little Casino. H–IV: 11.
Little Chief. F–VI: 11.
Little Comstock. E–V: 6.
Little Ella. E–VII: 3; I–II: 11.
Little Emma. H–IV: 8.
Little Fannie Extension. D–II: 14.
Little Giant. B–IV: 5.
Little Harry. C–VII: 10.
Little Joker. D–VIII: 1.
Little Johnny. C–V: 3.
Little Johnny Extension. D–V: 3.
Little Jonnie. G–V: 4.
Little Mack. D–VII: 4; E–VII: 13.
Little Star. H–III: 11.
Lizzie S. B–V: 2.
Loeber. D–VI: 8.
Logan placer. J–VIII: 3.
Lottie. F–I: 10.
Lost. C–VII: 3.
L. P. B–III: 11.
Lucania. B–II: 8.
Lucas. D–II: 7.
Lucerne. G–III: 13.
Lucerne Annex. G–III: 10.
Lucia. E–VII: 5.
Lucky Star. B–II: 5; C–IV: 5.
Lucy. E–IV: 4.
Lulu. D–VII: 6.
Luther. H–V: 6.

Mab. C–VI: 3.
McDonald. F–I: 2.
McKinley. C–V: 4.
McMickle. F–VIII: 1.
Madison. D–IV: 6.
Maggie. B–I: 3.
Maggie May. A–VII: 6.
Magnet. K–IV: 8.
Main Trunk. H–III: 9.
Majestic. A–III: 5.
Major Conger. D–V: 2.
Mancarrow placer. G–VIII: 1.
Mandolina (Yosemite) (6591). A–II: 1.
Manhattan. B–VIII: 5; K–III: 5.

Finding list of claims shown on map of Idaho Springs and vicinity—Continued.

Arranged alphabetically—Continued.

Margaret. E-III: 10.
Margaret M. A-V: 1.
Maria Collins. C-V: 7.
Marshall. E-I: 4.
Martha. G-IV: 4.
Martial. I-III: 12.
Martin. J-VIII: 1.
Mary. B-I: 5; F-IV: 11.
Mary F. J-IV: 2.
Mastodon. C-VI: 9.
Maud Monroe. C-VII: 4.
Maud S. J-V: 10.
Max. I-III: 14.
Mayflower. D-VIII: 3.
May Queen. B-V: 13.
May Queen Annex. B-V: 11.
May Queen Cross. B-V: 14.
May Queen Side. B-V: 12.
May Queen Tunnel. B-V: 10.
Memphis. K-III: 2.
Midnight. B-IV: 6.
Mill site 6002. L-V: 1.
Milwaukee. A-V: 13.
Miner. A-V: 11.
Miner mill site. A-V: 10.
Minneapolis. D-IV: 7.
Minnekato. K-III: 8.
Minnie. I-II: 9; B-I: 4.
Minnie Moore. H-II: 7.
M. I. X. F-IV: 14.
Mixsell Tunnel No. 1. D-II: 5.
Mixsell Tunnell No. 2. E-II: 5.
M. K. (17265). D-I: 15.
Modoc. G-V: 2.
Mona Mine. D-II: 15.
Mono. E-III: 2.
Mono Extension. F-II: 6.
Mons. C-III: 7.
Montague placer. I-VIII: 2.
Montana. L-IV: 4.
Monte Cristo. C-VI: 11.
Moon. C-VIII: 8; I-III: 2.
Moose. K-I: 12.
Moosehead. J-II: 7.
Morning Star. A-VII: 7; D-V: 5; I-II: 8.
Morning Star Extension. D-V: 9.
Motor. J-V: 6.
Mount Ætna. A-VII: 2.
Mountain No. 1. F-I: 7.
Mountain No. 2. F-II: 1.
Mountain No. 3. G-II: 2.
Mountain No. 4. G-II: 1.
Mountain No. 5. G-I: 9.
Mountain No. 6. G-I: 8.
Mountain No. 7. G-I: 7.
Mountain No. 8. G-I: 6.
Mountain No. 9. G-I: 5.
Mountain No. 10. G-I: 4.
Mountain Chief. D-III: 6.
Mount Olive. D-VII: 16.
Mount Pleasant. H-VIII: 1.
Mount Royal. F-VI: 10.
Mount Vesuvius (998). A-VI: 10.
Mount Vesuvius (1062). A-VII: 1.
Muff. I-III: 5.
Mugosy. F-I: 6.
Mugwump. A-III: 7.

Nansen. F-III: 11.
Nector. F-I: 4.
Nell Pitkin. C-II: 15.
Nest Egg. J-III: 2.
New Bedford. C-VI: 2.
Newbridge. F-II: 4.
New Century. E-VII: 4; J-II: 12.
New Discovery. D-V: 1.
Newton. G-VII: 1.
New Year. G-V: 6.
New Years Holiday. I-II: 3.
New York. C-II: 7; C-VI: 1; K-I: 9; K-III: 6.
Nicholas. E-IV: 9.
Night Hawk. L-III: 6.
Night Hawk Extension. K-III: 19.
Ninnian. D-VI: 9.
No Name. E-III: 3; J-IV: 18.
No Name mill site (14222 B). I-V: 3.
Nonpareil. D-II: 4; G-VI: 2.
Norma. A-I: 2.
North American. J-I: 9; J-II: 6.
Northern Light. I-V: 7.
North Park. G-III:16.
Not Forgotten. E-V: 2.
No. 2 Lode in Metropolitan Tunnel. H-IV: 12.
No. 14758. I-II: 2.

O'Conner. G-III: 3.
Oetta. G-III: 14.
Ogden. F-V: 5.
Ohio. B-III: 8; G-IV: 9.
Old Fry. K-I: 4.
Old Jink. C-VI: 10.
Old Proverb. G-V: 15.
Old Rackensack. G-VIII: 3.
Olga. F-I: 9.
Olive. F-VII: 5.
Oregon. C-I:13; D-I: 3.
Oro. C-VI: 7.
Oro Extension. C-VI: 5.
Oro Fino. J-III: 9.
Oriole. B-I: 6.
Oro placer. B-VI: 5.
Orr. J-V: 3.
Oscar. K-IV: 18.
Ottawa. I-IV: 18.
Outcrop. I-III: 10.
Owatonna. G-II: 8.

Pappoose. C-II: 1.
Park. G-IV: 1.
Park Side. G-IV: 2.
Parthenon. A-II: 4.
Patten. F-IV: 13.
Pay Rock. J-I: 6.
Peck. G-III: 8.
Pennsylvania. C-VI: 13.
Peralta. D-III: 5.
Perplexity. F-V: 1.
Peru. H-IV: 5.
Phillips. D-II: 6.
Phonolite. H-II: 6.
Photographer. A-IV: 1.
Pine Tree. K-II: 8.
Ping Pong. L-II: 6.
Pittsburg. F-I: 3.
Plymouth. B-I: 8.
Pogue. D-VII: 8.
Polaris. F-III: 12.
Polaris mill site (11228). F-III: 10.
Poor Luck. I-I: 3.
Post. G-III: 1.
Potosi. K-IV: 15.
Poutycymmer. C-I: 8.
Powell. C-VIII: 2.
President. B-IV: 11.
President Hayes. D-I: 2.
Pride of the West. C-VIII: 1.
Prince Henry. J-IV: 9.
Protection. F-VI: 1.
Proverb. H-V: 9.
Providence. E-VI: 4.
Pure Gold. L-III: 2.

Quartermaster. G-VII: 4.
Queen. F-VIII: 2; K-IV: 10.
Queen City. I-IV: 12.
Queen mill site. K-IV: 11.
Quincy. F-II: 7.

Rambo. D-III: 8.
Rannell. D-VII: 3.
Rara Avis. F-III: 7.
Rattler. G-V: 16.
Reade Street. K-I: 2.
Reciprocity. A-I: 4.
Red Jacket. F-IV: 12.
Refugee. E-VI: 1.
Reno. K-III: 10.
Republican. G-IV: 3.
Rescue. J-III: 5.
Revenue. D-III: 12.
Rhoderic Dhu. B-III: 3.
Richard placer. I-VIII: 3.
Richard III. A-IV: 9.
Richmond. C-II: 13.
Rio Grande. D-I: 10.
Rising Sun. B-VI: 2.
Robert Emmett. A-VII: 5.
Robinson placer. B-VI: 1.
Rochester. A-VIII: 9; J-II: 2.
Robson. F-VI: 2.
Rollins placer. L-VIII: 1.

Finding list of claims shown on map of Idaho Springs and vicinity—Continued.

Arranged alphabetically—Continued.

Ronalds. I–I: 6.
Root. K–II: 1.

Safe. G–III: 7.
Salisbury. D–VII: 11.
Sam Lee. C–I: 1.
Santa Fe. I–III: 7.
Satisfaction. A–I: 7.
Saxony. B–II: 1.
Scalloway. E–VII: 14.
Scott. C–I: 5.
Searle. I–I: 1.
Sears placer. J–VIII: 6.
Seaton. H–IV: 10; I–IV: 11.
Seaton Extension. J–IV: 13; K–IV: 4:
Second Lucerne. G–III: 11.
Seigel. E–II: 7.
Semel. E–I: 2.
Seminole. J–I: 4.
September. A–IV: 5.
Servia. B–II: 14.
Seven Twenty. J–IV: 14.
Shaw. G–VI: 1; K–II: 3.
Shafter (2280). E–V: 8; F–V: 7.
Shapleigh. J–III: 6.
Sheldon Jackson Patten Extension. G–IV: 7.
Sherbrook. D–IV: 8.
Ship Ahoy. L–IV: 7.
Silver Age. L–IV: 6.
Silver Age Extension. L–IV: 8.
Silver Age placer. K–VIII: 4.
Silver Cord. G–IV: 11.
Silver Gem. L–III: 8.
Silver Gem mill site. L–IV: 13.
Silver Horn (Silver Star). I–IV: 7.
Silver Link. G–III: 6.
Silver Queen. I–IV: 16; J–IV: 17.
Sioux City. B–I: 10.
Sister Mary. C–I: 6.
Smith placer. C–VI: 14.
Soltaire. L–II: 2.
Soudan. H–II: 5.
South. K–IV: 5.
South Lincoln. B–VII: 3.
Spear. C–III: 9.
Specie Payment. D–III: 7.
Specie Payment Extension. C–II. 14.
Specie Payment Extension East. D–II: 17.
S. P. Remington. G–IV: 8.
Squaw. A–VIII: 2.
S. S. B–III: 10.
Standard. A–I: 1.
Stanley. B–VIII: 8.
Star. A–VIII: 3; C–VIII: 9; E–V: 4; J–II: 4.
Stella. E–IV: 1.
Steneck. D–II: 16.
St. Joseph. L–III: 3.
St. Louis. J–V: 11; B–II: 2.
St. Paul. B–II: 3.
St. Vrain. H–II: 2.
Strong. E–V: 1.
Stump Tail. J–II: 3.
Sultan. G–I: 3.
Sullton No. 1. K–I: 13.
Sullton No. 2. K–I: 11.
Sullton No. 3. J–I: 5.
Summit. D–I: 1; D–VI: 7; H–III: 12; K–IV: 2; L–III: 1.
Sun. C–VIII: 5; I–III: 1.
Sunnyside. G–VII: 3; I–IV: 13.
Sunol. F–III: 9.
Sunshine. D–II: 2.
Sunset. K–III: 4.
Surplus. E–III: 11.
Surprise. A–IV: 6.
Swansea. E–III: 9.
Swift. H–II: 3.
Sylph. E–II: 8.
Syndicate. K–I: 14.
Syracuse. C–V: 6.

Taft. K–II: 2.
Tarifa. F–III: 4.
Tarik. G–II: 5.
Tee Gee Aitch. H–II: 1.
Tee Pee. D–VI: 5.
Telephone. C–II: 11.
Tenwall. I–IV: 17.
Terril placer (Fulton Water Power). G–VIII: 2.
Terrible. J–IV: 12.
Teutonic. A–III–9.
The Hartman. G–IV: 10.
Thirty Cents. G–I: 1.
Ticknor. H–IV: 1.
Tigris. H–V: 5.
T. M., Jr. F–I: 1.
Tom Boy. D–V: 4.
Tom Kirby. K–III: 14.
Tornado. B–V: 7.
Total Eclipse. H–IV: 17.
Tough Nut. A–V: 15.
Transvaal. D–V: 8.
Treasure Vault. I–VI: 1.
Trio. D–II: 18.
Trojan. J–IV: 15.
Tropic. I–IV: 10.
Trust. I–IV: 4.
Tunnel. B–II: 15; E–VIII: 10; L–IV: 5.
Tunnel Lode No. 1. H–IV: 16.
Tunnel Lode No. 3. H–IV: 14.
Twelve-Thirty. E–I: 1.
Two Brothers. E–III: 13.

U. G. W. B–IV: 2.
Umbra. A–III: 3.
Uncle George. B–V: 1.
Uncle Sam. E–II: 11.
Union. E–VI: 10.
U. P. R. B–II: 9.
U. S. E–IV: 5.

Valentine. F–IV: 1.
Valverde. E–III: 1.
Venwood. F–VIII: 7.
Verticle. K–I: 1.
Veto. J–IV: 7.
Victor. C–I: 12; H–IV: 3.
Vida. C–I: 14.
Virginia. E–VI: 11.
Virginia House. D–V: 6.
Vivian placer. D–VII: 14.

Wallace. C–VI: 4.
Wana & Browdoin placer. C–VII: 12; D–VII: 17.
Wano. A–III: 1.
Ward. G–VIII: 4.
Washington. J–IV: 3.
Wasp. L–II: 7.
Waterloo. K–IV: 3.
Waverly. C–III: 8.
Wedge. E–VII: 9.
Welch. C–III: 2.
Welch Boy. C–III: 5.
Welch placer. K–VIII: 2.
West Dove's Nest. F–III: 6.
Western. G–V: 13.
West Santa Fe. H–III: 8.
West Virginia. C–I: 3.
Whale (290). C–VII: 14.
Whale (850). D–VII: 15.
White Metal. I–III: 8.
White placer. E–VIII: 4.
William F. placer. B–VI: 4.
William Penn. J–II: 5.
Williams. D–I: 9.
Willie. A–VI: 3.
Windsor Castle. F–III: 3.
Winlock. B–I: 11.
W. M. S. K–III: 1.
Wonderful. K–III: 13.
Wolverine. D–III: 3.
W. P. R. G–III: 2.
W. R. D. C–IV: 1.
Wright. B–III: 1.
W. W. Kirby. A–II: 3.

"X". A–II: 9.

Yellowstone. B–I: 9.
York. B–VIII: 6.
Yosemite (12040). A–I: 8.
Young. D–III: 2.
Young Chief. C–IV: 7.

Zozo. K–III: 3.

CHAPTER VI.—GENERAL FEATURES OF THE ORE DEPOSITS.

INTRODUCTION.

The Central City quadrangle is primarily a gold and silver mining region, but ores of uranium, tungsten, copper, and iron also occur within its limits. The structural types include veins, stockworks, and magmatic segregations. All are believed to have been formed in Tertiary time and to be genetically related to the Tertiary (?) igneous rocks of the region. Long subsequent to the main mineralization the upper parts of many ore bodies were much altered through the oxidizing influence of the air and of meteoric waters. Such alterations have in some places greatly augmented the value of the ore.

GEOGRAPHIC DISTRIBUTION.

The region covered by this report forms part of a broad belt of mineralized territory extending from the La Plata and San Juan mountains on the southwest to northern Boulder County on the northeast. Within this belt lie all the important metal-mining camps of Colorado, including Telluride, Aspen, Leadville, Breckenridge, Georgetown, and many others. (See fig. 4.) As pointed out by Spurr and Garrey,[1] this mineralized belt corresponds in a general way with the distribution of the Tertiary (?) intrusive rocks of the State, and the significance of this correspondence will be discussed later.

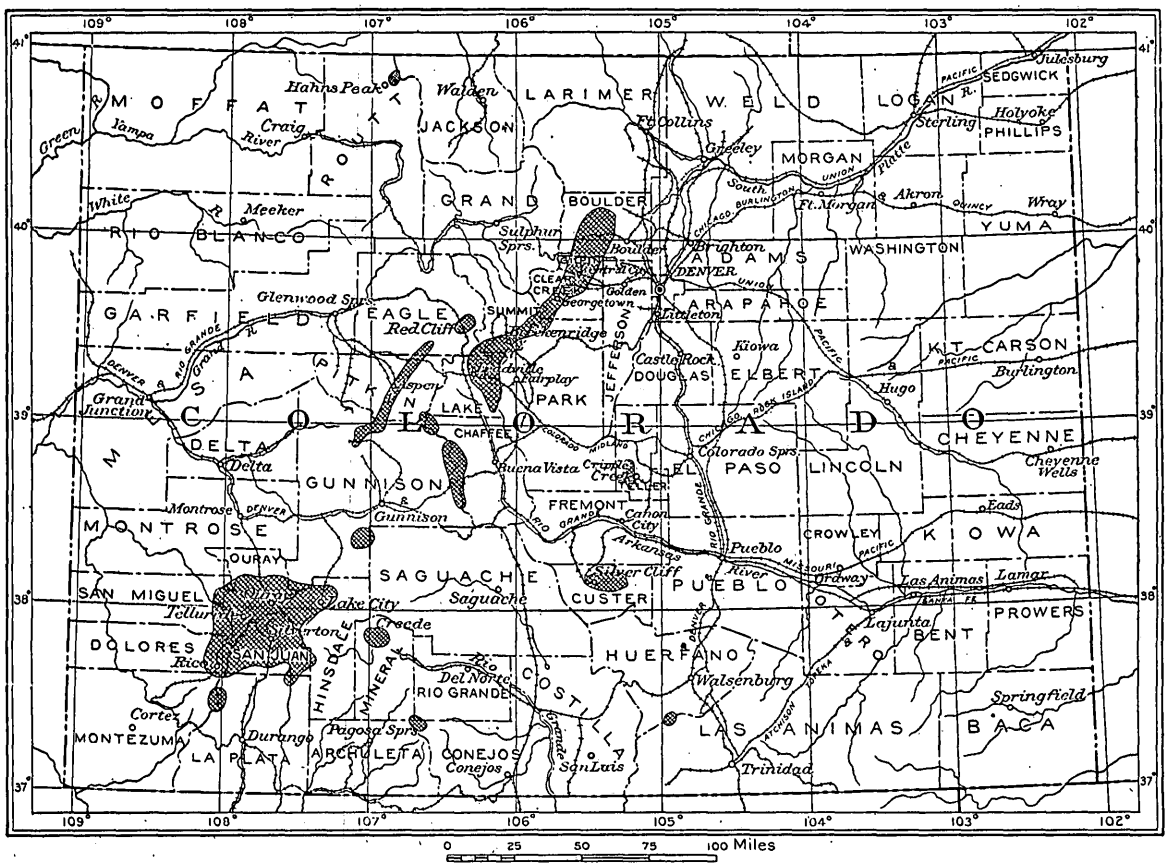


FIGURE 4.—Map showing approximate distribution of principal silver, lead, and gold regions in Colorado. (After Spurr.)

Mines have been developed in nearly all parts of the area surveyed in the Central City quadrangle, but they are most numerous in the region around Central City, Blackhawk, and Idaho Springs, which far surpasses in metal production the combined output of all the rest of the quadrangle. Camps of lesser importance

[1] Spurr, J. E., and Garrey, G. H., op. cit., pp. 67-71.

are Dumont, Lawson, Empire, Alice, Yankee, Apex, Perigo, Eldora, Nederland, and Caribou. In the western high mountainous part of the quadrangle there are almost no developed mines. As this country has been much prospected, the absence of mines probably signifies a real deficiency in mineralization and not merely lesser accessibility. This part of the quadrangle was not surveyed geologically.

CLASSIFICATION BY STRUCTURAL TYPES.

The ore deposits of this region may be classified according to structure as veins, stockworks, irregular bodies formed by magmatic segregation, and auriferous gravels. The veins and lodes comprise gold-silver, uranium, and tungsten ores; the stockworks comprise only gold-silver ores; the magmatic segregations comprise iron and copper ores.

VEINS.

The great bulk of the ores of the quadrangle occupy zones of minor faulting and therefore form true veins.

DISTRIBUTION.

Veins occur in largest numbers and in greatest size in the southeastern part of the area surveyed, near Idaho Springs and Central City, within the areas covered by the large-scale maps, Plates III and VI. They are moderately abundant near Clear Creek between Dumont and Empire, near Alice and Yankee, and near Caribou, but throughout the remainder of the region they are of only scattered occurrence.

The abundance of veins in different localities appears to be dependent primarily on the amount and character of the fracturing and secondarily on variations in the character or abundance of mineralizing solutions. As more fully discussed in a succeeding paragraph, the degree of fracturing was to a considerable extent dependent on the physical character of the rocks, and the absence of veins in certain areas is due to the fact that these areas are underlain by rocks, such as the schists of the Idaho Springs formation, which are unsuited to the development of large persistent fractures. As is pointed out in a later section, the veins in different parts of the region show differences in mineral composition attributable to progressive changes in the nature of the ore-forming solutions. The distribution of the different mineralogic types of veins does not, however, correspond in any way to the relative abundance of veins in different localities. It is believed, therefore, that within the area studied absence of veins in general means absence of fissures suitable for ore receptacles, and conversely that wherever suitable fissures were present ore-bearing solutions were sufficiently abundant and potent to form mineral veins.

Many of the veins are nearly parallel in trend to certain of the porphyry dikes, but this is due solely to the fact that the prevailing directions of fracturing at the time of the intrusion of the porphyry persisted into the vein-forming period. Aside from this, the distribution of veins bears no close relation to the surface distribution of the Tertiary (?) intrusives.

STRIKES AND DIPS.

The strike of by far the greater number of the veins lies between east and N. 45° E., but a few are northwesterly, and a very few others take still different directions. The general accordance in strike of most of them is believed to indicate that the fracturing which preceded the ore deposition was produced by stresses acting with considerable uniformity over large areas, though their effects were modified by local structural features such as the trend of foliation in the fractured rock.

Most of the veins have steep dips, generally more than 60° from the horizontal. Near Central City the dips commonly exceed 70°. Dips of less than 45° are exceedingly rare; the lowest dip noted was 2° to 17° in the Blue Bird vein, 2¾ miles northwest of Nederland, which traverses Silver Plume granite. The direction of dip within the area covered by the map of Idaho Springs and vicinity (Pl. VI) is prevailingly to the north and northwest; this is also the prevailing direction of dip of the foliation in the wall rocks. Farther north, within the area covered by the map of Central City and vicinity (Pl. III), the dips, which are steeper, are somewhat evenly divided between northwest and southeast. Changes of dip amounting to 20° along a single vein are not uncommon. The dip as well as the strike of some veins is markedly dependent on rock structure. Notable examples are found around the southern flank of Pewabic Mountain, as shown in Plate IV, where the veins change in strike and dip with the shifts in the schistosity of the Idaho Springs formation.

WIDTH.

The width of the workable veins ranges from half an inch or even less in the telluride veins, like those of the East Notaway mine, to about 40 feet in a mineralized zone identified as the John L. Emerson vein, cut in the Lucania tunnel. More usual vein widths are from 1 to 5 feet.

COMPLEXITY OF FRACTURING.

Exceptionally veins that are fillings of a single simple fissure have been followed in mining for considerable distances, as, for example, in the Gladstone mine, near Central City, where a sharp-walled vein ranging from a mere thread to 4 inches in width has been developed. Most of the veins are much more complex and are the result of mineralization along a number of subparallel fractures constituting a fracture zone. In many zones of fracturing the rock has been brecciated and the spaces between the fragments have become filled with ore minerals.

PERSISTENCE.

Few of the veins in this region can be definitely traced as single fracture zones either on the surface or in the mine workings for lengths of over 3,000 feet. The longest one noted was the Mammoth, near Central City, shown in Plate III, which is traceable on the surface almost continuously for about 6,000 feet. The Concrete, Gunnell, and Grand Army vein is traceable on the surface with considerable certainty for a little over 4,000 feet.

There seems to be no reason upon theoretical grounds why in such a system of fissures as those occupied by the veins of this region their vertical extent should on the average have been greater than their horizontal extent. Accordingly the vertical extent of the veins that now appear at the surface in this region should be of a somewhat lesser order of magnitude than their horizontal extent, their original upper parts having been removed by erosion. It was therefore to be expected that many of the smaller veins that appear on the surface should pinch out at moderate depths, as has been shown by mining operations. On the other hand, some of the tunnels have discovered veins that do not appear at the surface. Many of the larger veins, however, have been mined successfully to depths of 1,000 to 1,500 feet. The Old Town shaft is 1,950 feet deep and the California shaft 2,200 feet deep along the vein. The relations between depth and ore value are more fully discussed on pages 137–138. The veins commonly terminate horizontally by splitting into branches too small to be worked.

BRANCHING.

Although some of the veins (such as the Seaton, fig. 55, and the Windsor Castle, fig. 52) show few important branches in the distance that they have been followed in mining, the greater number are elements of complicated vein networks composed of master veins, usually with northeasterly trends, connected by oblique cross veins. In following such vein networks many of the mine workings become very complex, as shown in the plan of the Bobtail tunnel (see Pl. XX, p. 224); other characteristic branching vein systems are shown below in figure 5. Vertical branching of veins is no less characteristic and is exemplified by the union below the surface of the Slaughter House vein with the Concrete and of the Wautauga with the Old Town, in both cases the cause of disputes under the apex law. Vertical branching and pronounced curving are also shown in the veins of the Hubert mine (fig. 30, p. 219). Some lodes have a dual character, being composed of two nearly parallel veins. The most striking example is to be seen in the Gem mine, near Idaho Springs, in which the north and south veins are from 20 to 30 feet apart.

INFLUENCE OF WALL ROCK ON FRACTURING.

The nature of the wall rock has exerted a marked influence on the extent and character of the fracturing. Practically all the rocks of the region except the schists of the Idaho Springs formation possess a high degree of rigidity, and in these rocks were formed under regional stresses sets of fractures, branching and somewhat complex, but at the same time sufficiently persistent and open to afford favorable sites for ore deposition. The weak, easily crushed schistose rocks of the Idaho Springs formation as a rule yielded to the same stresses by forming innumerable short fracture seams, along many of which clayey gouge was produced. Only small open spaces were left, and the fractured portions of this formation were in general not favorable sites for ore deposition. Exceptions are to be noted in certain places where the fractures cut sharply across the schist foliation and where the rigidity of the Idaho Springs formation has been materially increased by the intrusion of large amounts of granitic material. Examples of this influence of the wall rock on fracturing are numerous. On the 332-foot level of the Gold Collar mine, near Central City, the vein in passing from granite gneiss to schist of the Idaho Springs formation dies out in a series of small branching fractures about parallel to the schistosity. In the Cœur d'Alene mine, just west of Central City, the mineralization where the walls are granite gneiss takes the form of sharp-walled sulphide veinlets that are plainly fissure fillings. Where the wall rock is schist of the Idaho Springs formation sulphide veinlets are usually absent and the fracture zone is either barren or carries only scattered grains of sulphides. In the Frontenac mine, on the fourth level west, the so-called Flat vein where inclosed by walls of schist heavily injected with pegmatite is a very definite zone of somewhat decomposed and mineralized gouge and brecciated wall rock from 6 to 18 inches wide, but where it enters an area of schist unmixed with pegmatite it breaks up into a zone 5 or 6 feet wide, throughout which there has been slipping between the schist folia but no mineralization.

The influence of the character of the wall rock on vein formation has also been recognized by George and Crawford[1] in the tungsten veins of Boulder County. It is exemplified on a large scale by the absence of notable veins over certain large areas which are occupied mainly by schist of the Idaho Springs formation. Such an area extends westward from Nigger Hill, near Central City, to Mount Pisgah and southward to the upper part of York Gulch.

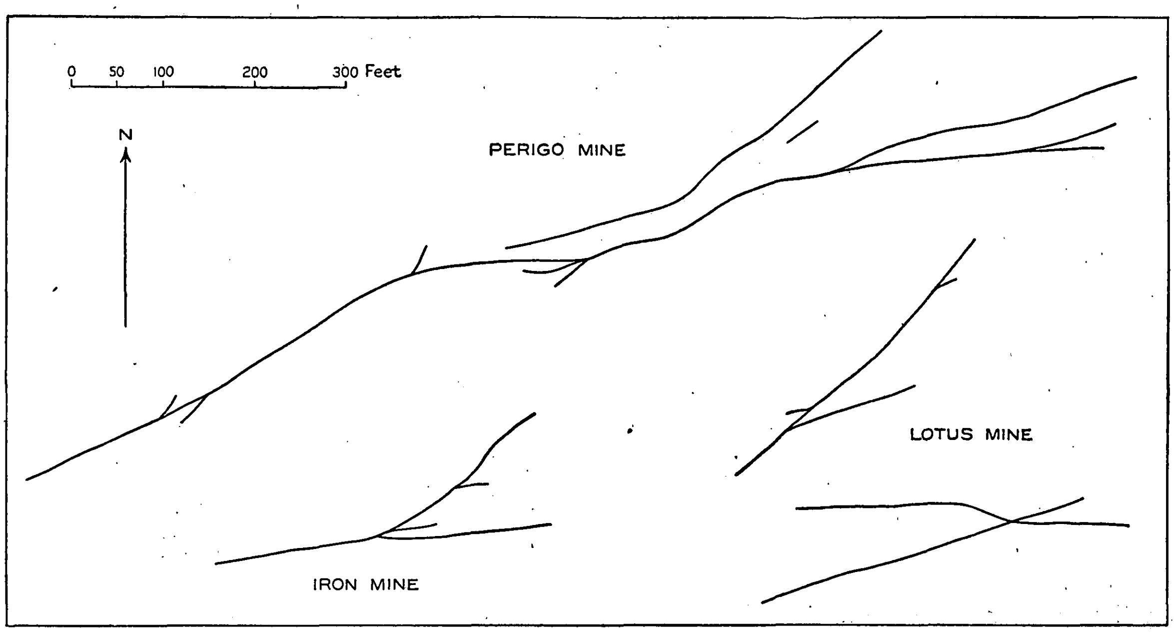


FIGURE 5.—Diagram showing characteristic branching vein systems as exposed in the workings of three mines.

STOCKWORKS.

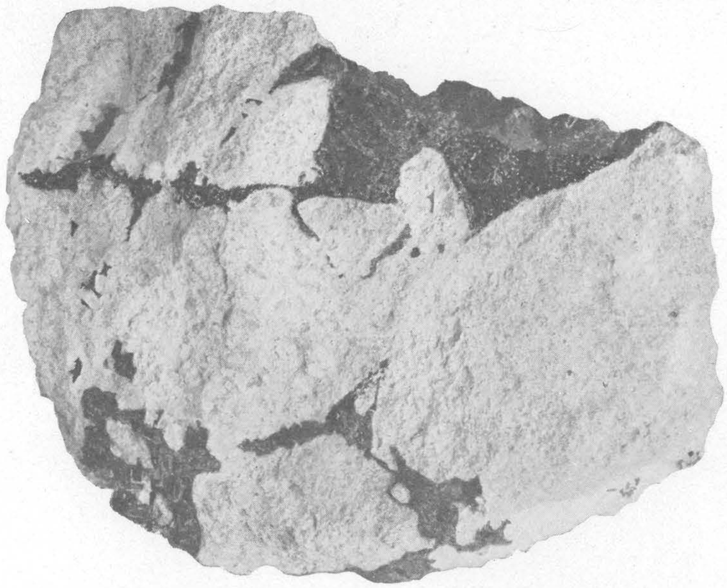
DEFINITION.

A stockwork is an ore deposit of irregular shape made up of innumerable small branching and anastomosing veinlets. The character and origin of those occurring in the Central City region may best be set forth by considering in some detail the largest of these ore bodies, the so-called Patch, developed in the San Juan mine, on Quartz Hill, near Nevadaville. Comparisons will then be made with a few of the smaller stockworks.

THE PATCH.

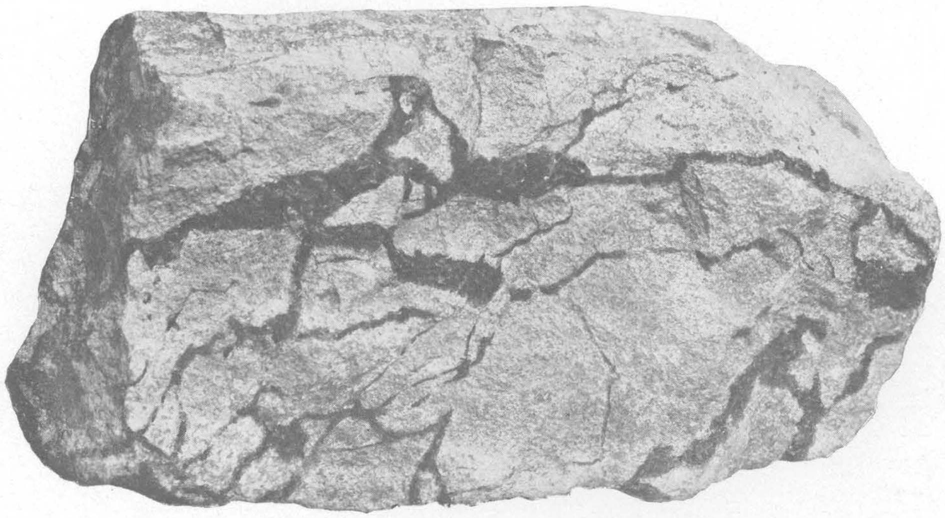
Structure.—The origin of this interesting deposit has been the subject of much specula-

[1] George, R. D., and Crawford, R. D., The main tungsten area of Boulder County, Colo.: Colorado Geol. Survey First Rept., p. 60, 1908.



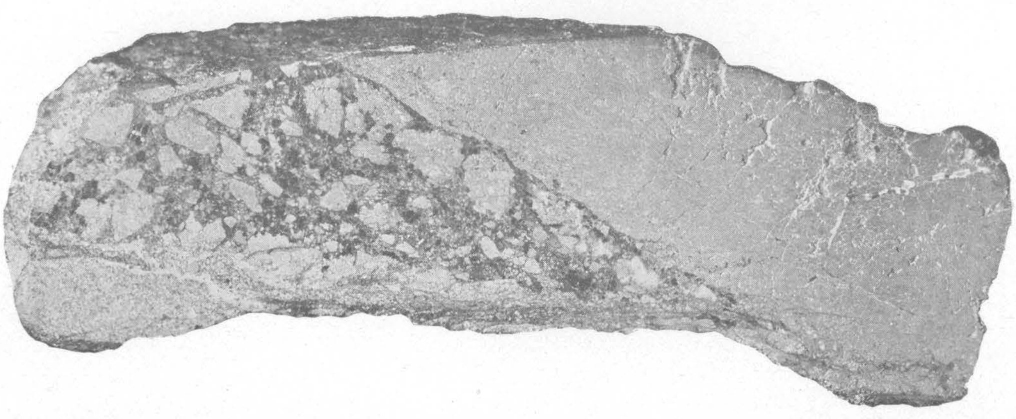
A. IRREGULAR MINERALIZATION TYPICAL OF STOCKWORKS OF THE PATCH TYPE AT HUBERT MINE.

The sulphides and quartz fill irregular spaces and form irregular replacements in fractured and sericitized granite gneiss. From 850-foot level. Natural size.



B. NETWORK OF SPHALERITE VEINLETS TRAVERSING SERICITIZED GRANITE GNEISS, BOULDER COUNTY VEIN NEAR CARDINAL.

Natural size.

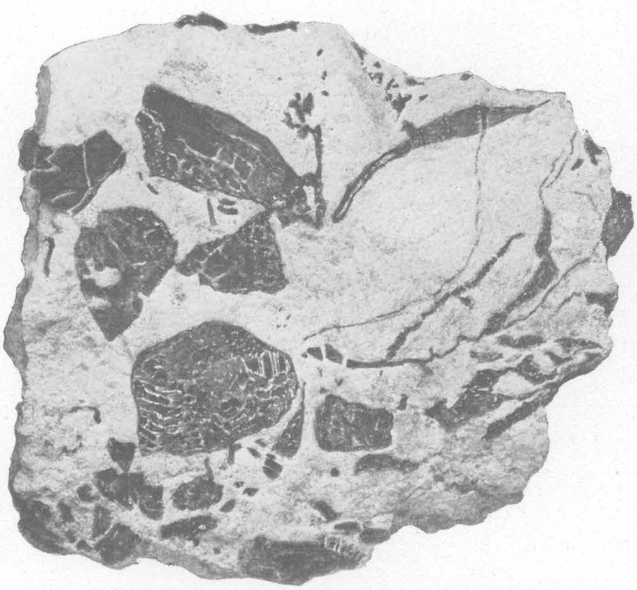


C. ORE OF COMPOSITE TYPE FROM FOURTH OF JULY MINE, NEAR CENTRAL CITY.

Pyritic ore has been brecciated and the fractures filled by ore of the galena-sphalerite type. Natural size.

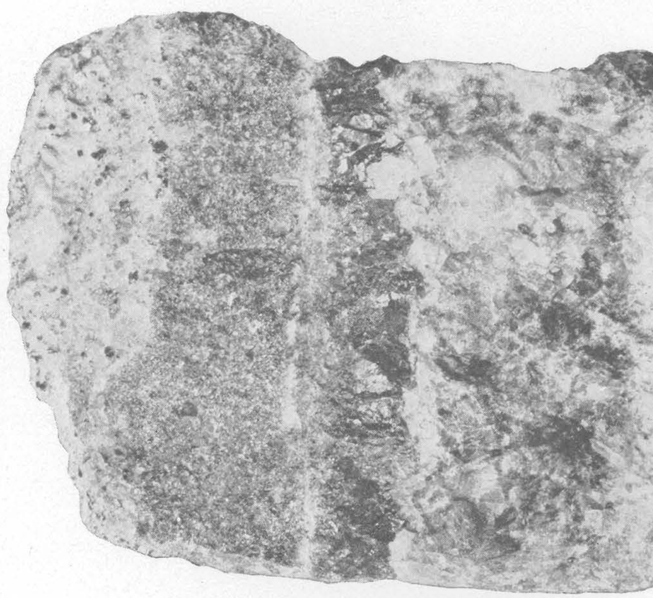
A. POLISHED SURFACE OF ORE FROM ALICE MINE, SHOWING PROGRESSIVE ALTERATION OF MONZONITE PORPHYRY.

Porphyritic texture still preserved on right but largely obliterated on left. Probable position of this specimen with respect to principal fracture lines is indicated in figure 7, page 98. *a*, Slightly altered porphyry; *b*, moderately altered porphyry; *c*, highly altered porphyry; *p*, pyrite. Natural size.



B. ORE BRECCIA FORMED BY POSTMINERAL MOVEMENT ALONG A VEIN IN IVANHOE MINE, NEAR NEVADAVILLE.

Fragments of galena and dark-colored quartz lie in a matrix of crushed granite gneiss. Natural size.



C. BANDED ORE FROM TOPEKA VEIN.

Central band of nearly black sphalerite is bordered on left by a band composed of fine aggregate of pyrite, dark sphalerite, and quartz; on right by a band of coarse "resin" sphalerite. Natural size.

tion and some controversy among mining men of the district. Structurally it is a body of irregularly fractured and brecciated rock. The degree of fracturing is variable. In some places the wall rock has merely been cut by an irregular network of fractures without much displacement (see Pl. XIII, *A*); elsewhere it has been broken into fragments that have been moved over one another, many of them becoming rounded by friction and fragments of different kinds becoming indiscriminately mingled. In places in the Argo tunnel the Patch is a breccia of rock fragments of many sizes, the largest 4 feet in diameter, in an arkose-like matrix. The brecciation reached a maximum along several northeastward-trending zones that are parallel to and in some places continuous with the veins entering the Patch. The principal veins entering the upper portion of the Patch are the California-Gardner and the Rhoderick Dhu, which appear to combine east of the Patch as the great Hecla-National-Mammoth lode. On the level of the Argo tunnel the principal veins of the Patch have been provisionally identified as belonging to the Kansas-Burroughs group, the Gardner vein at this depth having apparently passed out of and south of the Patch. The Patch fracturing therefore appears to have been produced by the same forces and at the same time as the neighboring vein fissures. It is situated where a number of large fracture zones approach one another closely and where the shearing movements, instead of being confined as in most cases to these zones, became distributed through all the intervening rock.

Form.—In surface outline the Patch, as shown in figure 36, is oval, having a diameter of about 750 feet from northeast to southwest and of about 400 feet from northwest to southeast. Its boundaries are commonly indefinite, but in the Argo tunnel it terminates sharply on the south against a vertical fault plane. From the surface down the breccia of the Patch persists without diminution in size but with marked diminution in mineralization to the Argo tunnel, a distance of approximately 1,600 feet. Its general form is therefore that of a "pipe" or "chimney" dipping steeply to the north. Its extent below the Argo tunnel is wholly conjectural.

Wall rocks.—The prevailing wall rock of the Patch is granite gneiss, but in places bostonite porphyry is abundant; pegmatite and schist of the Idaho Springs formation occur only rarely. The fractures traverse all these rocks indiscriminately.

Mineralization.—Some parts of the Patch are barren; others are heavily mineralized. The zones of maximum brecciation are in general also zones of maximum mineralization, as is very apparent from figure 36 and the plans of the San Juan workings (fig. 35). As in the neighboring veins (see p. 234), the mineralization is of two types—one showing pyrite, chalcopyrite, and quartz with a little tetrahedrite as ore minerals and the other showing galena, sphalerite, chalcopyrite, and subordinate pyrite. There is little mingling of the two types. The ore minerals fill fractures and angular cavities between fragments and also replace the silicates of the rock, and in most of the ore both processes have been operative. In many places the limits of profitable mining are determinable only by assay.

Further details concerning the Patch as exposed in the Argo tunnel and the San Juan workings are given on page 234.

OTHER STOCKWORKS.

A much smaller stockwork is developed by a large stope in the Hubert mine. Most of the

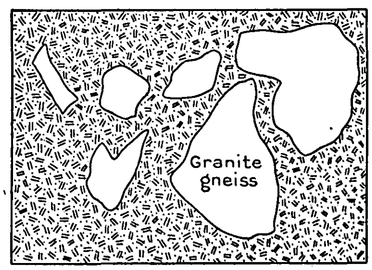


FIGURE 6.—Sketch of filled breccia in Hubert mine. Angular fragments of granite gneiss lie in a matrix of galena and sphalerite. One-half natural size.

workings of this mine follow veins, but near the west end of the 850-foot level the vein begins to branch and then passes into a network of sulphide stringers traversing the granite gneiss in all directions; this passes locally into a true filled breccia, whose appearance is shown in figure 6, and whose fragments have plainly been moved from their original position. The largest fragments are 3 inches in diameter and they usually show sharp, angular outlines. The stockwork has a known width of about 35 feet and a vertical extent of over

150 feet, apparently not reaching the surface. It is identical in appearance with certain portions of the Patch and was probably formed by similar processes acting on a much smaller scale. Here the movement, initiated along the south vein fracture and several branches leaving it at nearly the same point, apparently became distributed more or less through the intervening rock, which fractured irregularly, the fragments in places moving over one another. This fractured and porous mass became a favorable site for ore deposition.

The ore body of the Alice mine, near Alice, has been formed by the mineralization of an irregularly fractured body of porphyry, but it differs from the Patch in that most of the fracture openings are narrow and the fragments have suffered little displacement relative to one another. The mineralization was accomplished mainly by replacement rather than by fissure filling and was at a maximum where two or more fractures intersected, as is shown diagrammatically in figure 7. At such intersections nests of sulphides as much as 3 inches across have developed. Less commonly cavities or vugs 1 foot or less in diameter occur at such intersections and are lined with sulphides.

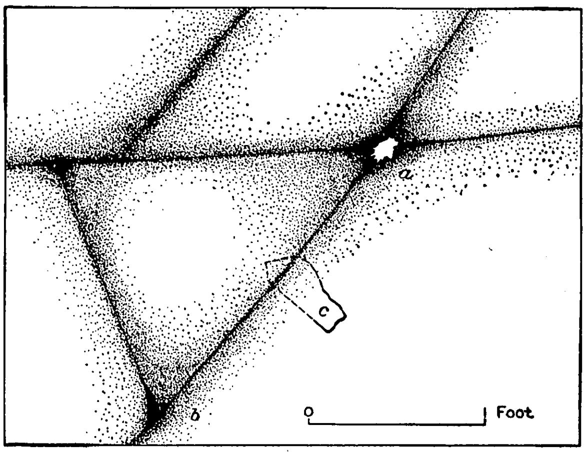


FIGURE 7.—Diagrammatic section showing relation of mineralization to fracture planes and their intersections at the Alice mine. The white areas are fresh or little altered porphyry. *a*, Vug at intersection of fractures; *b*, "nest" of minerals at intersection of fractures. The area *c* inclosed by the broken line illustrates the position which the specimen shown in Plate XIV, *A*, might have occupied when in place. The specimen itself was taken from the dump.

The ore of the Commercial Union mine, southwest of Alice, is structurally similar to that of the Alice mine, but the wall rock is schist of the Idaho Springs formation instead of porphyry.

These stockworks are described in more detail on pages 323–326.

ORES FORMED BY MAGMATIC SEGREGATION.

Within the Caribou monzonite stock occur four bodies of much more mafic (basic) rocks of irregular but more or less rounded outline. The greatest dimension of any of these bodies is a little less than a quarter of a mile. Within these in turn occur several small masses of iron ore, some of which are lens-shaped, while others are wholly irregular. The contact between ore and wall rock is in some places sharp and in others gradational.

The copper ores of the Evergreen mine, near Apex, occur within dikes of monzonite, and the metallic minerals, which are irregularly distributed within the dikes, crystallized for the most part contemporaneously with the silicate minerals of the monzonite. The ores are apparently a product of magmatic differentiation under localized and unusual conditions discussed at length on pages 126–129.

AURIFEROUS GRAVELS.

The auriferous gravels of the region, worked in the early days, have long since ceased to be of any economic importance. Aside from the fact that some of them, probably of preglacial age, are cemented, they present no structural peculiarities. Their bulk is small. The placer deposits are described on pages 60 and 120.

ORE TEXTURES.

With the exception of the tungsten ores, which were not studied by the writer, most of the ores of this region are massive—that is, the component minerals are distributed irregularly though not everywhere evenly throughout the ore mass. Brecciated structures are fairly common both in ores due to single mineralization, as shown in Plate XIII, *A*, and in those due to composite or dual mineralization, as shown in Plate XIII, *C*. In a few places brecciated structure has been produced by vein fracturing subsequent to mineralization, as illustrated in Plate XIV, *B*. Irregular banding continuous for only short distances is not uncommon and may be due to variations either in the proportions or in the coarseness of the component minerals, or in both. In some places such banding is the result of dual mineralization, a fissure filled with later ore having been formed parallel to an earlier vein along either its border or its center. Here and there, as shown in Plate XIV, *C*, banding even in ore deposited during a single period of mineralization is well defined, but such banding is local and is nowhere sufficiently persistent throughout an ore body to indicate a well-marked general sequence in the deposition of the component minerals.

Textures peculiar to the pitchblende ores are illustrated in Plate XV, *A*, and figure 12 (p. 124) and are due to the well-known tendency of pitchblende to crystallize in masses of grapelike or botryoidal form.

GEOGRAPHIC DISTRIBUTION OF ORE OF DIFFERENT CLASSES.

Gold-silver ores occur in nearly all parts of the area surveyed, although they are most abundant in the vicinity of Central City and Idaho Springs. The distribution of the several types of gold-silver ores is described on pages 115–116.

Uranium ores occur principally in a small group of mines on Quartz Hill, near Central City, but they have been found in small quantities at a few other properties, such as the Jo Reynolds mine, near Lawson. They are regarded as a local and unusual variety of the gold-silver ores.

Ores worked primarily for their copper content are confined to the Evergreen mine, near Apex, where they are the product of unusual and highly localized conditions.

Tungsten ores are confined to the region between Phoenix, Nederland, and Cardinal, and are associated with a series of dikes of intermediate to mafic (basic) composition that are unique in the Central City quadrangle.

Iron ores are confined to the immediate vicinity of Caribou.

MINERAL COMPOSITION OF ORES.

The ores of the Central City quadrangle may be classified on the basis of their most valuable metals into five groups—gold-silver ores, uranium ores, tungsten ores, copper ores, and iron ores. On the basis of mineral association, as discussed on pages 105–116, the gold-silver ores may be subdivided into three types—pyritic ores, galena-sphalerite ores, and telluride ores. The characteristics of each of these classes or subclasses of ores will be considered at length in succeeding chapters, but occasion will be taken here to present the mineral characters of all these types in tabular form (p. 100) and to mention certain mineralogic features of general significance. For reasons set forth in Chapter VIII (pp. 121–123) the uranium ores are believed to represent merely a local and unusual phase of the pyritic ores, and their minerals are therefore listed in the column devoted to that type. The tungsten ores were not studied by the writer and are not included in the tabulation; their characters are briefly summarized from the reports of others on page 123. The list includes not only the minerals noted by the writer but also those authoritatively reported by earlier observers.

While the physical conditions under which the ores of the several types were deposited will be discussed at length later, it may be noted in passing that all three types of gold ores show an entire absence of minerals characteristically formed under high temperatures or high pressures. Another noteworthy fact is the great preponderance of arsenic over antimony in both the pyritic and the galena-sphalerite types of gold-silver ores. In some of these ores the arsenic mineral enargite is abundant, and most of the so-called "gray copper" of the district proves on testing to be tennantite rather than tetrahedrite. A little antimony is indeed present in some occurrences of these minerals, but it is invariably, so far as the writer's observations show, much subordinate to arsenic. Stibnite has not been authoritatively reported.

It is significant also that the writer's observations in this region have failed to reveal any primary occurrences of the rich sulpho-compounds of silver, whereas they are abundant locally as products of downward enrichment. Important too is the fact that among these secondary silver minerals the arsenic compounds proustite and pearceite are much more abundant than the corresponding antimony compounds. The pyrite of the ores, if well crystallized, is commonly cubical or pyritohedral in form; octahedral crystals of pyrite were observed only in one mine, the Rooks County, between Apex and Tolland. On the octahedral pyrite crystals are implanted small crystals of a soda-potash feldspar, the only occurrence of this silicate noted in the ores of the region.

Ore minerals of Central City quadrangle.

[NOTE: The list includes minerals developed metasomatically in wall rocks as well as those that are fissure fillings. P, Primary minerals; S, minerals of secondary sulphide zone; O, oxidation products; *, mineral rare.]

Minerals.	Primary ores crystallized from magmas.						Primary gold-silver ores deposited by ascending thermal solutions under moderately intense heat and pressure.								
	Caribou iron ores.			Evergreen mine copper ores.			Pyritic ore type.			Galena-sphalerite ore type.			Telluride ores.		
Native elements:															
Gold				P			P	S?	O	P	S?	O	P	S?	O
Silver				P			P	S?	O?	P	S	O	P	S?	O?
Copper									O						
Bismuth							P*			P*					
Sulphur									O			O			O?
Sulphides:															
Pyrite							P			P			P		
Chalcopyrite				P			P	S*		P	S				
Bornite				P				S		P*	S*				
Covellite								S							
Chalcocite								S			S*				
Galena							P*			P					
Sphalerite							P*			P					
Molybdenite							P*			P*			P*		
Bismuthinite							P*								
Tellurides:															
Sylvanite							P?			P?			P		
Petzite													P*		
Sulpho-compounds:															
Tetrahedrite							P*			P?					
Tennantite							P			P					
Enargite							P			P*					
Pearceite											S				
Proustite											S				
Polybasite											S				
Stephanite											S?				
Haloids:															
Cerargyrite												O*			
Fluorite							P			P?					
Oxides:															
Quartz				P			P			P			P		
Chalcedony													P		
Tenorite									O*						
Hematite			O			O			O			O			O
Zincite												O*			
Ilmenite	P														
Ilsemannite $(M_0O_2.4M_0O_3)$															O*
Magnetite	P			P											
Limonite			O			O			O			O			O
Carbonates:															
Calcite				P?	S*		P			P					
Siderite							P			P					
Rhodochrosite										P					
Smithsonite												O*			
Cerusite												O*			
Malachite						O			O			O*			
Azurite						O			O			O*			
Aurichalcite												O*			
Silicates:															
Orthoclase				P											
Adularia										P*			P*		
Soda-potash feldspar							P*								
Albite				P											
Plagioclase (calcic)	P			P											
Augite	P			P											
Wollastonite				P											
Garnet				P											
Olivine	P														
Zircon				P											
Sericite							P			P			P?		
Biotite	P														
Epidote										P*					
Roscoelite													P		
Clinochlore										P*					
Serpentine			O												
Calamine												O*			
Titanite				P											
Phosphate: Apatite	P														
Uranate: Uraninite							P*								
Sulphates:															
Barite										P			P*		
Hydrous sulphate of iron and copper						O			O						
Basic sulphate of uranium, exact composition not determined, found coating uraninite at Wood mine, canary-yellow									O						
Goslarite												O*			

STRUCTURAL RELATIONS OF ORES AND PORPHYRIES.

As has been pointed out in Chapter III, the later intrusive rocks of the quadrangle, though showing some diversity in age, are all believed to have been intruded either in late Cretaceous or early Tertiary time. The iron ores of Caribou and the copper ores of the Evergreen mine, being products of magmatic differentiation, are manifestly of the same age as the monzonite in which they occur; the other ore deposits are, with a few exceptions, later than these igneous rocks.

Among the gold-silver ores, those of the pyritic type cut monzonite porphyry in the Alice mine, near Alice; in the San Juan, East Notaway, and Chase mines, near Central City; and at several places in the Argo tunnel. Ores of the pyritic type were observed to cut bostonite in the Rockford tunnel, near the mouth of Fall River; the Two-Forty mine, near Russell Gulch, and probably also in the Silent Friend and Earl of Kent mines, near Dumont.

Gold-silver ores of the galena-sphalerite type cut monzonite in the Edgar mine and Idaho tunnel, near Idaho Springs; in the Silver Age tunnel, in Gilson Gulch; in the San Juan mine, near Central City; and in a number of other mines. The galena-sphalerite ores cut bostonite in the Senator and Blue Ridge mines, near Lawson; also in the Edith S. vein as exposed in the Big Five tunnel, and in the Fairmont tunnel near the head of Virginia Canyon.

Telluride veins cut monzonite porphyry in the East Notaway mine (see p. 264), but nowhere else in the region were they found in contact with the late intrusives.

Uranium ores were not observed in association with porphyry, but as already pointed out they are believed to be a phase of the pyritic type of gold-silver ores. Like them they were probably formed later than the porphyry intrusions.

The tungsten ores have not been observed in contact with the Tertiary (?) intrusive rocks.

There are a few noteworthy exceptions to the general rule that the ores are either contemporaneous with or later than the Tertiary (?) intrusives. Spurr observed in the Stanley mine[1] near Idaho Springs biotite latite intruding not only the earlier bostonite porphyry but the gold-silver ore as well. The dike in the Stanley mine is the only known occurrence of biotite latite in the Central City quadrangle, and these rocks have a very sparse distribution in the adjacent Georgetown quadrangle. At several places in the Blue Bird mine, near Nederland, a gray fine-grained mica andesite porphyry distinctly cuts the Blue Bird vein at sharp angles and with "frozen" contacts.

[1] Spurr, J. E., and Garrey, G. H., op. cit., p. 344.

PRIMARY VARIATIONS IN METAL CONTENT IN ORE DEPOSITS.

Variations in the metal content in different parts of the same ore deposit may result either from variations in the degree or in the character of the mineralization—that is, the variations may be quantitative or qualitative.

Variations in the degree of mineralization occur in every ore deposit and are dependent primarily on the nature of the fracturing. The ore at one part of a vein may be a filling of a single wide fissure, while a little farther on it may fill several small nearly parallel fissures, necessitating the excavation of more wall rock to obtain the same quantity of valuable metals. Where two or more fracture zones approach each other closely, brecciation of the intervening wall rock may occur, and the breccia may become highly mineralized, forming ore bodies larger than the typical veins but usually of lower grade, because proportionately more wall rock must be mined with the sulphides. Large-scale examples of typical veins passing into mineralized breccias are found in the San Juan and Hubert mines, and examples on a small scale are common in many mines. A fissure that is strong and well mineralized in brittle rocks may in passing into less brittle rocks subdivide into numerous very minute fissures of small individual extent that are only feebly mineralized, or the more plastic rocks may crush to a mass of fragments mixed with a clayey gouge that is unfavorable for ore deposition. Variations in mineralization due to this cause were noted in a number of mines where veins pass from granite gneiss or pegmatite into schist of the Idaho Springs formation. Unusually heavy mineralization is common at the junctions of the larger members of a vein system; the vein fractures at such localities usually join at acute angles, and the wedges between the converging veins were commonly much shattered and afforded particularly favorable channels for the circulation of mineralizing solutions. Many of the most productive ore shoots of the region follow such junctions. An ore shoot formed in this way was noted in the Chase mine, at the locality shown by the letter C in figure 49 (p. 275). The Elizabeth vein, though itself rarely productive, has near its intersection with the productive veins of the Gunnell mine produced notable enlargements of their ore bodies.

Equally as important as the types of variations already noted are those due to changes in mineral composition. Gold and silver are nowhere equally abundant in all the ore minerals, and consequently variations in the proportions of the ore minerals entail variations in the value of the ore. In certain veins, such as the Mammoth, near Central City, the ore, which consists predominantly of pyrite, is workable only where chalcopyrite, a much more auriferous mineral than the pyrite, is also present. In the telluride veins variations in value dependent on the quantity of telluride present are likely to be very abrupt, and rich ore may be followed by lean ore of almost identical appearance. In certain ores the richer minerals formed more abundantly in the later stages of the mineralization; this is true, for example, of chalcopyrite and tennantite in the pyritic ores, and these minerals are therefore likely to be most abundant in the central portions of veins or near vugs. In general, however, these mineralogic variations seem to follow no definite law and to be an expression of minor variations in the composition of the ore-forming solutions comparable to those larger variations that are expressed by the different ore types.

A special phase of mineralogic variation is the result of the dual mineralization discussed more fully on pages 112–114. As there pointed out, many gold-silver ores of the pyritic type were subsequently fractured, and ores of the galena-sphalerite type were deposited along the fractures or in vugs in the pyritic ore. The second mineralization affected only portions of the pyritic ore bodies, so that there may be transitions along a single vein from ores wholly pyritic into composite ores and even into ores wholly of the galena-sphalerite type. The workability of certain ores is due to such dual mineralization, some of the earlier pyritic ore being below the commercial grade. The distribution of the composite ore being dependent on the irregularities of fracturing, is likely to be diverse, but in very many veins that have been mineralized twice the older pyritic mineralization is more extensive than the younger galena-sphalerite mineralization, and composite veins tend to pass into pyritic veins laterally or downward. Many of the veins along the line of the Argo tunnel that are composite at the surface are pyritic at the tunnel level, notable examples being the Sun and Moon and the Gunnell veins. Many veins that pass from areas of predominantly pyritic ores to areas of predominantly galena-sphalerite ores are pyritic at one end, of the galena-sphalerite type at the other, and composite between; the American-After Supper-Sleepy Hollow vein, in the vicinity of Blackhawk, appears to be of this type. Variations from composite ore at one end of a vein to ore of one or the other simple types at the other end are extremely common. The Hidden Treasure-California-Gardner vein is composite in its eastern portion and of the galena-sphalerite type in its western portion, and the same is true of the Owatonna-Frontenac-Aduddell-Druid-Kokomo lode.

Dual mineralization of another type is exhibited in the East Notaway mine, where the pyritic ore of the Homestake vein is locally traversed by later veinlets of telluride ore.

ALTERATIONS OF WALL ROCK.

The Central City quadrangle is not a favorable region for the detailed study of wall-rock alterations. For trustworthy chemical comparisons the element of variation in the character of the wall rock prior to alteration must be practically eliminated, and this can seldom be done in this region of frequently alternating rock varieties. The general character of the alterations has been determined, however, and seems to throw some light on the nature of the mineralizing solutions.

Many of the zones of fracturing along which the veins of the quadrangle were formed contained few large open spaces. The mineralizing solutions entered along many small fractures, some of them of microscopic minuteness, and from these gradually worked outward into the wall rock, replacing the rock minerals and converting the rock into ore for varying distances from the fractures.

In other fracture zones open spaces of considerable size existed and became filled with ore minerals, but the wall rock adjacent to such open spaces was also invariably mineralized, some of it to such a degree that it became workable as concentrating ore. The processes of replacement can in general be better studied in the walls of filled fissures than in the replacement veins.

Detailed description of the wall-rock alterations will be deferred to Chapter VII, but their general nature may here be summarized. The observations refer only to the gold-silver ores and their subtype uraninite-bearing ores; the tungsten ores are not considered.

The dominant wall-rock alteration associated with the gold-silver ores of both the pyritic and galena-sphalerite types consists in the replacement of all the original rock minerals except quartz and apatite by sulphides, sericite, and in some places carbonates (calcite or siderite). Quartz entirely resists the alteration or may recrystallize. Among the rock minerals that yield to these alterations are orthoclase, plagioclase, biotite, hornblende, and magnetite. It may be inferred, therefore, that these ores were not deposited at extremely high temperature or high pressure, for under such conditions these silicates and oxides are usually stable.

In the early stages of alteration the replacements are selective, sericite, for example, developing at the expense of certain rock-forming silicates and not of others and pyrite replacing magnetite before it replaces other minerals. In the alteration of ferromagnesian silicates, such as biotite and hornblende, chlorite and epidote may form as temporary products, to give way to sericite, pyrite, and calcite as the alteration continues. Such features indicate that in the early stages at least the replacement is not a bodily removal of one mineral in solution and the deposition of another in its place but involves chemical interchanges between the original minerals of the wall rock and the mineralizing solutions.

The association of minerals formed by replacement in the walls of filled fissures is in general different from that deposited in the fissure itself, in spite of the fact that both mineral associations were obviously formed almost contemporaneously and under the same general conditions of pressure and temperature. One of the most striking exemplifications of these contrasts is the scarcity or entire absence of galena and sphalerite in the walls of many fissure fillings in which these minerals are very abundant; in such walls pyrite is the dominant sulphide. Carbonates may be present in a filled fissure but absent from its walls. Conversely, sericite, the commonest alteration product in the walls, is never found in the fissure fillings. Chalcopyrite and tennantite, common constituents of certain fissure fillings, are rarely found in the walls.

Differences in mineral character analogous to those between a filled fissure and its wall rock may in a few places be noted along the strike of a vein. For example, a fracture system that passes from an area of granite gneiss to an area of schist of the Idaho Springs formation commonly changes from a zone having a few open fissures to one having many very minute tight fissures. In consequence, fissure filling, the predominant process in the granite gneiss, gives way to replacement in the schist. In the Cœur d'Alene mine, where a change of this sort was noted, sharp-walled veinlets, some of which carry galena and sphalerite, occur in the granite gneiss but are supplanted where the fracture zone enters schist by disseminated ore carrying pyrite as its main sulphide. In places half the volume of this ore is pyrite.

Few opportunities were afforded for determining with precision the wall-rock alterations associated with the deposition of the rich telluride ores. In the Eldora district there was little chance to observe these ores, and in the vicinity of Idaho Springs and Central City the telluride ores were everywhere associated with sulphide ores, so that the alterations connected with each type could not be entirely differentiated.

In the War Dance mine, near Central City, much of the ore is a replacement of schist by fluorite, pyrite, sericite, and sylvanite. Schist replacement by fluorite was also noted in ore on the dump of the neighboring Powers mine.

The extent to which the original wall-rock texture is destroyed in the replacement process varies with the nature of the texture and the severity of the alteration. In many places it is wholly effaced, and the only indications that what is now ore was once rock are found in the presence of sericite in the ore and its complete gradation into undoubted wall rock. In a few localities the extreme of alteration is represented by a structureless mass of minute sericite plates. Near many ore bodies, on the other hand, the alterations have been less severe and original foliated or porphyritic textures are still preserved.

While the principal key to the composition of the ore-forming solutions is the mineral composition of the fissure fillings, the abundance of sericite in the walls contributes the additional information that the solutions were very rich in potash. The nature of the mineralizing solutions is more fully considered on pages 131–135.

INFLUENCE OF WALL ROCK ON MINERALIZATION.

The different rocks of this region, under the regional stresses that produced the vein fractures, yielded in different ways dependent on their varying rigidity. As a direct consequence of these differences in the nature of the fracturing, differences resulted not only in the degree but also in the kind of mineralization, as has been pointed out above. These influences of the wall rocks on mineralization, which are purely mechanical in their nature, are most conspicuous where veins pass from areas of granite gneiss into areas of schist of the Idaho Springs formation.

What may be termed a chemical influence of the wall rock on mineralization, due to the mineral composition of the rock, was only doubtfully recognizable in a few places. Changes in the character of the wall rocks seem to exert no influence on ores that are fillings of open fissures. On the other hand, ores that are replacements show some variations with the nature of the rocks replaced. In the Druid mine (p. 273), for example, the more micaceous folia in the Idaho Springs formation seem to have been replaced by valuable ore minerals more readily than less micaceous layers. In a number of the mines near Caribou where the veins pass from areas of monzonite into areas of gabbro or even more mafic (basic) rocks the change in wall rock must have resulted in changes in the nature of the replacement ores, but opportunities were lacking to study this feature. In general the chemical influence of changes in wall rock on mineralization appears to have been minor and local. In this connection should be noted the absence from this region of limestone, a rock particularly likely to exert a considerable influence on mineralization.

Chapter VII.—GOLD-SILVER ORES.

PREDOMINANCE AND GENERAL CHARACTER.

Most of the ore deposits of the Central City region are veins or stockworks that are worked primarily for the gold and silver which they contain. In some deposits copper or lead or rarely zinc is sufficiently abundant to be of supplementary economic importance. A few ores contain pitchblende, and though these ores also carry considerable gold and silver and are probably merely a phase of the gold-silver mineralization, their description will for convenience be deferred to Chapter VIII (pp. 121–123). In most of the gold-silver ores gold greatly predominates over silver in value, but in a few, usually as a result of downward enrichment in silver, the reverse is true. In the early days of the region placer gravels were of much economic importance and the gossans of many of the lodes were worked by placer-mining methods, but placer mining is now practically extinct.

CLASSIFICATION.

The gold-silver ores may be classified as lode ores and placers. The lode ores may be classified under four types—pyritic ores, galena-sphalerite ores, composite ores (a combination of the pyritic and galena-sphalerite ores), and telluride ores.

LODE ORES.

PYRITIC ORES.

DEFINITION.

The pyritic ores consist predominantly of pyrite and gangue minerals, with subordinate amounts of chalcopyrite, tennantite, and in places enargite and other metallic minerals. In these ores gold greatly predominates in value over other metals. They constitute one of the principal types of gold ores in the region, the entire output of the Saratoga, Old Town, Alice, and many other mines belonging to this type.

PRIMARY MINERALS.

In the pyritic ores pyrite is always the predominant sulphide. The principal copper mineral is chalcopyrite, which usually constitutes less than 5 per cent by weight of the ore, equivalent to less than 1.5 per cent metallic copper. In some shipments of rich smelting ore the proportion of chalcopyrite rises to nearly 50 per cent, or the equivalent of about 17 per cent of copper. Tennantite is commonly present but is very subordinate to chalcopyrite. Enargite is abundant in a few veins. Silver and gold, probably alloyed, occur in the sulphides but are rarely visible. Other metallic minerals present here and there in small amounts are galena, sphalerite, molybdenite, and native bismuth. In the Alice mine argentiferous bismuthinite occurs in places.

Where the ore is a replacement of the wall rocks the gangue minerals are the wall-rock minerals or their alteration products, notably sericite. Where the ore is a filling of open spaces the predominant gangue is quartz. Siderite is a subordinate gangue in certain deposits, and fluorite is abundant in a few veins. In ore deposits formed by replacement as well as in those formed by fissure filling gangue minerals may be either abundant or negligible, and there may be great variation in this regard even within a single ore body.

The ores containing enargite are regarded as a subtype of the pyritic ores. This mineral is practically confined to a few veins within the areas covered by the large-scale maps (Pls. III and VI), on which these veins are shown by a special symbol. They include the Frontenac-Aduddell-Kokomo, Hazeltine, Anchor, Iroquois, Powers, Silver Dollar-Hampton, War Dance, Bosen Plume, Argo, Pittsburg, and Two-Forty, all lying within a radius of three-quarters of a mile of the Hazeltine mine, in South Willis Gulch. In a few veins, such as the Silver Dollar, enargite is about as abundant as pyrite, but in most others it is very subordinate in amount. Some of the enargite-bearing veins are of the composite type described later, but in these the enargite appears almost invariably to belong with the pyritic phase of the mineralization. In the enargite-bearing veins tennantite is rare or absent.

Fluorite, as shown on page 114, is a characteristic gangue mineral in certain of the rich telluride ores, but it occurs also in certain of the pyritic ores, particularly in those that carry enargite. This association is not, however, invariable, for in some enargite-bearing veins, such as the Two-Forty, fluorite has not been reported, and conversely in the fluorite-bearing Togo vein enargite has not been noted. In fluorite-bearing veins of the composite type the fluorite, like the enargite, invariably belongs with the minerals of the pyritic mineralization. Fluorite-bearing veins are shown by a special symbol on Plates III and VI. They include the Chase, War Dance, Silver Dollar-Hampton, Powers, Iroquois, Anchor, Hazeltine, Togo, and Hill-Bunk House. The fluorite is green or purple or more rarely colorless and in the pyritic veins is always a subordinate vein material. At one place in the Chase vein a lens 3 inches thick was composed wholly of fluorite.

Tellurides occur in several localities in close association with ores of the pyritic type, but in some such occurrences—for example, in the East Notaway mine—the tellurides were clearly deposited later than the pyritic ore. Tellurides were reported to occur in the Gregory, Sleepy Hollow, Kokomo, Casino, and Gem mines, but no opportunities were afforded for determining their precise mode of occurrence. The question whether the tellurides crystallized contemporaneously with the characteristic minerals of the pyritic ores must therefore remain unanswered for the present. As pointed out on page 277, it is by no means certain that the telluride ore of the War Dance mine is not to be regarded as a phase of the pyritic mineralization.

In one mine, the Rooks County, between Apex and Tolland, small crystals of snowy-white feldspar, probably soda orthoclase, are implanted on octahedral pyrite in a vug. It is noteworthy that this is the only occurrence of octahedral pyrite seen by the writer in the region, the usual crystal forms being cubes or pyritohedrons. Molybdenite in aggregates of very small plates is present in a few veins, commonly as a narrow band next the walls.

MINERAL PARAGENESIS.

Detailed studies on many ore samples show that most of the minerals mentioned above as characteristic of the pyritic ores were deposited during a single period of mineralization. There can be recognized among them, nevertheless, a prevailing order of crystallization analogous to that among the minerals of a massive igneous rock. In the very few veins in which molybdenite occurs it appears to have been the first mineral to crystallize; a half-inch veinlet from the Anchor mine shows bands of molybdenite one-sixteenth to one-eighth inch thick along the walls, but the center is largely quartz and pyrite. In most of the ores pyrite was the first metallic mineral to crystallize; it continued to form throughout the period of ore deposition and very commonly lines vugs. The enargite is contemporaneous with pyrite. Chalcopyrite began to form early in the period of mineralization, but its deposition reached a maximum in the later stages, as is shown by its characteristic abundance in the medial portions of certain veins and in and near many vugs. The tennantite shows similar relations, except that the period of maximum deposition of this mineral seems to have been even later than that of chalcopyrite. The bismuthinite in the Alice mine is apparently contemporaneous with chalcopyrite. In a few places galena and sphalerite are found apparently intergrown contemporaneously with the characteristic minerals of the pyritic veins, but their quantity is always extremely small.

Among the gangue minerals quartz crystallized throughout the period of mineralization, and some vugs are lined wholly with quartz, indicating that the deposition of this mineral locally persisted after metallic minerals had ceased to form. Fluorite formed most abundantly during the later stages of the mineralization. In places it is intergrown contemporaneously with pyrite or with pyrite and enargite. In the Iroquois mine quartz and fluorite form veinlets traversing pyritic ore and line vugs in it. In the few places where siderite is abundant it seems to have formed late in the period of mineralization. In the Alice mine it commonly lines vugs. In the one mine in which soda-potash feldspar was noted it was distinctly of later formation than the pyrite crystals upon which it was implanted, and it may have been formed much later and under wholly different physical conditions.

The chemical significance of these mineral relations may be summarized in the statement that copper, arsenic, antimony, bismuth, and fluorine were precipitated mainly in the later stages of mineralization, while iron, silica, and sulphur were deposited throughout the process.

STRUCTURE AND TEXTURE.

The pyritic ores are as a rule irregularly massive in texture. Banding is almost nowhere developed. In stockworks such as the Patch the sulphides fill small irregular spaces between the rock fragments or replace the rock irregularly, as fully described on page 97 and figured in Plate XIV, *A* (p. 97). The structure of the vein deposits depends mainly on the relative importance of fissure filling and replacement in the vein formation.

The appearance of a pyritic vein that is mainly the result of fissure filling may be typified by a small vein exposed in the stream bed just below the juncture of Illinois and Leavenworth gulches. This vein is nearly vertical and cuts sharply across the foliation of granite gneiss. It consists of a main sharp-walled band of nearly solid pyrite from half an inch to 1½ inches wide which gives off a few small branches. Parallel to this main band are a number of minor fractures, some of which carry pyrite, and minute pyrite grains are disseminated through the granite gneiss for 2 to 3 feet on each side of the main pyritic band. The granite gneiss in the fractured zones shows much silicification, some masses of nearly pure quartz 3 inches or so wide and 4 or 5 inches long being developed. In these quartz masses, whether large or small, the long axes are usually parallel to the general plane of the vein. Many of the larger ones have a central stringer of pyrite. The vein is paralleled by a number of barren fractures spaced 1 to 8 inches apart.

An example of a pyritic replacement vein is the Syndicate, near Dumont. In one place in the western workings it is bounded next to the hanging wall by a slip plane showing a little gouge. A zone 4 feet wide below this consists of pegmatite traversed by very irregular veinlets of pyrite that lack definite boundaries and grade into pegmatite only slightly impregnated with pyrite. A few small vugs in the veinlets are lined with crystals of quartz and pyrite.

In the Old Town mine both replacement and fissure filling have occurred. On the fourth level about 800 feet west of the shaft the vein consists of 4½ feet of granite gneiss heavily impregnated with pyrite and traversed by numerous subparallel pyrite-chalcopyrite veinlets none over a quarter of an inch in width and by four or five postmineral gouge-filled slip planes.

Vugs are only moderately abundant in the pyritic veins and are usually small. One of extraordinary size noted in the National mine was 6 by 4 inches by 2 feet. It was surrounded by gneiss impregnated with pyrite and was lined with quartz crystals, some of them half an inch in diameter.

ALTERATIONS OF WALL ROCK.

The principal minerals developed by metasomatic processes in replacement veins or in the walls of filled fissures are sericite and pyrite. Carbonates have been formed in a few places. In the early stage of alteration the changes produced are markedly selective in character, certain of the original minerals of the wall rock altering earlier than others and in a different manner. The alterations in this stage clearly involve chemical interchanges between the original minerals and the entering solutions and are not the result of simple substitution. Characteristic features are the replacement of plagioclase phenocrysts by sericite before sericite is developed in the groundmass or in orthoclase phenocrysts, the replacement of the outer rims in zonal phenocrysts of plagioclase before the inner parts are affected, and the replacement of original magnetite by pyrite before this sulphide is extensively developed by replacement of other minerals. The last-named process was well shown in monzonite porphyry bordering the Lake vein as exposed in the Big Five tunnel. The pyrite is associated with a whitish, opaque alteration product, of indeterminate character, and the areas occupied by the two minerals have outlines characteristic of magnetite, as is shown in figure 8. The lined areas are pyrite and the white areas around them are "leucoxene," whose composition was indeterminate. The outlines of the whole suggest those of magnetite, probably titaniferous, which the pyrite and leucoxene are believed to replace. Minor amounts of carbonates, usually in small irregular aggregates, were developed in this stage in some deposits but not in others. The rocks have become somewhat bleached, but their major textural features, such as foliation or porphyritic texture, are still preserved.

The incipient stages of alteration were well shown in monzonite porphyry 80 feet south of the Bride vein in the Idaho tunnel. This monzonite is bleached, but the porphyritic texture is still well preserved. It is traversed by small fractures, along which pyrite is developed in small irregular masses. The feldspar phenocrysts are nearly all plagioclase, well above balsam in index, whose precise variety can not be determined. These are flecked with abundant shreds of sericite except in the center of a few crystals, which remain clear. In the microgranular groundmass, on the other hand, no sericite is present, but calcite and quartz (probably in part secondary) are abundant. In contrast to both of these, certain roughly oblong areas, probably representing original hornblende or pyroxene, now consist mainly of green chlorite, epidote, and

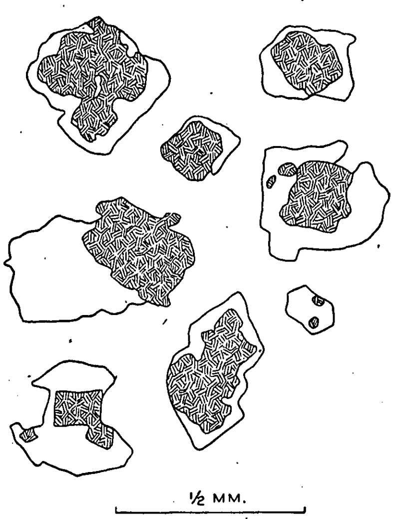


FIGURE 8.—Camera lucida sketches of pyrite grains in altered monzonite porphyry bordering the Lake vein in the Big Five tunnel.

a fine aggregate, which appears gray in reflected light and is probably also epidote but very finely divided. Iron oxides, in part hematite and in part magnetite, occur in minute grains and aggregates in the chlorite-epidote areas and in the groundmass. Pyrite occurs in scattered grains and irregular aggregates in the groundmass, but both pyrite and iron oxides are practically absent from the phenocrysts.

More extensive alteration in or near pyritic ore bodies commonly results in the complete sericitization of all feldspar of whatever variety, in the sericitization of any chlorite or epidote that may have formed as a temporary alteration product in earlier stages, and in the development of pyrite as a replacement not only of magnetite but of quartz and silicates. The original quartz is in some rocks apparently unaffected but in others has undergone recrystallization. Carbonates may have increased in abundance or may still be absent. The sericite flakes have commonly increased in size. The original texture of the rock may be wholly effaced.

Specimens showing various stages of wall-rock alteration in an unusually complete manner were obtained in the Alice mine. One of these is figured in Plate XIV, *A* (p. 97), and shows in a width of 4 inches almost all stages in the conversion of quartz monzonite porphyry into typical ore. The probable situation of this specimen with respect to the general fracture system of the mine is shown at *c* in figure 7 (p. 98). In the least-altered (right-hand) portion of this specimen (at *a*, Pl. XIV, *A*) the porphyritic texture is very conspicuous. Under the microscope the groundmass is seen to have been wholly recrystallized to an aggregate of quartz and orthoclase feldspar, showing the sharpness of a mosaic and considerable uniformity of grain; both minerals are clear and fresh. In the hand specimen the recrystallized groundmass has the appearance of a gray opaline matrix in which the feldspar and biotite phenocrysts are embedded. The phenocrysts of plagioclase have been wholly replaced by an aggregate of minute plates that are probably sericite, though on account of their minuteness the aggregate shows low double refraction. With this are associated small grains and aggregates of an iron-stained carbonate, presumably siderite. The biotite phenocrysts remain practically unaltered. The original magnetite is for the most part unaltered, though in a few places partly or wholly replaced by pyrite, which also occurs in a few small grains in the groundmass. Quartz phenocrysts appear to have been recrystallized and some of them merge around their borders with the quartz of the recrystallized groundmass.

In a more highly altered part of the rock (*b*, Pl. XIV, *A*, p. 97) the porphyritic texture is not prominent in the hand specimen, though under the microscope it is fairly conspicuous. The same types of alteration observed in the specimen just described have progressed much further. The sericite, which replaces the plagioclase, has aggregated into larger flakes; siderite has in places grown into good-sized crystals that show rhombohedral cleavage;

the biotite phenocrysts have altered to muscovite and siderite; magnetite has entirely disappeared; and pyrite has increased greatly in abundance. The matrix still retains its fresh mosaic-like appearance, and its orthoclase shows no alteration.

In the most highly altered facies (*c*, Pl. XIV, *A*) the porphyritic texture is entirely obliterated and the whole rock has been converted into an irregular and rather fine grained aggregate of quartz and sericite associated with irregular areas of relatively coarse quartz. In this rock the feldspar of the groundmass has finally succumbed to sericitization. Pyrite occurs in greater abundance and in larger crystals than in the less altered varieties. Of the original minerals only apatite remains unaltered.

METAL CONTENT.

Some conception of the metal content of the smelting ores of the pyritic type may be gained from the following table. The figures were obtained by averaging a considerable number of sampling-works assays of smelting ore from each mine, and they appear to represent for the most part primary ore unaffected by enrichment.

Metal content of typical gold-silver ores of the pyritic type.

Mine.	Year.	Quantity (short tons).	Gold (ounces).			Silver (ounces).			Copper (per cent).
			Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	
Perigo	1901–1909	42.5	3.16	0.44	1.23	4.70	1.20	1.26	
Corydon	1892–1897	51	2.62	1.08	1.74	15.00	2.00	5.63	Up to 8.
O. K	1893–1908	185	4.28	.30	1.13	10.20	3.40	5.59	2 to 10.25.
O'Neil	1897–1908	48	12.00	.60	3.10	11.45	3.14	7.13	1.80 to 8.18.
"Fifty"	1888–1909	410	26.40	.52	2.58	21.00	1.50	5.40	Up to 13.75.
Carr	1893–1910	400	9.06	.72	2.88	21.20	2.00	7.62	Up to 11.70.
San Juan [a]	1888–1909	117	12.20	Trace.	2.09	34.00	2.15	6.81	Up to 9.
Barnes	1893–1907	108	2.68	0.27	1.19	17.40	4.00	11.81	3 to 9.55.
Rockford	1910	([b])	....	....	1.09	....	....	4.35	
Gladstone	1893–1910	29	8.10	.56	1.49	14.00	2.40	5.35	Up to 10.
Aurora	1889–1910	114	4.88	.87	2.24	17.15	1.30	6.32	Up to 13.65.
Argo	1889–1908	30	5.00	.50	2.39	12.13	2.50	7.31	2.10 to 16.
Pittsburgh	1894–1909	243	12.72	.45	2.37	18.30	1.50	7.52	Up to 16.60.
	1910	435	25.35	.52	5.77	22.65	2.00	8.93	0.30 to 16.30, average, 6.65.
Two-Forty	1910	([b])	....	....	.95	....	....	5.82	Average, 0.69.
Saratoga	1893–1909	1,019	8.41	.12	.90	13.90	1.00	2.32	Nearly always less than 1.5.
Chase	1893–1908	193	8.20	.29	1.98	28.40	1.90	6.53	Usually less than 1.5.
Specie Payment [a]	....	506	7.09	.32	1.88	37.00	.70	5.80	Up to 7.
Puritan	1910	6	2.60	1.12	1.56	6.00	1.50	2.27	Up to 2.
Princess Alice	1910	(?)	....	....	1.14	....	....	4.00	
Megalona vein in Rockford tunnel	1910	2,000	....	....	.427	....	....	.769	Less than 0.40.
Donaldson vein in Rockford tunnel	1910	([b])	....	....	.618	....	....	1.567	0.335.
	1911	1,000	....	....	1.1096	....	....	3.20	1.189.

[a] Ores mainly pyritic.
[b] Total shipments.

From this table it is seen that the average gold content of the smelting ores is usually between 1 and 3 ounces and the average silver content between 4 and 8 ounces. The copper content in most of the ores is below the commercial limit of 1.5 per cent and so is not recorded in the sampling-works assays. In some ores, on the other hand, it may form 15 to 16 per cent. The silica content is extremely variable, but in most lots is between 30 and 70 per cent. The gold content is in general highest in veins which, like the Pittsburgh, are comparatively rich in chalcopyrite.

It seems unwise here to attempt any generalizations in regard to the metal content of the concentrating ore. The grade of the ore that can be profitably worked, being intimately dependent upon the cheapness of the mining methods and on the milling practice, varies greatly in different mines. Such details as were obtained are given in the descriptions of individual mines.

The average value of the ores and concentrates from the vicinity of Central City has been computed by Mr. Percy Alsdorf, who has kindly consented to the publication of his figures here. The computations cover the shipments for one recent year, but take no account of varying mineral character of the ores.

Average content of ores and concentrates from Central City and vicinity.

	Gold (ounces).	Silver (ounces).	Copper (per cent).	SiO_2 (per cent).	Fe (per cent).
Smelting ore	1.67	4.10	3.10	47	28
Concentrating ore	.38	1.40	.60	69	10
Concentrates	.80	3.00	2.00	11	44

GALENA-SPHALERITE ORES.

DEFINITION.

In the galena-sphalerite ores the predominant primary sulphides are galena, sphalerite, and pyrite; chalcopyrite and in places other sulphides are present in lesser amounts. The common gangue minerals in the ores that are fissure fillings are quartz and either calcite or siderite. Ores of this type like those of the pyritic type, occur principally in veins but locally in stockworks. Their deposition was accomplished both by fissure filling and by replacement.

PRIMARY MINERALS.

The principal metallic minerals of these ores are galena and sphalerite; pyrite is next in abundance and then chalcopyrite. Tennantite and bornite are present in some of the veins in small amounts. A little enargite is associated with the galena and sphalerite at one point in the Gem vein in the Argo lateral and also in the Clay County mine, but enargite is not characteristic of this ore type. Native bismuth and molybdenite occur rarely. Primary argentite is possibly present in a few veins. Quartz is the principal gangue mineral, but either siderite or calcite is abundant in some veins of this type; these carbonates in several veins were tested for manganese with negative results. In a few veins of this type, such as the Franklin and Seaton, rhodochrosite is found. In the Franklin vein it is in places the most abundant gangue mineral and is so intercrystallized with galena, sphalerite, and other sulphides as to show unquestionably that it crystallized contemporaneously with them. In three veins belonging to the composite type, the Moose, Bellman (in Gilson Gulch), and Gem, rhodochrosite is locally very abundant. In the Bellman vein it is intergrown contemporaneously with barite, galena, and sphalerite. In places in the Gem mine veins of coarse pyrite as much as 1 foot in width are cut by a network of rhodochrosite veinlets. These veinlets in places carry specks of galena and chalcopyrite so that they probably were formed at the time of the galena-sphalerite mineralization. All the rhodochrosite-bearing veins are in the region near the head of Gilson Gulch. Barite is locally abundant in a number of veins.

Gold and silver, probably alloyed, are finely distributed within the sulphides and in a few veins visible gold is abundant. The most striking examples of its occurrence are in the Klondike vein, in the Topeka mine, where it is intergrown with quartz and the primary sulphides so intimately as to leave no doubt that it is a primary constituent contemporaneous with them.

MINERAL PARAGENESIS.

A distinct sequence in the order of crystallization of the minerals of the galena-sphalerite ores is much less evident than in the pyritic ores. Galena, sphalerite, pyrite, chalcopyrite, bornite, enargite, quartz, siderite, barite, free gold, and rhodochrosite seem in most of the ores to have crystallized contemporaneously. Siderite and calcite, while in some places early crystallizations, are elsewhere the latest and occur alone or with quartz as a lining of vugs. Tennantite is much less common than in the pyritic veins; where it occurs it was usually one of the last minerals to form.

STRUCTURE AND TEXTURE.

The galena-sphalerite ores are in general similar structurally and texturally to those of the pyritic type. One of the very few occurrences of banded structure is illustrated in Plate XIV, *C* (p. 97). Somewhat more pronounced banding noted in a specimen from the dump of the American Sisters mine near Lawson is due to the alteration of narrow bands of siderite and sphalerite near both walls of a 4-inch vein. The irregular distribution of sulphides characteristic of the stockwork deposits has been described on page 97 and is illustrated in Plate XIII, *A* (p. 96). A vein network from the Boulder County mine is shown in Plate XIII, *B* (p. 97).

ALTERATIONS OF WALL ROCK.

Near ores of the galena-sphalerite type, as near the pyritic ores, the most conspicuous alteration of the wall rock is the development of sericite and pyrite. The alterations differ from those near pyritic ores mainly in the more common and more abundant development of calcite, and the local development of galena and sphalerite. As pointed out on page 103, the ratio of pyrite to sphalerite and galena is greater in the altered wall rocks than in the ore that fills fissures. Certain ores of the galena-sphalerite period of mineralization that formed mainly by replacement contain pyrite as their predominant sulphide.

As in the wall rock of the pyritic ores, the early stages of replacement are selective. This is well illustrated by a specimen of the granite gneiss that bordered the Hayseed vein. In this rock original microcline and quartz are wholly unaltered, but grains that appear originally to have been plagioclase have been entirely converted into an aggregate of sericite and calcite.

In a specimen from the walls of the Topeka vein the alteration of granite gneiss has proceeded further; the quartz is unaltered, but all the feldspar has been replaced by an aggregate of sericite, pyrite, and sphalerite. In this specimen very little calcite is present. Very similar alterations were noted in the granite gneiss walls of the Princess of India vein near Lawson. In porphyry that bordered the Lombard vein the feldspar phenocrysts have been wholly sericitized, whereas in the groundmass both sericite and calcite have been abundantly developed.

Metasomatism of an unusual type was noted in the walls of the Gold Collar vein, where chlorite (pennine) is abundantly developed in the granite gneiss walls, in addition to sericite and a light-colored carbonate; the chlorite gives the rock a greenish tint.

In the Up to Date mine, near Caribou, pyroxenite is in places the wall rock of the Dardanell No. 2 vein. The original minerals of the pyroxenite were biotite, pyroxene, apatite, and titaniferous magnetite. The biotite has been altered to muscovite and some calcite, through which small grains of iron oxide are scattered. Pyroxene has been replaced by a mixture of calcite and sericite or by sericite alone. Titaniferous magnetite has wholly disappeared, its place being apparently taken by a mixture of siderite and hematite. Secondary quartz has formed in aggregates of small grains. Irregular masses of galena and some sphalerite appear to have replaced each of the original minerals except apatite, which remains wholly unaltered.

The nature of the wall-rock alteration near the Boulder County vein, near Cardinal, is well shown on the tunnel level about 200 feet east of the line of the tunnel. Three specimens showing different stages of alteration were collected from a 6-inch to 1-foot dike of hornblende diorite, which is cut sharply and without displacement by the vein. The vein at this place is 6 to 15 inches wide and carries from 40 to 90 per cent of quartz. The first specimen, which was almost unaltered, was taken several feet from the vein; it is a dark-gray aphanitic hornblende diorite crowded with idiomorphic lath-shaped crystals of fresh green hornblende varying greatly in size and oriented in all directions. Small stubby phenocrysts of plagioclase, slightly sericitized, are scattered sparingly through the rock. The remainder of the rock consists of small grains of magnetite and feldspar, the latter showing some alteration to sericite and calcite. The second specimen of the dike was taken 2 feet from the vein. It is bleached to a buff color and carries numerous small grains of pyrite disseminated through it. Under the microscope the outlines of some of the feldspar phenocrysts are still recognizable, but the hornblende has entirely disappeared, the rock being converted into an association of pyrite, sericite, calcite, and quartz. The third specimen was taken from the exact contact of vein and dike. Here the dike has been completely altered to an aggregate of pyrite, quartz, calcite, and sericite, and the original porphyritic texture has been wholly obliterated. The quartz is clearer and more abundant than in the second specimen.

The extreme of wall-rock alteration is exemplified by the occurrence, next to a vein in the Metropolitan tunnel, of 1 to 2 inches of white plastic material which resembles kaolin but which on testing proves to be wholly sericite.

METAL CONTENT.

In the ores of the galena-sphalerite type the variations in metal content are even greater than in the pyritic ores. Their maximum richness is probably represented by an 88-pound piece of ore from the Klondike vein, in the Topeka mine. This piece carried abundant free gold and on smelting yielded $5,449. Averages that are representative of the primary ore of smelting grade can be given only for those veins in which the gold content is relatively high, for only such ores are workable below the limit of downward enrichment in silver.

Metal content of certain gold-silver ores of the galena-sphalerite type.

Mine.	Years.	Quantity (short tons).	Gold (ounces).			Silver (ounces).			Copper (per cent).	Lead (per cent).	Zinc (per cent).
			Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.			
Pine Grove	1906	[a]	....	....	0.24	....	....	35.00	....	....	....
	1907-8	[a]	....	....	.28	....	....	24.00	....	....	....
Hayseed	[b]	....	....	....	.75	....	....	12.00	....	45 to 55	....
Concrete [c]	(?)	307	....	....	1.03	....	....	8.00	....	23.80	10.60
Hubert	1888-1909	131	5.80	0.74	2.39	17.60	2.00	13.16	Up to 6.50	Up to 37	Up to 32
	1910	72	1.70	1.04	1.38	15.90	8.00	14.00	....	Up to 30	....
Ivanhoe [c]	1898-1902	11	.90	.10	.59	21.40	7.62	13.95	....	10.90 to 54.10	8 to 18
Egyptian	1899-1909	63	5.77	.28	2.98	22.30	2.70	12.33	Up to 9.50		
	1910	154	5.48	.64	2.40	23.50	2.00	17.35	Up to 4.65	....	....
Windsor Castle	1897-1909	30	.68	.08	....	23.00	8.40	....	Up to 2.80	4 to 16	5 to 16
Owatonna	1897-1910	117	.50	.12	.23	[d] 58.80	5.70	27.57	....	Up to 36	Up to 25
Santa Fe	1888-1904	91	4.00	.25	....	38.00	2.70	....	Up to 2.30	Up to 20	Up to 5
Franklin and Silver Age	1888-1910	1,374	1.52	.05	.146	[d] 161.00	4.00	22.74	....	....	....
Seaton	1902-1910	202	2.35	.12	1.13	[d] 105.00	7.50	39.66	Up to 2.55	Up to 26.40	Up to 24
Crystal	1888-1910	35	3.00	.15	.76	[d] 95.00	5.50	37.40	Up to 3.00	3 to 17	6 to 16
Albro	1908	202	2.77	.48	.54	13.00	2.50	5.65	2.40 to 17.00	....	....
	1909	160	1.02	.39	.65	21.00	7.60	10.09	[e] 3 to 10.20	....	....

[a] Total shipments.
[b] Reported average.
[c] Ores mainly of galena-sphalerite type.
[d] High silver values probably due to downward enrichment.
[e] Average, 4.45.

In contrast to some of the ores tabulated above, the galena-sphalerite ores of Lawson and vicinity and of Silver Hill, near Blackhawk, are characteristically poor in gold, which in many shipments is present only in traces. Ten lots of ore shipped from the Bellevue-Hudson mine, near Empire station, in 1908 showed the following range in metal content: Gold, 0.03 to 0.20 ounce to the ton; silver, 12.60 to 54.20 ounces to the ton; lead, 4 to 31.60 per cent; zinc, 3 to 14 per cent. This ore has apparently been only slightly affected by downward enrichment in silver. Although a high gold content is found in some of the oxidized surface portions of the silver lodes near Lawson and Empire station, the gold content of most of the unoxidized ore does not exceed 0.25 ounce to the ton.

In general the primary ores of the galena-sphalerite type are poorer in gold and copper and richer in silver than those of the pyritic type. It is not practicable to give a summary statement of the metal content of the concentrating ores of this type, because of the variety of milling practice and because at many plants both lead and zinc concentrates are obtained, so that it is difficult to calculate the composition of the ore. Some data concerning these ores are given in the detailed mine descriptions.

COMPOSITE ORES.

Many of the gold-silver ores of the region are the result of double mineralization, first with minerals characteristic of the pyritic ore type and later with minerals characteristic of the galena-sphalerite ore type. Veinlets of the galena-sphalerite type sharply cutting ore of the pyritic type were noted in the Salisbury mine, west of Idaho Springs; in the Rocky Mountain Terror mine and the Fairmont tunnel, near the head of Virginia Canyon; in the Frontenac lateral from the Argo tunnel; in the Druid mine, in South Willis Gulch; in the Fourth of July mine, near Central City; in the Geiger mine, south of Apex; in the Marshall & Russell tunnel, near Empire station; and in a number of others.

In the Marshall & Russell tunnel a 2-inch vein of quartz, pyrite, and chalcopyrite 1,800 feet from the portal is cut without displacement by a vein a few inches in width carrying sphalerite, chalcopyrite, and siderite with a little pyrite and galena. On the west wall of the Argo tunnel about 8,925 feet from the portal a 20-inch vein of solid pyrite is crossed by a ⅛-inch stringer of galena and sphalerite. In the Fourth of July mine ore composed of nearly solid pyrite with some chalcopyrite has been brecciated and the fragments have been cemented by quartz, galena, sphalerite, and chalcopyrite, as is shown in Plate XIII, *C* (p. 96). At places in the Centennial and Two Kings vein pyritic ore is sharply separated by a band of comb quartz from ore of the galena-sphalerite type, showing that the two are not contemporaneous. The mode of occurrence of the ores in many other mines suggests though it does not demonstrate a similar relation, and nowhere was the reverse relation, of pyritic ore cutting galena-sphalerite ore, observed.

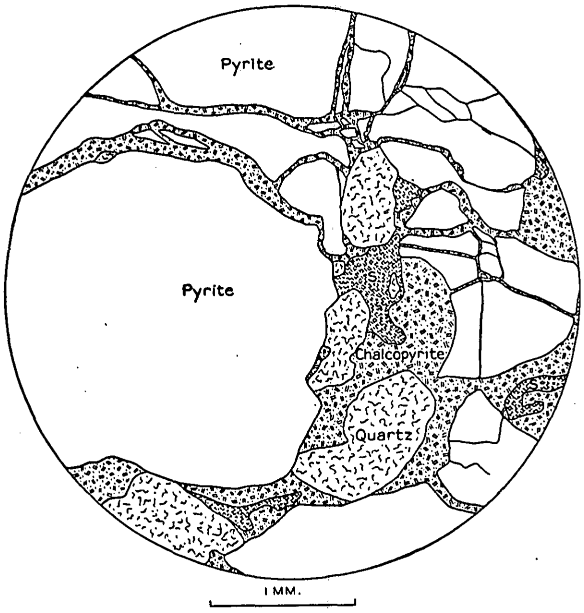


FIGURE 9.—Camera lucida drawing of polished surface of ore from Specie Payment vein, showing pyrite of the early mineralization brecciated and traversed by veinlets of ore of a later period of mineralization, consisting of chalcopyrite, quartz, and sphalerite (S).

The field evidences of dual mineralization are amply confirmed by the microscopic studies of polished specimens. Ore from the Little Annie workings on the Specie Payment vein (see p. 286) shows that an association of pyrite and light-gray quartz has been brecciated and the spaces between the fragments completely filled with sphalerite, dark-gray quartz, and subordinate galena and chalcopyrite. Minute veinlets of these minerals occupy cracks in the pyrite or wholly inclose pyrite fragments. In the latter case the form of adjacent fragments shows clearly that they once fitted together (See figs. 9 and 10.) Microscopic study of ore from the Maud S. vein near Empire station shows that pyrite has been brecciated in a somewhat similar manner and the interspaces have been filled with chalcopyrite associated with a little sphalerite and quartz.

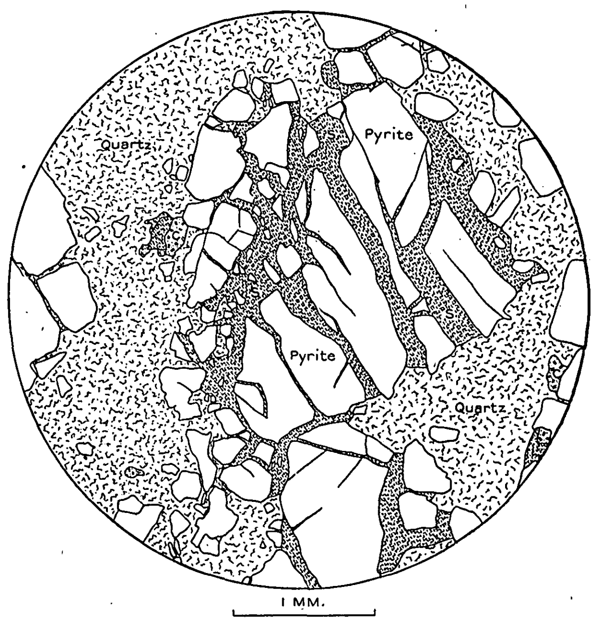


FIGURE 10.—Camera lucida drawing of ore from Specie Payment vein, showing pyrite of first mineralization brecciated and penetrated by sphalerite, quartz, and chalcopyrite of a later period of mineralization. S, sphalerite; C, chalcopyrite.

The relations described above appear to demonstrate conclusively that certain ores are the result of dual mineralization. The earlier group of minerals in these ores is identical as regards kind and proportion of minerals with the typical pyritic ores, while the later group is identical with the typical galena-sphalerite ores. As pointed out on page 102, there are numerous transitions from the composite ores to one or the other of the pure types. There can be no question, therefore, that the composite ores are the result of successive deposition from two solutions, each of which elsewhere deposited ore of simple types, either pyritic ore or galena-sphalerite ore. The interval between the two mineralizations, for reasons set forth more fully on page 133, is believed to have been short, but it was sufficient to permit much local brecciation of the earlier ore before the later ore was deposited. The later galena-sphalerite portions of the ore obviously can not be attributed to downward sulphide enrichment acting on primary pyritic ore, for the requisite lead and zinc are not present in the pyritic ore. Moreover, downward sulphide enrichment in which an entirely different suite of minerals was developed was noted locally in fractures in the composite ore.

The metal content of the ores of the composite type is in general intermediate between those of the two simple types, the pyritic and the galena-sphalerite ores. Naturally it varies greatly with the proportion of the two types present, and an attempt to arrive at an average would be more or less futile and misleading.

TELLURIDE ORES.

GENERAL FEATURES.

The telluride-bearing ores of the Central City quadrangle show more diversity in mineral character than the ores already described, and it is not certain that all were formed at the same time. Tellurides of gold and silver may occur here and there in ores of the pyritic or galena-sphalerite type, but this has not been fully demonstrated. Pearce[1] noted the presence of tellurium in certain ores from the Gregory mine, near Blackhawk, but the nature of the tellurium mineral from which it came is unknown. Ore from a pocket on the twelfth level of the Gem mine carried sylvanite. A sample of this ore seen by the writer showed gray quartz as the only other mineral, so it is still uncertain whether the sylvanite formed an integral part of the typical sulphide ore or occurred in later veinlets cutting the sulphide ore, as in the East Notaway mine. The Casino vein, on Seaton Mountain, has yielded rich telluride ores, but as only roasted samples were seen by the writer the relations of tellurides to sulphides there could not be demonstrated. In those mines in which the occurrence of tellurides could be carefully studied they were not a component of typical sulphide ores but occurred under peculiar conditions, to be described in the succeeding paragraphs. The most important producers of telluride ores at the present time are the War Dance and East Notaway mines, near Central City, and the Treasure Vault mine, near Idaho Springs. Small amounts of telluride ores are produced near Eldora, in Boulder County, and such ores have been found in the Casino, Gem, Kokomo, Sleepy Hollow, and Gregory mines. The telluride-bearing veins between Idaho Springs and Central City are shown by a special symbol on Plates III and VI.

PRIMARY MINERALS AND THEIR PARAGENESIS.

The rich telluride ores of the War Dance and Treasure Vault mines show fluorite as an abundant gangue mineral. In this respect, though not in most others, they resemble the telluride ores of Cripple Creek. In the Treasure Vault mine the telluride, which is light yellow, carries considerable silver as well as gold and is probably sylvanite. Samples suitable for detailed mineralogic study were not available. The telluride occurs in a gangue of blue-gray cherty silica, with which are also associated small amounts of fluorite, ferruginous calcite, and fine pyrite. The pyrite is less abundant in the veins than in the wall rocks. Banding of cherty silica and ferruginous calcite was noted locally, and fluorite and calcite line some vugs and were there the last minerals to form; in general, however, no very consistent sequence was observable in the order of crystallization of the ore minerals. All the telluride ore thus far found has been obtained within 125 feet of the surface and carries free gold in even greater abundance than tellurides. This gold is partly and perhaps wholly the result of the oxidation of sylvanite.

For many years development in the War Dance mine was confined to a sulphide vein of the composite type; only in 1908 was the

[1] Pearce, Richard, The association of gold with other metals in the West: Am. Inst. Min. Eng. Trans., vol. 18, p. 449, 1890.

rich telluride ore a few feet away discovered. Although the sulphide and telluride ores occur near together, they are not intermingled and show marked differences in precious-metal content. An assay of the sulphide ore in one place showed 0.2 ounce of gold and 30 ounces of silver to the ton, while the telluride ore close by ran 20 ounces in gold and 3.5 ounces in silver. The telluride ore occurs as a network of small veinlets or an irregular replacement of the wall rock near fractures. The ore minerals are fluorite, quartz, pyrite, and a telluride of gold and silver that is probably sylvanite. The telluride occurs as flakes or plates of pale brass-yellow color, many of which show numerous striations in one direction; in places the telluride flakes are very abundant. Native gold occurs but is less abundant compared with sylvanite than in the Treasure Vault mine.

The telluride veins of the East Notaway mine are characteristically 1 to 3 inches wide and consist of dark-gray cherty silica, fine-grained pyrite, some antimoniacal tennantite, and varying amounts of telluride. In places there are several small anastomosing veinlets instead of a single veinlet. A study of polished surfaces of the rich telluride ore, supplemented by an examination of a thin section by transmitted light, shows that all the vein minerals are essentially contemporaneous, though sulphides appear relatively more abundant near the borders of the veinlets and sylvanite more abundant near the center. Most of the sylvanite occurs in isolated bladelike or tabular crystals, but some is intergrown and apparently contemporaneous with antimoniacal tennantite.

Most of the mines near Eldora that have produced telluride ores were idle at the time of the writer's visit, and admittance was denied to the only one in operation. Little new information was obtainable, therefore, in regard to the character of these ores; fortunately, they had previously been studied by Lindgren and others. In the Enterprise vein, according to Rickard,[1] "The dark-gray quartz carries finely disseminated tellurides, chiefly petzite, which render a width of 2 to 2½ feet sufficiently rich to yield an average of 2 ounces of gold per ton."

[1] Rickard, T. A., The veins of Boulder and Kalgoorlie: Am. Inst. Min. Eng. Trans., vol. 33, p. 568, 1902.

In speaking of the telluride ores of Eldora and vicinity, Lindgren[2] says:

> 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,[3] is believed to be the rare mineral ilsemannite, a compound of the oxides of molybdenum ($MoO_2.4MoO_3$).
>
> 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.

GEOGRAPHIC DISTRIBUTION OF ORES.

The most widely distributed ores of the region are those of the pyritic type, to which belong most of the ores between Central City and Blackhawk on the north and Pewabic Mountain on the south, most of those along Fall River below the mouth of York Gulch, most of those near Alice, Yankee, and Apex, those near Perigo, Moon Gulch, and Phoenixville, some near Eldora, and some on Idaho Mountain near Caribou. These ores are commonly referred to in the region as gold ores, their value being mainly in that metal.

Of the subtypes under the pyritic ores, the enargite and fluorite bearing veins are all located within three-quarters of a mile of the Hazeltine mine, in South Willis Gulch.

[2] Lindgren, Waldemar, Some gold and tungsten deposits of Boulder County, Colo.: Econ. Geology, vol. 2, pp. 453-463, 1907.

[3] U. S. Geol. Survey Prof. Paper 54, pp. 114, 123, 1906.

To the galena-sphalerite type belong most of the ores near Lawson and Empire station, those of Caribou Hill, most of those of Seaton Mountain, near Idaho Springs, most of those of a group on Alps Hill, northwest of Russell Gulch camp, and most of the ores of Nigger Hill, Maryland Mountain, and Silver Hill, near Central City and Blackhawk.

Ores of the composite type are, as might be expected, most common in the border zones between areas occupied largely by pyritic ores on the one side and by galena-sphalerite ores on the other. They occur principally immediately east and west of Central City and between South Willis Gulch and the summit of Seaton Mountain.

The gold-silver ores of the telluride type are confined to the vicinity of Eldora and to a narrow belt extending from Bobtail Hill, near Central City, southwestward nearly to Idaho Springs. The second area is economically the more important.

RELATIONS OF PRIMARY GOLD AND SILVER TO COMMONER ORE MINERALS.

GENERAL RELATIONS.

The distribution of the precious metals in the commoner minerals of the gold-silver ores has been ably investigated by George E. Collins,[1] who has long been associated with the mining industry of this district. With regard to his method of investigation Collins says:

> With a view to further study of the association of gold and silver with various minerals, classified samples were taken from representative ores, the particles being picked out with the aid of a lens, and the resulting samples separately assayed.

The results of these tests, rearranged from the original tables, are given on pages 117 and 118. Collins says:

> When more than one figure is given under the same heading, it is for the purpose of directing attention to the widely different results obtained from duplicate tests.

The present writer is responsible for the grouping of the veins under pyritic ores, galena-sphalerite ores, and ores of uncertain character. Very likely many of the samples listed in the third group belonged to one or the other of the simple ore types, but as the veins from which they came are known to have produced, at one point or another, both types, their exact classification is uncertain.

PYRITIC ORES.

The assays given by Collins corroborate in a definite way the general experience of mining men in this district. The pyritic ores which are richest in gold and silver are in general those which carry the largest amounts of chalcopyrite or tennantite. The "Fahlerz" of Collins, presumably in the main tennantite, in places antimonial, appears to carry silver more abundantly than any other sulphide.

Further, it is well known that coarse free gold (alloyed with silver), in the few places where it occurs, is more commonly intergrown with quartz than with sulphides; these assays show, as might be expected, that much of the fine gold also is associated with the quartz gangue. As in general chalcopyrite and tennantite formed more abundantly late than early in the pyritic mineralization, it is evident that gold and silver were also deposited most abundantly in the later stages.

In ore of the pyritic type from the Gardner lateral in the Argo tunnel workings the portions carrying noticeable amounts of chalcopyrite and "gray copper" (probably tennantite) contained as much as 3.24 ounces of gold and 9 ounces of silver to the ton, whereas those portions in which pyrite was the only sulphide carried 0.05 to 0.50 ounce of gold and 0.50 to 3.50 ounces of silver.

Coarsely crystalline pyrite of the pyritic ores is proverbially of low grade in this district. A sample collected by the writer from the eleventh level of the Gem mine assayed only 0.07 ounce of gold and 0.33 ounce of silver to the ton. Coarse pyrite collected by the writer from the Saratoga vein, in the Argo lateral 2,900 feet east of the tunnel, assayed 0.16 ounce of gold, 1.84 ounces of silver, and 0.10 per cent of copper.

The "amorphous sooty sulphides" mentioned in Collins's table are probably, in part at least, pulverulent chalcocite formed by downward sulphide enrichment. As chalcocite is known to be a very efficient precipitant of silver from its sulphate solution and of gold from its chloride solution (see p. 141), it is not surprising that this material should be rich in both these metals.

[1] The relative distribution of gold and silver values in the ores of Gilpin County, Colo.: Inst. Min. and Met. Trans., vol. 12, pp. 480–499, 1903.

Gold, in ounces per ton, contained in various minerals of representative Gilpin County veins.

	Pyritic ores.			Galena-sphalerite ores.			Ores of uncertain character.								
	Harsh.	Baltimore.	Wautauga.	Indiana.	Owatonna.	Boodle.	Rocky Mountain Terror.	German.	Minnesota.	Forfar.	Burroughs.	Running Lode.	Clay County.	Kokomo.	Clark-Gardner.
Picked from jig concentrates:															
Pyrite:															
Clean		0. 29	0. 42	0. 84		0. 71	0. 43	0. 67	0. 19	0. 18	0. 66		0. 26	0. 52	5. 74
With a little adherent quartz		1. 20	. 56	1. 48									. 64		
Chalcopyrite:															
Clean	0. 46		{. 18 3. 62}	1. 08				. 60			. 22		. 45		
Nearly clean			{1. 58 3. 24}	4. 32	0. 42		1. 73		. 72	2. 16		1. 22	2. 10	. 65	4. 61
"Fahlerz" (probably tennantite):															
Clean									. 58						
Nearly clean		. 81	{1. 38 6. 88}	5. 45					. 81	2. 15			. 60		4. 57
Galena:															
Clean							. 75				. 36			. 86	
Nearly clean					. 20	. 16				. 83		. 22	. 27	. 88	. 21
Sphalerite:															
Clean															
Nearly clean				3. 07	. 22									. 20	1. 10
Amorphous sooty sulphides	1. 83									1. 28					
Mixed quartz and pyrite			. 50					2. 56	1. 10	. 23	. 86		. 46		
Picked from jig waste:															
Dark flinty-looking quartz:															
Cleanest practicable				. 06									. 10		
With specks of pyrite and copper minerals		1. 00							. 68		. 84		. 82		
Light-colored quartzose gangue:															
Cleanest practicable			. 08	. 10		. 09			. 12				. 06	. 14	1. 42
With a little pyrite			. 15			. 25			. 27	. 44			. 14		
With small amounts of copper minerals		. 34							. 76						

Silver, in ounces per ton, contained in various minerals of representative Gilpin County veins.

	Pyritic ores.			Galena-sphalerite ores.			Ores of uncertain character.								
	Harsh.	Baltimore.	Wautauga.	Indiana.	Owatonna.	Boodle.	Rocky Mountain Terror.	German.	Minnesota.	Forfar.	Burroughs.	Running Lode.	Clay County.	Kokomo.	Clark-Gardner.
Picked from jig concentrates:															
Pyrite:															
Clean		1.5	2.9	4.1		2.4		2.0	1.0	0.8	1.9		1.6	1.2	7.1
With a little adherent quartz		3.6	4.0	4.6			4.4				5.0	5.9	14.4		
Chalcopyrite:															
Clean	7.9		6.6	9.1	4.0			4.5			7.9	11.8	15.4		
Nearly clean			11.3	14.1			12.0	8.4	16.9				17.1	12.6	31.5
"Fahlerz" (probably tennantite):															
Clean									19.5						
Nearly clean		13.3	24.9	57.2					13.3	10.7	21.9		61.8	44.9	67.1
Galena:															
Clean						27.5	19.7				31.4		15.2		
Nearly clean					11.8					18.8		19.8	16.7	30.7	31.2
Sphalerite:															
Clean				9.6		5.8						3.0		7.0	
Nearly clean				9.6											16.3
Amorphous sooty sulphides	29.4									21.4					
Picked from jig waste:															
Dark-colored flinty quartz:															
Cleanest practicable			2.1	.3	7.6								1.5		
With specks of pyrite and copper minerals	3.4		9.0	1.3											
Light-colored quartzose gangue:															
Cleanest practicable			.7	.9	.7	.9							1.2	1.2	
With a little pyrite	1.1		1.9					6.6	5.9	2.0			2.7		4.2
With specks of pyrite and copper minerals					8.0	5.9		{8.1 59.7}	13.5				7.7		

It is not probable that downward enrichment has influenced the gold and silver contents of the other samples described by Collins. All seem to have been unaltered or little-altered primary ore materials.

GALENA-SPHALERITE ORES.

Collins's tables show that in ores of galena-sphalerite type, as in those of the pyritic type, gold is more abundantly associated with the copper minerals chalcopyrite and tennantite than with pyrite. In places it is abundantly associated with sphalerite, although there seems to be much variability in this regard. Silver is associated in particular abundance with tennantite and galena and locally to a notable extent with chalcopyrite and sphalerite. It is a general rule that the veins of the galena-sphalerite type are richer in silver than those of the pyritic type; they may or may not be poorer in gold.

Silver seems to be more characteristically associated with sphalerite than has been generally recognized. Sphalerite concentrate from ore from the eleventh and twelfth levels of the Gem mine which originally contained some galena, pyrite, chalcopyrite, rhodochrosite, and quartz was picked under the lens as free as practicable from these minerals. On assay it yielded 1.10 ounces of gold and 22.62 ounces of silver to the ton, 12.20 per cent of lead, and 24.17 per cent of zinc. A specimen from the dump of the American Sisters mine, near Lawson, which was mainly sphalerite with a little galena, showed on assay a trace of gold, 79.20 ounces of silver to the ton, 9 per cent of lead, and 46.60 per cent of zinc.

Galena in general appears to be comparable with pyrite as a gold carrier and of varying importance as a silver carrier. A sample from the dump of the American Sisters mine that appeared to be wholly fine-grained galena gave on assay a trace of gold, 6.24 ounces of silver to the ton, 61 per cent of lead, and 2.10 per cent of zinc. "Steel" galena from the Elida tunnel, near Lawson, that appeared to carry no other minerals, assayed, according to R. B. Morton, 14 ounces of silver to the ton and 73 per cent of lead. Ore from the Gem mine, 250 feet east of the shaft on the Argo lateral, consisting mainly of fine-grained galena with a little chalcopyrite and pyrite, assayed 0.06 ounce of gold and 7.30 ounces of silver to the ton, 0.48 per cent of copper, and 65.50 per cent of lead. So-called "lead ore" from the eleventh level east in the same mine assayed 0.25 ounce of gold and 15.80 ounces of silver to the ton, 23.45 per cent of lead, and 9.35 per cent of zinc.

TELLURIDE ORES.

In the telluride type of gold-silver ores some of the gold (with alloyed silver) occurs free, but most of the gold and silver is combined with tellurium in the tellurides. The associated sulphides, particularly tennantite, doubtless carry considerable amounts of the precious metals, but no data are available on this point.

FINENESS OF GOLD AND SILVER.

The following table, showing the fineness of the gold saved by amalgamation in a number of mines of the Central City quadrangle that produce sulphide ores, is given by Collins:[1]

Gold and silver fineness of retort bullion from representative mines.

Mine.	1870–1880		1880–1900	
	Gold.	Silver.	Gold.	Silver.
Bates	0.746	0.241	0.757	0.214
Bobtail	.858	.134	.861	.118
Buell	0.800–.860	0.120–.140	.780	.200
Burroughs	.827	.162	.834	.146
Gregory	.810	.176	.803	.174
Kansas	[a].770	[a].200	.758	.215
Kent County	[a].730	[a].240	.700	.277
Gold Dirt	.870	.100	.878	.105
Perigo	[a].860	[a].110	.873	.105

[a] Approximate.

The last two mines (at Perigo) yield exclusively ores of the pyritic type; the others have yielded ores of both the pyritic and galena-sphalerite types.

Four tests of bullion obtained by amalgamation from ore of the Gunnell mines are as follows:

Gold.	Silver.
0.805	0.154
.823	.163
.825	.162
.825	.162

[1] Collins, G. E., op. cit., pp. 492–493.

The Gunnell vein has yielded both pyritic and galena-sphalerite ores. The fineness of the bullion obtained by amalgamation from the pyritic ores of the St. Louis mine, near Caribou, varies from 0.582 to 0.655 for gold and from 0.315 to 0.378 for silver.

The average fineness of Gilpin County retort bullion is given by Collins as gold 0.787, silver 0.198, and copper 0.015 for 1870 to 1880, and gold 0.778 and silver 0.207 for 1880 to 1900.

PLACERS.

Although placer mining has persisted in the region covered by this report from the first discovery of placer gold near Idaho Springs to the present day, it ceased to be of much importance before the end of the sixties. In the early days North Clear Creek, Russell Gulch, and Gamble Gulch near Perigo were the scenes of active gravel mining, and for some time after the discovery of the first lodes placer-mining methods were applied in working their oxidized surface portions. Even as late as 1876 the stream gravels in the lower part of Russell Gulch and in Clear Creek below Blackhawk were yielding some gold to placer miners.

The most extensive placer workings were in the valleys of Chicago Creek and Clear Creek near Idaho Springs and developed not only the present stream gravels but also glacial outwash gravels and gravels of possible preglacial age. These deposits have been fully described by Spurr and Garrey.[1]

The surface portions of the great stockwork of the Alice mine, near Alice, although not forming a placer deposit in the stricter sense of the term, were worked by placer-mining methods. Burchard[2] describes these workings as follows:

> At Fall River the hydraulic mines of the Alice Mining Co. are the most extensive placers in the county. This company owns 1,500 acres of placer land in the forks of Fall River and Silver Creek. * * * A high ridge lies between the streams, and it is on the eastern slope of this ridge that operations are being carried on. About 700 feet of pipe is used to carry water to the giant, which is 8 inches in diameter at the sand box. The débris removed consists of from 3 to 6 feet of coarse gravel and soil, 2 feet of fine yellow dirt, and about 3 feet of shattered bedrock, which consists of white and gray talcose rock, filled with vugs of quartz crystals and iron pyrites. This talcose rock has been uncovered for a distance of about 500 feet in length and 200 feet in width. * * * The yellow dirt immediately overlying the talc is said to be quite rich and will wash an inch string of gold to the pan. The débris is easily removed, and but few large bowlders met with. On account of the precipitous ground the flume is less than 100 feet in length, with a dip of 5 inches in 12 feet.
>
> The ground washed at present is known to be much richer than any heretofore washed, and the gold coarser. * * * Work is kept up day and night, several large locomotive headlights being used at night. The company has a line of pipes laid at the lower end of the placer, but no work is being done at that point.

[1] Spurr, J. E., and Garrey, G. H., op. cit., pp. 311-314.

[2] Burchard, H. C., Production of precious metals in the United States during the calendar year 1883, p. 280, 1884.

CHAPTER VIII.—URANIUM ORES.

INTRODUCTION.

The large amount of public interest that has recently been manifested in radium because of its apparently beneficial influence in certain cases of cancer lends particular importance to the study of the uranium ores from which radium is derived.

The quantity of uranium ore mined in the United States is exceedingly small and in 1913 appears to have been equivalent to about 38 short tons of uranium oxide (U_3O_8), or approximately 32 tons of metallic uranium.[1] This is considerably larger than the production in 1912, which was equivalent to about 26 short tons of uranium oxide, or in 1911, which was equivalent to about 25 short tons. Practically the entire quantity produced in 1911 and 1912 and about half that in 1913 went to foreign countries. Of this tonnage nearly all came from sandstones of the high plateau regions of southwestern Colorado and southeastern Utah, in which the uranium occurs disseminated as the canary-yellow mineral carnotite ($2UO_3.V_2O_5.K_2O.xH_2O$) or its calcium-bearing equivalent tyuyamunite ($2UO_3.V_2O_5.CaO.xH_2O$). The small remaining portion of uranium ore mined in the United States, amounting in 1912 to only 275 pounds, was uraninite, or pitchblende, a complex uranate of variable composition to which a definite chemical formula can not yet be assigned. This mineral occurs in two distinct ways—in small amounts in granite pegmatites, notably in North Carolina, and in intimate association with metallic sulphides in certain mineral veins, most of which are in Quartz Hill, within the area covered by this report. For many years a small and sporadic production has come from this group and has been used mainly for specimens and for experiments. Quartz Hill is not only the one important locality in the United States where pitchblende occurs in mineral veins but one of the few in the world. As the geologic relations at Quartz Hill differ in important particulars from those at foreign localities, a summary of the genetically important features of the principal European occurrences is given below for purposes of comparison. The writer's thanks are due to Mr. Frank L. Hess, of the Geological Survey, for placing at his disposal additional specimens for study, and to Mr. Forbes Rickard for the loan, through the Bureau of Mines, of many particularly fine specimens.

[1] Hess, F. L., Preliminary statement of the production of uranium and vanadium: U. S. Geol. Survey Press Bulletin, January, 1914.

PRINCIPAL FOREIGN OCCURRENCES OF PITCHBLENDE.

In preparing the following summary of the principal foreign occurrences the writer has so far as possible consulted original sources. The chief localities outside of the United States at which pitchblende has been found in mineral veins are the western part of the Erzgebirge, near the German-Austrian boundary, and the Cornwall district, in England. A brief summary of the geologic occurrence of uranium minerals is also given in a recent article by P. Krusch.[2]

THE ERZGEBIRGE.

TYPES OF DEPOSITS.

Müller[3] recognized in and near the granite batholiths of the western Erzgebirge in Bohemia and Saxony four types of ore deposits, which he classified as follows:

A. Older ore-forming period:
  1. Veins of the tin type.
  2. Veins of the pyritic lead-zinc type.

B. Younger ore-forming period:
  3. Veins of the cobalt-silver type.
  4. Veins of the iron and manganese type.

Deposits of types 1 and 2 are connected by transitions. The tin ores are confined to the granite and its immediate vicinity; the pyritic lead-zinc veins are a little farther removed from the granite batholiths. The veins of types 3 and 4 are later than those of types 1 and 2.

At Joachimsthal, in Bohemia, and at Schneeberg, Annaberg, and Johanngeorgenstadt,

[2] Über die nutzbaren Radium-Lagerstätten und die Zukunft des Radium-Marktes: Zeitschr. prakt. Geologie, vol. 19, pp. 83-90, 1911.

[3] Müller, Hermann, Die Erzgänge des Annaberger Bergrevieres, Erläuterungen zur geologischen Specialkarte des Königreichs Sachsen, p. 66, Leipzig, 1894.

across the border in Saxony, the veins of principal economic importance belong to Müller's cobalt-silver type (No. 3). It is with the veins of this type that the pitchblende is exclusively associated.

JOACHIMSTHAL, BOHEMIA.

According to Stěp and Becke[1] the ores of the cobalt-silver type in the Joachimsthal district may be further subdivided into two classes—cobalt-nickel-arsenic ores and rich silver ores. In the writer's opinion the ores of the first class represent the primary ore deposition and those of the second class are in all probability the result of downward enrichment acting on the primary ore. The pitchblende, with its accompanying gangue minerals, quartz and dolomite, has rarely been observed in actual contact either with the rich silver ores or with the cobalt-nickel-arsenic ores. Usually the pitchblende and its gangue minerals have as metallic associates only variable amounts of pyrite and chalcopyrite, which appear to be in part earlier and in part later than the pitchblende. In a few places, however, the pitchblende, quartz, and dolomite coat ore containing cobalt or nickel minerals (smaltite, chloanthite, or niccolite), and therefore apparently are later than those minerals. The relation of the uranium ores to the rich silver ores can be inferred only from museum specimens in which ruby silver or proustite occurs in vugs in the pitchblende ore and in minute veinlets traversing it. It appears fairly well established, therefore, that the uranium ores of Joachimsthal were deposited somewhat later than the nickel-cobalt-arsenic ores, but before the development of rich silver sulphides, which in these deposits were probably formed by much later enrichment due to the action of meteoric waters.

ANNABERG, SAXONY.

In the Annaberg region also the cobalt-silver type of ore is economically the most important, and its veins in many places cut or even materially displace the earlier tin, copper, and pyritic lead-zinc veins. According to Müller[2] the pitchblende is characteristically though nowhere abundantly associated with the cobalt-silver type of veins. It usually forms compact spherulitic or grapelike masses, some of which have shell-like or concentric structure, as a coating on siderite and fluorspar. Rarely it forms layers as much as 7 centimeters thick.

The primary minerals of the cobalt-nickel veins are, according to Müller, barite, fluorite, quartz, siderite, rammelsbergite ($NiAs_2$), niccolite, chloanthite, smaltite, native bismuth, tetrahedrite, stibnite, chalcopyrite, pyrite, reddish sphalerite, and berthierite ($FeS.Sb_2S_3$). The pitchblende, together with siderite, calcite, and some pyrite and chalcopyrite, is later than the cobalt-nickel group of minerals, but earlier than the rich silver minerals, whose origin, as at Joachimsthal, may be attributed with much probability to downward enrichment.

JOHANNGEORGENSTADT, SAXONY.

In the Johanngeorgenstadt district, which has been described by Viebig,[3] the most valuable uranium ores are also associated with Müller's cobalt-silver type, but the latter are characterized by an unusual abundance of native bismuth and bismuth compounds and are valuable mainly as a source of that metal and only subordinately for the nickel, cobalt, or silver they carry. The principal primary minerals of these veins are arsenopyrite, cobaltite, chloanthite, native bismuth, quartz, dolomite, siderite, calcite, and rarely barite and fluorite. The pitchblende is invariably associated with the veins of this type. It is in part disseminated and in part in solid crusts or bands, some of which reach a thickness of 6 to 8 centimeters. Kidney-shaped and concentric forms are common. Characteristic metallic associates are fine-grained galena and chalcopyrite and native bismuth, small masses of these minerals being locally inclosed in the pitchblende ore. The common gangue mineral is an iron-manganese carbonate. In other parts of the Erzgebirge the pitchblende is irregularly distributed in nests, but in the Gottes Segen Spat mine, in this region, it occurs in considerable quantities and with much regularity.

SCHNEEBERG, SAXONY.

In the Schneeberg district, according to Müller,[4] pitchblende is a characteristic though

[1] Stěp, Josef, and Becke, F., Das Vorkommen des Uranpecherzes zu St. Joachimsthal: K. Akad. Wiss. Wien Sitzungsber., vol. 113, pp. 585–618, 1904.

[2] Müller, Hermann, op. cit., pp. 94, 98–100.

[3] Viebig, W., Die Silber-Wismutgänge von Johanngeorgenstadt in Erzgebirge: Zeitschr. prakt. Geologie, vol. 13, pp. 89–115, 1905.

[4] Müller, Hermann, Der Erzdistrikt von Schneeberg in Erzgebirge, in B. von Cotta's Gangstudien, vol. 3, pp. 129–138, 1860.

not an abundant accompaniment of the cobalt-silver type of veins. Its kidney-shaped or rounded shell-like masses are ordinarily associated with chalcopyrite, galena, and brown carbonate. Müller regarded the pitchblende and its accompanying minerals as of slightly later formation than the primary cobalt and nickel minerals and earlier than the rich silver minerals.

CORNWALL DISTRICT, ENGLAND.

In and near the granite batholiths of Cornwall occur not only tin and copper lodes but also, usually at a greater distance from the granite, younger lodes of two types—(1) those containing uranium and nickel ores and (2) iron-manganese lodes.[1] In the vicinity of Bodmin, for example, there occur certain lodes containing arsenic and copper minerals and smaller quantities of uranium, cobalt, and nickel ores. These lodes cross the tin and copper lodes that are the main mineral resources of the district and are therefore somewhat younger, although it is believed that all the lodes are genetically connected with the granitic intrusives of the region.

In the St. Austle Consols mine, according to Williams,[2] uranium minerals have been found in certain small veins that cross the main tin-copper lode. The associates of the uranium minerals in the cross veins are locally copper ores but more commonly ores of nickel and cobalt. The uranium minerals also occur on the sides of the veins.

At Dolcoath, according to Pearce,[3] pitchblende occurred "associated with native bismuth and arsenical cobalt in a matrix of red compact quartz and purple fluorspar." At South Tresavean it occurs with "kupfernickel, native silver, and rich argentiferous galena." "I believe," says Pearce, "in all the localities I have named, it was found in little veins crossing the lodes" (that is, the tin lodes).

At the South Terras or Uranium mine, in Cornwall,[4] "The uranium lode * * * is said to vary in width from 3 to 5 feet, but the uranium ore is confined to a leader a few inches in width, consisting partly of pitchblende and calc and copper uranites with copper pyrites, mispickel, and galena, and small quantities of nickel, cobalt, and chromium ore in a veinstone of quartz and green garnet rock."

PITCHBLENDE IN THE CENTRAL CITY QUADRANGLE.

Within the area of the Central City quadrangle pitchblende has been reported from the Alps, Belcher, Calhoun, German, Kirk, Mitchell, and Wood mines, on Quartz Hill; from the 200-foot level west, in the Pewabic mine, in Russell Gulch; and from the Jo Reynolds mine, near Lawson. The pitchblende occurs as a minor component of gold-silver ores, and most of the mines mentioned above have been

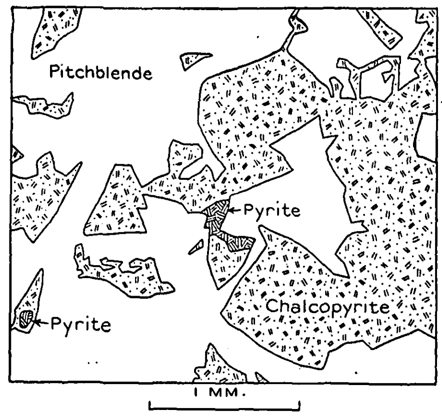


FIGURE 11.—Camera lucida drawing of polished section of ore from the Wood mine, Quartz Hill, showing contemporaneous intergrowth of pitchblende, chalcopyrite, and pyrite.

worked primarily for gold and silver rather than for pitchblende.

Although few opportunities were afforded for studying the richer pitchblende ores in place, because of suspension of mining at most of the mines, many excellent specimens from these mines were polished and studied under the reflecting microscope and found to show clearly the relations of the pitchblende to the sulphides which accompany it in the veins.

In a number of specimens it is evident that the pitchblende crystallized contemporaneously with chalcopyrite, pyrite, and probably gray quartz. A specimen from the Wood mine, obtained through the courtesy of Mr. W. C. Denison, presented, when polished, the appearance shown in figures 11 and 12. Some of the intergrown chalcopyrite and pitch-

[1] Ussher, W. A. E., Barrow, G., and MacAlister, D. A., The geology of the country around Bodmin and St. Austell: Geol. Survey England and Wales Mem., Expl. Sheet 347, p. 134, 1909.

[2] Williams, R. H., Notice of the occurrence of nickel and cobalt at St. Austle Consols mine, near St. Austle, Cornwall: Roy. Inst. Cornwall Thirty-ninth Ann. Rept., pp. 32–34, 1857.

[3] Pearce, Richard, Note on pitchblende in Cornwall: Roy. Geol. Soc. Cornwall Trans., vol. 9, pp. 103, 104, 1875.

[4] Ussher, W. A. E., Barrow, G., and MacAlister, D. A., op. cit., p. 157.

blende of this specimen show angular outlines, as indicated in figure 11, but more commonly the pitchblende areas are ringlike in cross section, chalcopyrite occupying the center of the ring and inclosing it, as indicated in figure 12. Pyrite and gray quartz, apparently contemporaneous with the pitchblende and chalcopyrite, are present in small amounts. Specimens from the Wood and German mines in the mineral collections at the State Capitol in Denver show chalcopyrite and pitchblende so intimately intergrown as to leave little doubt of their contemporaneous crystallization. In other specimens from the Wood mine botryoidal

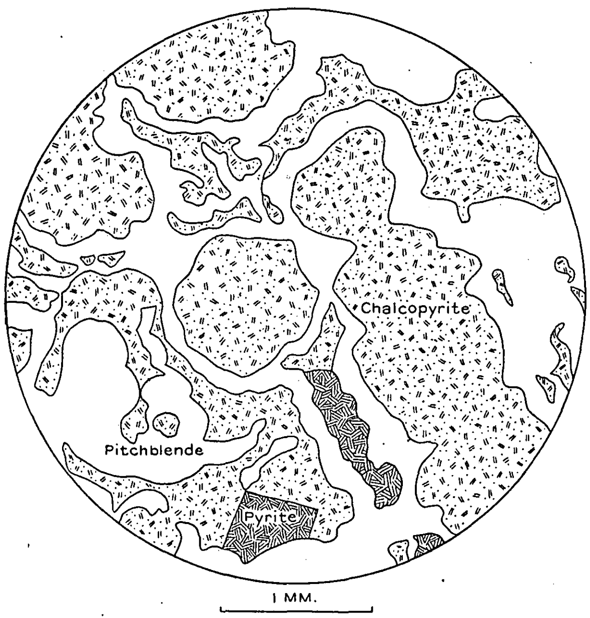


FIGURE 12.—Camera lucida drawing of polished surface of pitchblende ore from the Wood mine, Quartz Hill, showing contemporaneous intergrowth of pitchblende, chalcopyrite, and pyrite. In contrast with figure 11, which was drawn from another part of the same specimen, the pitchblende areas show rounded outlines.

pitchblende has cores of pyrite and is in places fringed with pyrite, as shown in Plate XV, *A*. To summarize, the manner in which the minerals are intergrown in several specimens shows conclusively that pitchblende crystallized contemporaneously with chalcopyrite and probably with minor amounts of pyrite and gray quartz.

Other specimens carry sulphides which are later than the pitchblende. A specimen of rich ore from the Calhoun mine, obtained through the courtesy of Mr. Hugh C. Brown, consists principally of pitchblende, but this mineral is sharply cut by veinlets one-eighth inch or less in width, composed of sphalerite, pyrite, and some galena. The form of some of these veinlets is shown in figure 13. Similar relations in a specimen from the German-Belcher mine, lent by Mr. Forbes Rickard, are shown in Plate XVI, *B*. Another specimen from the Calhoun mine shows pitchblende shattered to minute fragments which lie in a matrix of pyrite and chalcopyrite with some galena, sphalerite, and quartz. Similar brecciation of pitchblende in ore from the German-Belcher mine is shown in Plate XVI, *A*.

Specimens of pitchblende ore from the Jo Reynolds mine near Empire were kindly lent by Mr. R. B. Morton. They came from the tunnel level near the bottom of the old

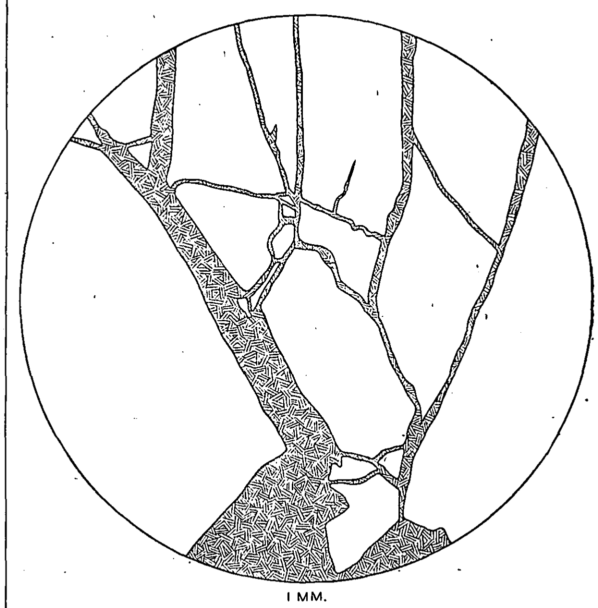
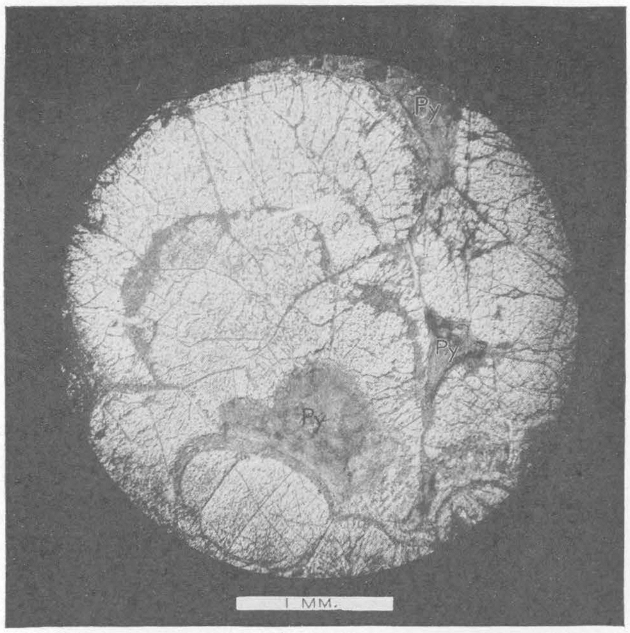


FIGURE 13.—Camera lucida drawing of polished face of ore from the Calhoun mine, showing pitchblende (white) traversed by later veinlets of pyrite, sphalerite, and galena (patterned).

shaft, from a point about 1,000 feet below the surface. Microscopic examination of polished surfaces of the ore showed fragments of pitchblende having characteristic botryoidal forms embedded in a matrix of quartz, siderite, sphalerite, galena, and chalcopyrite. In places minute veinlets of one or more of these minerals traverse the pitchblende. It is clear from the study of these specimens that after the period of pitchblende deposition the ores were fractured and the fractures filled with quartz, sphalerite, galena, chalcopyrite, pyrite, and, in the Jo Reynolds ore, siderite. In the Jo Reynolds ore no sulphides contemporaneous with the pitchblende were noted.

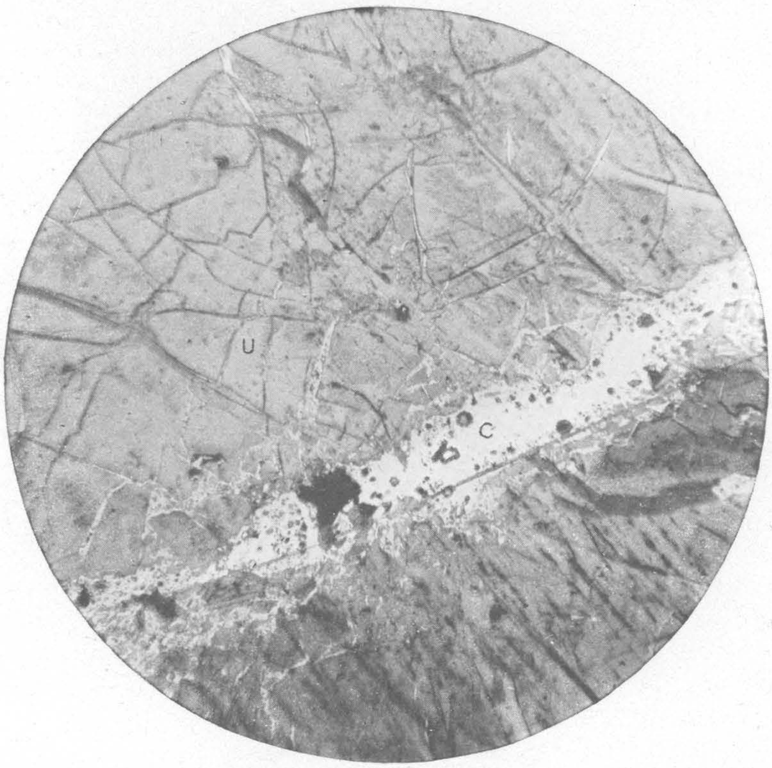


A. POLISHED SECTION OF PITCHBLENDE ORE FROM THE WOOD MINE, QUARTZ HILL, GILPIN COUNTY.

Showing botryoidal forms characteristic of much of the pitchblende. Py, intergrown pyrite.

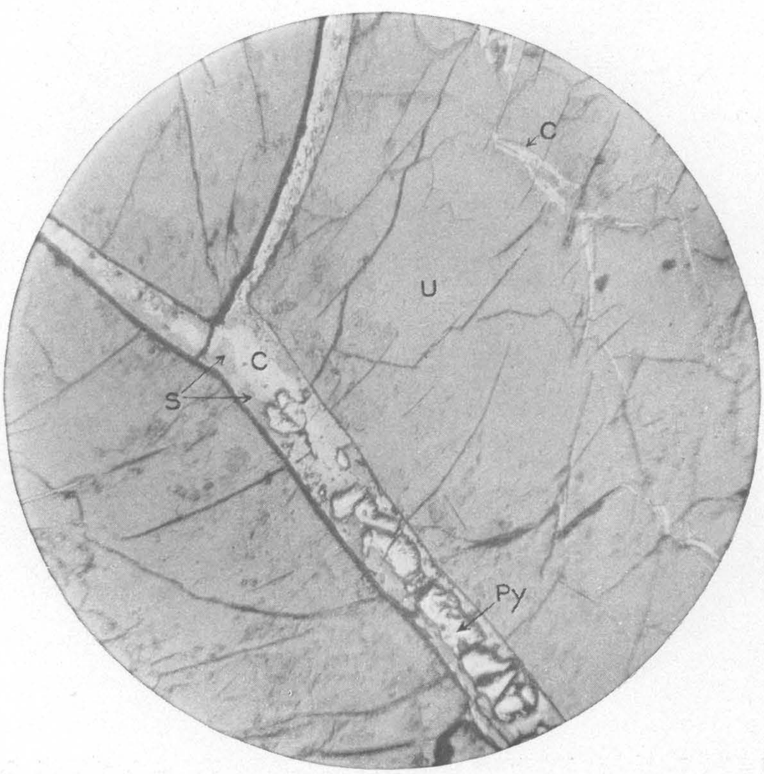
B. DIKE ROCK FROM EVERGREEN MINE, PINE CREEK VALLEY, GILPIN COUNTY.

Clear-white to light-gray mineral is quartz; cloudy light-gray mineral in irregular grains is feldspar; fibrous prismatic mineral is wollastonite; mottled dark-gray and black mineral is principally green augite; small black areas in the lower southeast part of photograph are bornite and chalcopyrite. Note the sharp contact of the last two minerals with the others and the generally fresh character of the rock. Enlarged 15 diameters.



A. URANINITE OR PITCHBLENDE (U) FRACTURED AND BRECCIATED AND INTERSPACES FILLED WITH ORE COMPOSED PRINCIPALLY OF CHALCOPYRITE (C), WITH SOME GALENA, PYRITE, AND SPHALERITE.

Ore taken from German-Belcher mine. Enlarged 100 diameters.



B. URANINITE OR PITCHBLENDE (U) TRAVERSED BY SULPHIDE VEINLETS.

Ore taken from German-Belcher mine. C, Chalcopyrite; S, sphalerite; Py, pyrite. Enlarged 110 diameters.

The significance of the contrasting and apparently contradictory modes of association of the pitchblende with the sulphide minerals becomes apparent when it is recalled that there have been in this region two periods of mineralization, an earlier pyritic mineralization and a later galena-sphalerite mineralization. The minerals intergrown contemporaneously with the pitchblende are those characteristic of the pyritic mineralization; those which are later than the pitchblende are characteristic of the galena-sphalerite mineralization. On this evidence it is believed that the pitchblende ores were deposited during the earlier or pyritic mineralization; that they were later fractured; and that ores of the later or galena-sphalerite type were deposited in the fractures. They are, according to this interpretation, merely a local and unusual variation in the main sulphide mineralization of this region—a variation of the same order as the occurrence of enargite in a neighboring group of veins near South Willis Gulch. No evidence was found to indicate that the pitchblende mineralization is genetically connected with the intrusion of the pre-Cambrian granitic rocks;[1] on the contrary, the writer believes that, together with the sulphides that accompany them, they are genetically related to the Tertiary (?) monzonite intrusives.

The general geologic relations and the absence of characteristic high-temperature minerals in the deposits of Quartz Hill, as well as in those of Cornwall and the Erzgebirge, indicate that the pitchblende was deposited under conditions of moderate temperature and pressure. Unlike the European pitchblende, however, the pitchblende of Quartz Hill is not associated with nickel and cobalt minerals, which so far as known have never been found in that region even in small quantities. The occurrence of pitchblende in pegmatite as well as in mineral veins of the type here described shows that the mineral may also form under conditions of high temperature and pressure.

[1] See Rickard, Forbes, Pitchblende from Quartz Hill, Gilpin County, Colo.: Min. and Sci. Press, vol. 106, pp. 851-856, 1913.

CHAPTER IX.—TUNGSTEN, COPPER, AND IRON ORES.

TUNGSTEN ORES.

The tungsten ores of the Central City quadrangle are confined to the region between Rollinsville and Nederland and between Nederland and Caribou. Just outside of the quadrangle tungsten ores are found near Sugarloaf, Ward, and Magnolia. Although mining for gold and silver had been in progress in this part of the region since 1870, the true nature of the tungsten minerals and their economic value was not realized until 1900, when tungsten mining was begun. The ores were not studied by the writer, and the following summary of their occurrence is abstracted from a report by George and Crawford.[1]

The only abundant tungsten mineral of the deposits is ferberite, a tungstate of iron and manganese. This occurs in veins with prevailing northeasterly trends and steep dips. The veins are zones of brecciation, and most of the ferberite occurs in the matrix of these friction breccias. Small amounts of one or more of the minerals scheelite, pyrite, chalcopyrite, galena, sphalerite, molybdenite, gold tellurides, and possibly fluorite and adularia have been found in association with the ferberite. In some of the veins earlier formed ferberite has been brecciated and cemented by later ferberite.

The relation of the tungsten ores to ores of other types is further discussed on page 132.

The ores are treated at two large mills at Lakewood and Nederland and at a number of smaller mills. The production of the entire Boulder County tungsten field in 1915 amounted to 960 short tons of 60 per cent tungstic oxide.

For further information in regard to the tungsten deposits the reader is referred to the report by George and Crawford already cited, to a report by Hess and Schaller,[2] and to the annual reports by Hess [3] on the production of tungsten.

[1] George, R. D., and Crawford, R. D., The main tungsten area of Boulder County, Colo.: Colorado Geol. Survey First Rept., pp. 7-103, 1909.

[2] Hess, F. L., and Schaller, W. T., Colorado ferberite and the wolframite series: U. S. Geol. Survey Bull. 583, 1914.

[3] U. S. Geol. Survey Mineral Resources, 1906-1914.

COPPER ORES.

GENERAL FEATURES.

In a region where most of the ore deposits are typical fissure veins whose principal values are in gold and silver, the Evergreen mine stands unique because it is worked primarily for copper and because the ore minerals are not in a fissure vein but are disseminated through an igneous rock. It is situated in the valley of Pine Creek about half a mile south of the little mining camp of Apex. Its unusual features attracted the attention of Étienne Ritter,[4] who described the mine in an interesting article in which he showed that the copper sulphides crystallized contemporaneously with the other minerals of the igneous rock.

GEOLOGIC RELATIONS.

The prevailing rocks at the Evergreen mine are schists of the Idaho Springs formation injected by small amounts of granite pegmatite. Both schist and pegmatite have been intruded by dikes of light-gray rock, which are probably offshoots from the large stock of monzonite that crops out less than half a mile north and east of the mine. (See Pl. I.) The ore minerals, which are chalcopyrite and bornite, are largely confined to the dikes and to the igneous breccias formed by the shattering of the wall rocks during the intrusion of the dikes. The mineralization is commonly greatest in the breccias, but in these the sulphides are confined to the igneous matrix and are wholly absent from the contained fragments of wall rock. These fragments are angular and show little evidence of metamorphism by the dikes. As a consequence of this distribution of the ore most of the development work has followed the dikes, though some exploratory workings are mainly in schist. The north drift on the 200-foot level follows a dike for about 250 feet. This dike is 1 to 1½ feet wide, strikes on the average about N. 25° W., and dips about 50° E. The drift on the 150-foot level follows what

[4] Ritter, É. A., The Evergreen copper deposit, Colorado: Am. Inst. Min. Eng. Trans., vol. 38, pp. 751-765, 1908.

may be the same dike for 130 feet. On this level the dike rock has intensely brecciated its host and the igneous breccia is in places 4 feet wide. In the tunnel dikes are encountered at several places. They are interrupted by numerous faults and their exact relations to one another are thus rendered uncertain. The narrower dikes exposed in this tunnel are 2 to 3 feet wide, while larger masses exceed the width of the tunnel by an indeterminate amount.

PETROLOGY OF THE ORE-BEARING DIKES.

The dike rocks exposed in various portions of this mine are in general of similar character. They are light-gray rocks, in places porphyroid in texture through the development of pink feldspar crystals above the average in size. The porphyroid phases to the unaided eye appear closely similar to the monzonite of the neighboring stock, but when studied microscopically they show notable differences. In a common type which is even grained a great abundance of minute colorless prisms are recognizable with the unaided eye. Under the microscope the porphyroid phases are found to be almost perfectly fresh, granular in texture, and composed dominantly of feldspar, augite, and wollastonite. (See Pl. XV, *B*, p. 125.) The feldspars are mainly of the orthoclase and microcline varieties, finely (perthitically) intergrown with albite, and the grains are of many sizes, the largest about 5 millimeters in diameter. Here and there is a small crystal of plagioclase (oligoclase or andesine). Quartz in smaller grains is very abundant. The grass-green augite is nearly equal to quartz in abundance. Its crystals are as a rule not over 5 millimeters long, but in the matrix of some of the igneous breccias augite prisms 5 millimeters wide and 8 millimeters long occur. Wollastonite forms abundant prisms commonly less than 1 millimeter in length. In portions of the dikes it is nearly equal to feldspar in amount and in a few specimens from the dump it formed needles 1 centimeter or less in length. It is the white fibrous mineral so characteristic of certain hand specimens. Titanite, usually showing crystal outlines, garnet crystals of irregular outline, and small zircons are accessory minerals. Small amounts of calcite are present locally. In some specimens the calcite is plainly an alteration product of wollastonite, being pseudomorphous after the long prisms of that mineral, but in others the calcite forms irregular masses showing sharp contacts with fresh feldspar and augite and may be original. Most of the dike rock contains no opaque minerals with the exception of some small grains of magnetite, but locally chalcopyrite and bornite occur in small and very irregular patches. These sulphides are particularly abundant where the dike rock incloses numerous fragments of wall rock and thus forms an igneous breccia. The chalcopyrite and bornite are contemporaneous and are irregularly intergrown with each other, and they are commonly accompanied by garnet, a mineral which is rare elsewhere. The garnet and sulphides are unquestionably contemporaneous with the other minerals of the rock, being in sharp contact with perfectly fresh individuals of all the principal constituents. In some places the bornite incloses augite and wollastonite. Needles of wollastonite also penetrate bornite. In other places bornite is wholly inclosed by quartz. Chalcopyrite and bornite occur inclosed between prisms of wollastonite.

Rogers [1] in a recent paper figures chalcocite associated with bornite from the Evergreen mine and suggests that the chalcocite is a product of upward enrichment. Chalcocite is a very inconspicuous mineral at this mine and is generally not recognizable except under the microscope. In one of the specimens examined by the present writer chalcocite is irregularly associated with chalcopyrite and bornite. The origin of this particular chalcocite is indeterminable. In most other specimens, however, chalcocite has developed along incipient fractures in the bornite and along contacts between bornite and silicate minerals. This relation between chalcocite and bornite is totally different from the relation between bornite and chalcopyrite and indicates that the chalcocite is secondary. As the mine workings are all shallow, it appears impossible to say whether the chalcocite was deposited by ascending or by descending solutions. The writer is much inclined to the latter and more usual origin.

The richest ore that has been produced at this mine was taken from a large chamber stope about 120 feet from the mouth of the tunnel.

[1] Rogers, A. F., Secondary sulphide enrichment of copper ores with special reference to microscopic study: Min. and Sci. Press, vol. 109, p. 686, 1914.

The stope is near the surface, and the geologic relations are much obscured by oxidation, but two distinct dikes are recognizable. Much of the ore from this stope is a breccia of angular fragments of gray quartz in a matrix of dike rock. To the unaided eye the sulphides, which are abundant, appeared to be confined to the matrix. Under the microscope this matrix shows no important differences from the ordinary dike rock of other parts of the mine. The quartz of the fragments interlocks at its borders with the minerals of the matrix, indicating some recrystallization and welding at the time of the intrusion, but matrix and quartz fragments are very distinct when viewed in the hand specimen. In the slide the matrix is seen to send off small branches or stringers of bornite and feldspar into minute cracks which traverse a single quartz crystal or penetrate between two crystals of the fragments. The origin of the quartz that forms the fragments of this breccia is uncertain, but it probably represents a quartzose phase of the pegmatite which is so abundantly associated with the schists of the Idaho Springs formation. That the large quartz masses do not represent coarse crystallizations of quartz within the dike rock is apparent from their commonly angular character, from the absence of comparably coarse crystallizations of the other dike minerals, and from the great contrast in size (several inches as compared with 1 millimeter or so) between the large quartz masses and the quartz of the matrix.

Ritter[1] called the dike rock evergreenite. The long prisms of a colorless mineral were identified by him as enstatite or diallage. Their optical properties, however, show unquestionably that they are wollastonite. These properties may be summarized as follows: Inclined extinction; index of refraction notably greater than that of quartz; double refraction low for sections parallel to the prism and high for sections across the prism axis; cleavage parallel to prism, intersecting at nearly right angles; biaxial; optically negative; plane of the optic axes perpendicular to prism axis. The occurrence of garnet in association with the sulphides is not mentioned by Ritter. Covellite is described by him as an alteration product of bornite in a few specimens.

[1] Op. cit., p. 751.

RELATIONS OF ORE-BEARING DIKES TO NEIGHBORING MONZONITE STOCK.

The mineralogy of the porphyry stock near the Evergreen mine shows beyond reasonable doubt that the dikes at this mine are related to it. The rock as exposed 1 mile southeast of the mine is a monzonite which, like the dike rock, is characterized by predominant orthoclase in perthitic intergrowth with albite and by abundant grass-green augite. It differs from the dike rock in the absence of quartz, garnet, wollastonite, and copper sulphides and in the presence of abundant magnetite. In other phases quartz is fairly abundant. Porphyry occurring on the hill northwest of the Evergreen mine and probably a continuation of the Evergreen dikes is similar in every way to the dike rock of the mine except for the absence of sulphides, garnet, and wollastonite.

ORIGIN OF THE ORE.

The origin of the copper sulphides, which are the valuable minerals at this mine, is somewhat uncertain. They unquestionably crystallized contemporaneously with the other minerals of the dikes, and the dikes are without doubt offshoots from the large neighboring monzonite stock. Several hypotheses of origin may be stated:

1. The sulphide-bearing dike rocks may have been formed solely through magmatic differentiation from the monzonite mass.

2. Sulphides and the materials necessary to form the minerals wollastonite and garnet, which are characteristic of the dikes, may have been absorbed from the immediate wall rocks. This view is made hardly tenable by the sharp contacts between dike and wall rock, even where the latter is much brecciated, and the absence of variation in the composition of the dike toward the walls.

3. The sulphides and materials necessary to form the wollastonite and garnet that are especially characteristic of the dikes as distinct from the typical monzonite may have been absorbed by relatively deep-lying portions of the monzonite magma from wall rocks or veins with which it came into contact. The magma thus modified in composition moved into fissures in the wall rocks and there crystallized as dikes. By the time it had reached

its present position it was so cooled and formed masses relatively so narrow that its absorption of the wall rock was slight.

4. The ore-bearing dikes may represent the combined effect of magmatic differentiation and digestion of wall rock.

In the opinion of the writer the abundance of garnet and wollastonite, minerals particularly characteristic of contact metamorphism, in the dikes is strongly suggestive of digestion of calcareous wall rock, wollastonite in particular never having been described as occurring so abundantly in rocks of purely magmatic origin. Such digestion of material probably took place before the rock reached its present position, as suggested under hypothesis No. 3. The sulphides may have been derived either from the wall rocks through absorption or from the magma by magmatic differentiation. The deposit under this view represents an endomorphic effect produced by contact metamorphism at the border of a large intrusion of monzonite.

LATER FRACTURING AND MINERALIZATION.

Subsequent to the intrusion of the ore-bearing dikes the rocks of this vicinity were broken by numerous fractures and faults. These increase the difficulties of mining by displacing the ore-bearing dikes and forming water channels. They are not in general mineralized, though some are quartz-filled and bordered by narrow leached zones. At one place narrow seams of calcite and quartz cut both dike and schist. One fracture plane traversing the schists in the tunnel showed about an inch of quartz and calcite with a little chalcopyrite. On the dumps a number of fragments were found which showed narrow veins as much as a quarter of an inch wide composed almost wholly of chalcopyrite, traversing the schist. In one specimen such a veinlet of chalcopyrite cut sharply through typical dike rock bearing chalcopyrite and bornite and inclosing schist fragments. Other fragments from the dump are fine-grained aggregates of quartz, calcite, chalcopyrite, specularite, pyrite, and sphalerite (in part resinous), with a little galena and bornite. Some of the specularite blades penetrate calcite crystals, and a few are half an inch across. The mineralization recorded by some and probably by all of these occurrences is primary and of the vein type and is later than the intrusion of the ore-bearing dikes. Economically it appears to be unimportant. No evidences of downward sulphide enrichment were noted, although, as already stated, the upper or 60-foot level was not accessible.

TITANIFEROUS IRON ORES.

Several deposits of titaniferous iron ore occur on the northeast and south slopes of Caribou Hill, in the northern part of the Central City quadrangle. The iron ore forms irregular bodies within masses of gabbro and pyroxenite, which in turn are within a large stock of monzonite. The gabbros and pyroxenites and the ores are believed to have been formed by a process of differentiation within the monzonite magma, as has already been discussed in detail on pages 42–49. Even before 1880 the ores had, according to Putnam,[1] attracted the attention of miners, and sample shipments had been hauled to the smelter at Boulder. Putnam also states:

> All the ore is very magnetic and exhibits polarity to so marked a degree that the dip of the needle changes from +90° (north end down) to −50° (south end down) in the distance of 10 paces. There is undoubtedly a large amount of iron ore in the hill, but it is probable that the rich ore is too irregularly distributed through the rocks to permit of its being economically mined.

Recently the deposit has been studied in detail by Jennings,[2] and his analysis of the ore with two analyses of the associated rocks are quoted in the table on page 43. The more extended studies of the present writer show the presence of olivine-rich iron ores and olivine monzonites not described by Jennings.

In regard to the utility and origin of the ores Jennings says: "These interesting deposits have little or no economic importance but are excellent examples of iron ores of igneous origin."

The locality has recently been studied also by Singewald,[3] and the following excerpts are quoted from his report:

> On Caribou Hill are several intrusions of basic material, and it is within these that the ore occurs. The most important one is the dike on the northeast slope of the hill, which can be traced for over 1,500 feet. It begins at a point 500 yards west of Caribou and runs up the hill slope in a south-

[1] Putnam, B. T., Tenth census, vol. 15, p. 476, 1886.

[2] Jennings, E. P., A titaniferous iron-ore deposit in Boulder County, Colo.: Am. Inst. Min. Eng. Trans., vol. 44, pp. 14–25, 1913. Illustrated by microphotographs of ores and rocks.

[3] Singewald, J. T., jr., The titaniferous iron ores in the United States: U. S. Bur. Mines Bull. 64, pp. 126–128, 1913.

easterly direction for about 400 feet, where it bends sharply to the east and continues for about 1,000 feet to the edge of Caribou. A second intrusion, having more of a stock shape, occurs on the southeast slope of the hill, half a mile southwest of Caribou. A third smaller outcrop occurs near the top of the hill about 100 yards southeast of the summit. These rocks show considerable local variations but are essentially pyroxenitic in character. Associated with the pyroxene in places is feldspar and biotite. The texture ranges from that of a coarse pyroxenite to a very fine grained rock.

Some magnetite occurs as an accessory constituent of the basic rocks, and this becomes segregated into richer pockets, forming a medium grade ore. But even in the ore-bearing parts of the rock the composition is not uniform. It is rather a rock rich in magnetite, with numerous stringers and veinlets of almost pure magnetite. The magnetite is highly magnetic and much of it is natural lodestone. These stringers of pure ore never exceed 6 inches in thickness and seldom measure more than an inch or two They may form such a network within the leaner rock as to constitute a medium-grade ore. Such ore bodies do not reach a width of more than a foot or two or a length of more than a few feet. The ore in the pits and trenches that have been made along the western end of the dike northwest of Caribou consists of a series of closely crowded lenses of that character. The dike has a width of 50 to 100 feet or over, but only a small part consists of ore of even this grade. The ore in the other two occurrences is still leaner and there is still less of it. Thin sections of the ore show that it consists essentially of the ore minerals and pyroxene, the latter ranging in composition from diopside to augite. The pyroxene is frequently altered to serpentine and in part to hornblende. Some biotite is also usually present. Inclusions of dark-green spinel in the magnetite are common. * * *

A metallographic study of the ore shows little of interest. The richer veinlets consist of medium-grained aggregates of magnetite and ilmenite with a little gangue. The ilmenite is far less abundant than the magnetite and occurs in smaller grains, in many places as small particles filling interstices between the magnetite and the gangue grains. The leaner ore, which grades over into the country rock, contains scattered grains of magnetite and ilmenite, with the femic minerals in excess.

Intergrowths of ilmenite in the magnetite are not abundant. Most frequently they consist of dots and small particles scattered irregularly through the magnetite. Regular intergrowths of tabular ilmenite in the magnetite are not numerous. * * * The best of the ore is only medium grade and the ore lenses are very small. On account of its small size the deposit can never have any economic value.

To these descriptions the present writer has little to add that is of economic significance. According to his field studies the iron-ore occurrences in and north of Caribou form two closely adjacent bodies rather than a single one and are not dikelike in form. The deposit half a mile south of Caribou also consists of two irregular bodies. All these features are brought out on the map (Pl. I). The deposit near the summit of Caribou Hill is too small to appear on a map of this scale.

As is well known no iron ores containing notable amounts of titanium are at present used in the iron industry, though experiments looking toward their utilization are now in progress. The presence of titanium is not injurious in steels used for certain purposes; in fact, titanium is the material most widely used to give steel certain desired properties. Its detrimental effect in an iron ore is due to the fact that it produces a refractory slag that is difficult to handle in the blast furnace, and 0.5 per cent seems to be almost as detrimental as 10 or 15 per cent. The percentages of magnetite and titanic oxide in samples of the Caribou ore analyzed by Jennings and by this Survey are as follows:

	1	2	3
Magnetite (Fe_3O_4)	64.73	30.55	23.90
Titanic oxide (TiO_2)	4.48	2.69	2.52

1, E. P. Jennings, analyst; 2, 3, lean ore, George Steiger, analyst.

The high titanium content reported by Chauvenet[1] (36 per cent of titanic acid, with 36 to 38 per cent of iron) is probably exceptional or in error.

Even if the metallurgic difficulties involved in the high titanium content can be overcome, the inaccessibility and small size of these deposits preclude all possibility of successful exploitation.

[1] Chauvenet, Regis, Preliminary notes on the iron resources of Colorado: Colorado School of Mines Bienn. Rept., for 1886, p. 16, 1888.

CHAPTER X.—GENESIS OF THE PRIMARY ORES.

PURPOSE OF THE DISCUSSION.

The genesis of the ores has already been touched upon at several points in the descriptions of the several ore classes. It is the writer's desire in this chapter to place each of the ore classes in its proper genetic position with respect to the others and to emphasize certain features in the mineralization of this region that are of particular genetic significance.

RELATION BETWEEN MINERALIZATION AND VOLCANISM.

The mineralized portions of the Central City quadrangle, as has been shown on pages 93–94, form part of a large mineralized belt that includes nearly all the important mining camps of Colorado. Within this belt the ores exhibit great variations in mineral composition and in mode of occurrence, their only unifying feature being their invariable areal association with intrusive igneous rocks of probable Tertiary age, the "porphyries" of the miners. (See fig. 4.) Beyond the areas containing "porphyry" intrusions the ore deposits also disappear. This association, suggestive as it might be, would certainly not be a sufficient basis for concluding that the ores and the "porphyries" are genetically related were it not for the fact that a similar intimate association of ores and igneous rocks has been noted in practically every region where lode deposits of gold and silver ores have been studied geologically. Further, it is probable from geologic observations in this quadrangle that the mineral veins were formed late in the period of "porphyry" intrusions; the veins are younger than the bulk of the "porphyry" but older than a few scattered "porphyry" dikes. It is known also that the titaniferous iron ores are strictly of igneous origin, having been formed by magmatic differentiation within a monzonite stock. It is confidently believed, therefore, that a genetic connection exists between the mineral veins of this region and the Tertiary (?) intrusive rocks.

The precise nature of this genetic connection is largely a matter of inference on the basis of well-established principles of ore deposition rather than of direct observation. It is not practicable to expound here many of the fundamental principles that are involved; to students of the science of ore deposits they are already familiar and they have been admirably set forth by Lindgren,[1] to whose book the lay reader is referred. The recognized principles of ore deposition will therefore not be discussed in detail, although specific evidence of genesis afforded by this district will be presented.

AGENT OF ORE DEPOSITION.

With the exception of the Caribou iron ores and the copper ores of the Evergreen mine, which are integral parts of the Tertiary (?) intrusives, all the ore deposits of the Central City quadrangle are believed to have been deposited by thermal solutions that escaped from the "porphyry" magmas probably during their crystallization. The "porphyries" now exposed at the surface may have given off solutions which deposited ores at higher horizons in the portions of the crust now removed by erosion, but the existing veins and stockworks were deposited by solutions emanating far below the present surface. This is shown by the fact that the ore deposits, with a few minor exceptions, cut the "porphyries" now exposed. There appears to be no basis for the belief locally current that the occurrence of an ore deposit in or within a short distance of "porphyry" is a favorable indication; the relations between ores and "porphyries" are of a much larger and more generalized order than that implied in any such concept.

REGIONAL VARIATIONS IN MINERALIZING SOLUTIONS.

There is ample evidence, as explained later, of progressive changes in the character of the ore-depositing solutions during the general mineralizing period. In addition, there is evidence that even solutions which were strictly contemporaneous were of different character in different parts of the district.

[1] Lindgren, Waldemar, Mineral deposits, 1913.

The ores of the pyritic type appear to have formed for the most part contemporaneously in the earlier part of the mineralizing period, yet among these there are several subtypes showing mineralogic peculiarities and confined to small areas. Such are the group of enargite-bearing veins, all of which lie within a radius of three-quarters of a mile of the Hazeltine mine, in South Willis Gulch. (See p. 105.) Many of the pyritic veins of that vicinity also carry fluorite, a mineral rarely noted elsewhere in veins of this type. The presence of pitchblende (uraninite) in a group of veins on Quartz Hill appears to be another case in point. The study of polished specimens of these ores indicates that the uraninite crystallized contemporaneously with a suite of minerals identical with those characteristic of the pyritic gold-silver ores and that it is cut by veinlets mineralogically similar to the galena-sphalerite gold-silver ores. The evidence of these relations is set forth at length on pages 121–125. The uranium ores are therefore believed to be merely a local and unusual variety of the gold-silver ores and, like them, probably of Tertiary age. Analogous variations occur in veins of the galena-sphalerite type—for example, the occurrence of rhodochrosite in a few veins on Seaton Mountain and near the head of Gilson Gulch. Such variations can not be satisfactorily explained by differences in the nature of the wall rocks or in any other external conditions and must be attributed to local peculiarities in the composition of the solutions that rose through fissures and deposited the ores.

The tungsten ores of the quadrangle, though not studied in detail by the writer, appear from all available geologic evidence to present an example of regional variation of a different sort and on a somewhat larger scale. These deposits form the subject of a special report by George and Crawford.[1] According to these writers,[2] minerals characteristic of the gold-silver deposits are exceedingly rare in the tungsten veins. Small amounts of pyrite, chalcopyrite, galena, sphalerite, and sylvanite have, however, been noted in some of the veins, and in places their relations suggest contemporaneity with the tungsten minerals. Although no conclusive proofs have been obtained, it has been the opinion of most geologists who have studied the tungsten deposits that they are closely related to the gold-silver deposits and probably of nearly the same age. This opinion has been expressed by Lindgren[3] and by Hess.[4] Hess says:

> Although the data at hand are not very extensive, it seems probable that the connection between the three classes of veins [sulphide, telluride, and tungsten veins] may be fairly close and that there may not be a great difference in the ages of the several types.

George and Crawford[5] have given no very definite opinion, but from the following statement it appears that they also believe that the tungsten deposits are in some way connected with the gold-silver veins in origin. They say:

> While the gold and silver deposits and the tungsten deposits are not intimately associated, the two seem to conform roughly to the trend of the belt of intruded porphyries which extends from the middle of Boulder County in a southwesterly direction into Gilpin, Clear Creek, Summit, and Lake counties. Tungsten is known within this belt in Boulder, Gilpin, and Clear Creek counties.

Three features of the occurrence of these ores appear to the writer to have an important bearing on their origin and their relation to other classes of ores. (1) In the region where they are most abundant they almost wholly supplant other types of ores. (2) They occur in the only part of the Central City quadrangle in which Tertiary (?) dikes of intermediate and mafic (basic) composition are abundant and adjacent to the only monzonite stock which exhibits extreme mafic differentiation (the Caribou stock with its iron ores). (3) The tungsten district lies between an area of productive gold-silver veins on the west and a region barren of valuable mineral deposits on the east. These facts and the mineral associations already cited are in harmony with the view provisionally adopted by the present writer that the tungsten ores represent an unusual phase of the Tertiary (?) mineralization of the region and are possibly connected in some way with the pronounced mafic (basic) differentiation exhibited by the monzonite magmas of this vicinity.

[1] George, R. D., and Crawford, R. D., The main tungsten area of Boulder County, Colo.: Colorado Geol. Survey First Rept., pp. 7–103, 1909.

[2] Idem, pp. 75–76.

[3] Lindgren, Waldemar, Some gold and tungsten deposits of Boulder County, Colo.: Econ. Geology, vol. 2, p. 462, 1907.

[4] Hess, F. L., and Schaller, W. T., Colorado ferberite and the wolframite series: U. S. Geol. Survey Bull. 583, p. 10, 1914.

[5] George, R. D., and Crawford, R. D., op. cit., p. 85.

DIFFERENCES IN COMPOSITION OF ORE-FORMING SOLUTIONS IN DIFFERENT PARTS OF MINERALIZING PERIOD.

The two distinct types of sulphide ores of gold and silver recognizable in this region have been termed the pyritic type and the galena-sphalerite type, and it has been shown by a large number of observations that where ores of the two types occur together the galena-sphalerite ores are the later. The interval between the deposition of one type and that of the other was sufficient for the fracturing of the pyritic ores by renewed movement along some of the veins and for the development of some new fractures. It may not everywhere have been of the same duration, but probably in geologic terms it was short and is to be interpreted as an episode in a single general ore-forming period rather than as a notable interval between two distinct periods. Certainly the ores of both types were deposited under similar general conditions of depth and temperature, followed the same or parallel lines of fracturing, and appear to have broadly the same geographic distribution. Moreover, according to J. D. Irving,[1] at Leadville, within the same great metallogenetic province, where ores similar to the pyritic and galena-sphalerite ores of this region are also present, although the pyritic portions of the ores were in general the first to be deposited, there is no evidence of an interval between them and the portions of the ores rich in galena and sphalerite. Evidence of such an interval would presumably be less readily recognizable in replacement ores like those of Leadville than in ores that are fissure fillings, or it may be that the mineralization which progressed pulsatingly in Gilpin County progressed more uniformly at Leadville.

TEMPERATURE AND PRESSURE OF ORE FORMATION.

For his concept of the temperature and pressure under which ore deposits were formed the geologist is dependent upon (1) physiographic and stratigraphic evidences of the extent of erosion subsequent to mineralization; (2) direct laboratory data in regard to the range of stability of various ore minerals; and (3) indirect knowledge of the conditions under which certain ore minerals are stable, derived from estimates of the amount of post-mineral erosion in a large number of mining districts. Only meager laboratory data are yet available, but through the application of one or both of the other criteria it is generally possible to determine whether the ores were formed under conditions of great, moderate, or slight intensity as regards temperature or pressure or both, even though it may not be possible to express these conditions accurately in the dynamic units of degrees of temperature or pounds per square inch of pressure.

The application of the first of these criteria to the deposits of this region is attended by many uncertainties. The intrusive "porphyries" are believed to be of Tertiary age; inasmuch as effusive rocks that may reasonably be regarded as their equivalent first appear on the flanks of the range in the Dawson arkose, of Tertiary age, and there are other reasons, set forth on page 39, for regarding them as Tertiary. Ball recognized in the Georgetown quadrangle small masses of sandstone that he regarded as probable remnants of the Fountain formation (Pennsylvanian) of the foothills. If these correlations, the latter admittedly uncertain, are accepted, it is quite probable that the entire series of sediments, from the Fountain to the Laramie formation, inclusive, now upturned along the east flank of the range, covered the Georgetown and Central City quadrangles not long before the intrusion of the Tertiary (?) "porphyries." The thickness of these sediments between Boulder and Castle Rock has been variously estimated at 8,000 to 10,000 feet.[1] To this, in estimating the depth of formation of the ore deposits, must be added an unknown amount for the thickness of the pre-Cambrian rocks that have since been eroded, and it may be, another amount for the thickness of possible effusive phases of the "porphyries." The possibility of erosion on a considerable scale during the interval between the deposition of the Pennsylvanian Fountain formation and the Tertiary (?) volcanism can not be excluded, but the scarcity of coarse sediments in the formation representing this time interval along the flank of the range points rather to fairly continuous sedimentation.

Geologic observations within the Central City quadrangle show that the gold-silver ores

[1] Oral communication.

[1] Richardson, G. B., U. S. Geol. Survey Geol. Atlas, Castle Rock folio (No. 198), 1916. Martin, G. C., The Niobrara limestone of northern Colorado as a possible source of Portland cement: U. S. Geol. Survey Bull. 380, pp. 314-318, 1909.

extend without notable changes in character from an elevation of about 7,500 feet near the mouth of the Argo tunnel to an elevation of about 11,000 feet near Alice, a range of 3,500 feet. A part of this difference is probably the result of differential uplift since the ores were formed, but individual lodes have been followed in mining to depths of more than 2,500 feet without revealing changes indicative of markedly different conditions of formation.

The somewhat uncertain evidence available therefore points to the formation of the ore deposits of this region at depths between 7,000 and 11,000 feet. At a depth of 9,840 feet (3,000 meters) the hydrostatic pressure would be about 300 atmospheres and the rock pressure about 810 atmospheres. Under the normal increment of temperature with increasing depth a temperature of 100° C. should be reached at a depth of about 9,000 feet, but in a region like that under discussion, owing to the presence of Tertiary (?) intrusive rocks, the temperature would presumably increase more rapidly. More probably it lay between 150° and 300° C.

Laboratory observations on the range of stability of minerals offer no data applicable to the ores of this region, but the mineral character of the ores, interpreted in the light of what is known of conditions of ore deposition elsewhere, is of much significance. The mineral composition of the ores has been summarized in tabular form on page 100, and this table brings out clearly the fact that all the ores listed as deposits from ascending thermal waters are lacking in minerals indicative of very high temperature, high pressure, or both, or of low temperature and shallow condition. The absence of silicates, except feldspar and sericite, is noteworthy. Oxides, except silica, are not present as primary minerals. Pyrrhotite, a sulphide characteristic of intense conditions, is absent. Chalcedony, a mineral occurring usually in deposits of shallow origin though locally in those formed under conditions of moderate intensity, is present only in small amounts in a few telluride veins. Realgar, orpiment, stibnite, and many other minerals characteristic of deposits formed at slight depths are absent. On the other hand, tennantite and enargite, which find their principal habitat in deposits formed under moderately intense conditions, are fairly abundant in certain of the deposits of this region. The mineralogic as well as the physiographic and stratigraphic evidence therefore points to the formation of the gold-silver ores, the pitchblende ores, and probably also the tungsten ores under conditions of moderate intensity.

COMPOSITION OF MINERALIZING SOLUTIONS.

The composition of the solutions that deposited the gold-silver ores and the pitchblende ores of the Central City quadrangle may be inferred in a qualitative way from the mineralogy of the ores and the alterations produced in the wall rocks by the ore-forming solutions. As the thermal-spring waters of Idaho Springs and the gaseous emanations in certain mines are regarded as the last phases in the activity of the ore-depositing solutions, their composition should also be taken into account. On theoretical grounds the solutions are believed to have been aqueous and heated, their temperature probably not exceeding 350° C.

The following list shows the components present and calls attention to certain substances whose absence is noteworthy.

Alumina (Al_2O_3), not abundant; presence indicated by rare occurrences of feldspar in fissure fillings.

Antimony (Sb), not nearly so abundant as arsenic.

Arsenic (As), moderately abundant.

Barium (Ba), locally fairly abundant, as shown by occurrence of barite in many veins and recent deposition of barite from hot springs at Idaho Springs.

Bicarbonic acid (HCO_3), abundant in thermal waters at Idaho Springs.

Bismuth (Bi), rare.

Boron (B), only in minute amounts in thermal waters at Idaho Springs.

Bromine (Br), not definitely known.

Calcium (Ca), abundant.

Carbon dioxide (CO_2), abundant as shown by carbonates in veins and altered walls and CO_2 emanations in some mines.

Chlorine (Cl), not abundant; small amounts in thermal waters at Idaho Springs.

Copper (Cu), moderately abundant.

Fluorine (F), abundant locally.

Gold (Au), universally present in small amounts.

Iodine (I), not definitely known.

Iron (Fe), abundant.

Lead (Pb), abundant.

Lithium (Li), rare; traces in thermal waters at Idaho Springs.

Magnesium (Mg), not abundant; small amounts in thermal waters at Idaho Springs.

Manganese (Mn), locally abundant (rhodochrosite).
Mercury (Hg), absent.
Molybdenum (Mo), rare.
Nickel (Ni), rare; small amounts in matte from smelters.
Phosphorus (P), not noted.
Potassium (K), abundant.
Radium (Ra), locally present as shown by pitchblende.
Silica (SiO_2), abundant.
Silver (Ag), universally present in small amounts.
Sodium (Na), abundant in thermal waters at Idaho Springs.
Strontium (Sr), traces in thermal waters at Idaho Springs.
Sulphate radicle (SO_4), present in small amounts as shown by local barite.
Sulphur (S), abundant.
Tellurium (Te), present locally in fair abundance.
Tungsten (W), locally abundant.
Uranium (U), locally present in minor amounts.
Vanadium (V), locally present in minute amounts.
Zinc (Zn), abundant.

To summarize, it appears that the solutions which deposited the ores were alkaline or neutral in character and that they were rich in alkalies, silica, carbonic, and bicarbonic acids, iron, lead, zinc, and arsenic and carried lesser amounts of copper, antimony, gold, and silver. Locally they carried manganese, the sulphate radicle, barium, tellurium, fluorine, uranium, and vanadium.

CHAPTER XI.—PROCESSES AFFECTING THE ORES SUBSEQUENT TO PRIMARY MINERALIZATION.

POSTMINERAL FAULTING AND FRACTURING.

Subsequent to the primary mineralization faulting occurred in many parts of the region. Many of the fault fractures followed veins for a part or all of their length and produced local brecciation of the ores. Other faults cut across and displaced mineral veins, but the displacements as a rule do not exceed a few feet or tens of feet. Examples of postmineral brecciation were noted on the western part of the California vein, in the Ivanhoe vein (Pl. XIV, *B*, p. 97), in the Homestake vein of the East Notaway mine, and at many other places. An example of vein displacement by a postmineral fault making a small angle with the vein is the offset of the Frontenac vein by the barren "flat vein"; in this case the continuation of the vein beyond the fault had not at the time of this survey been found. The Chase vein is displaced by a cross fault that is well exposed on the 300-foot level about 520 feet east of the shaft.

By facilitating the descent of meteoric waters along the veins postmineral fracturing has had an important influence on downward enrichment.

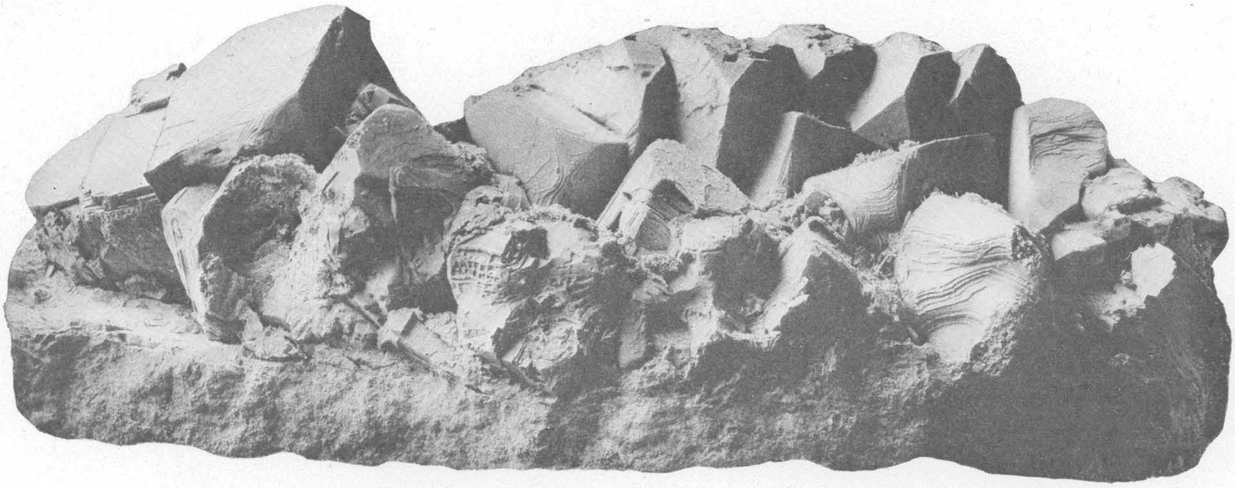
POSTMINERAL DEPOSITION OF QUARTZ AND CARBONATE.

Postmineral fracturing has been followed in certain places by the deposition of white or gray quartz, much of which is very fine grained and of cherty appearance, though microscopic examination shows it to be crystalline. This quartz does not appear to be confined to the portions of the ore deposits near the surface or to be particularly more abundant there than at greater depths. It seems probable, therefore, that the quartz is a deposit from ascending, probably thermal, waters rather than descending waters. So far as known it carries no valuable metals, although it is very similar in appearance to the fine-grained quartz of certain telluride veins such as the Notaway. The postmineral quartz is nowhere abundant; it was noted more frequently in the region just southeast of Central City than elsewhere. In the composite ore of the Specie Payment mine, on Bellevue Mountain, gray quartz is clearly later than both periods of sulphide mineralization.

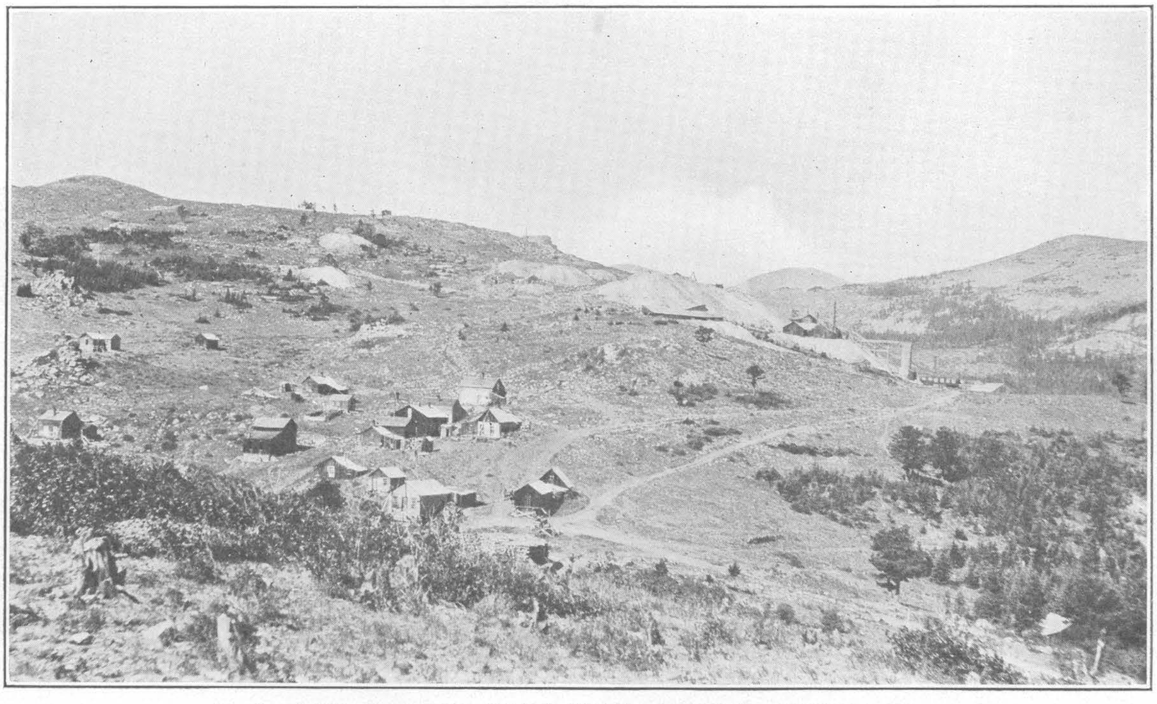
In the Hayseed mine, in Chase Gulch, coatings composed of an association of siderite and small needles of quartz occur on the galena, chalcopyrite, and pyrite of some vugs. Some of the siderite is contemporaneous with and some later than the quartz. These minerals appear to have been deposited at a distinctly later period than the sulphides, for they coat their free crystal faces, and, as explained in the next section, their deposition seems to have been synchronous with etching of the galena. In the Pettibone mine, on Silver Creek, ore of the galena-sphalerite type has been brecciated, and the fractures and vugs have been partly or wholly filled with quartz and some siderite. The central portion of the later veinlets is in general coarsely crystalline quartz, and the one-eighth of an inch or so next to the walls consists of cherty-looking silica or of siderite. Thin layers of white quartz coat the sulphides in vugs.

ETCHING OF PRIMARY MINERALS.

Etching of the primary ore minerals below the ground-water level is nowhere conspicuous. In one mine—the Hayseed, in Chase Gulch—it has locally produced somewhat striking effects, which are shown in Plate XVII, *A*. In the Hayseed vein vugs are of rather common occurrence, and some are several inches long in the plane of the vein and contain very beautiful crystals of sulphides and of quartz. In some of these vugs the solvent action of solutions circulating through the ore is shown by conspicuous etching of the galena, as shown in Plate XVII, *A*. It is significant to note that the pyrite and chalcopyrite associated with the galena have not been etched and that the quartz and siderite referred to in the preceding paragraph as deposited on crystals of galena, pyrite, and chalcopyrite do not occur on the



A. ETCHED CRYSTALS OF GALENA FROM VUG IN HAYSEED VEIN, NEAR CENTRAL CITY.
Crystals were coated with film of ammonium chloride to avoid reflections in photographing.



B. CARIBOU, LOOKING WEST FROM BOULDER COUNTY HILL.

etched surfaces. If the quartz and siderite had once coated all parts of the galena crystals and had been dissolved by the solutions that etched the galena, it is difficult to see why the quartz and siderite should have remained on other parts of the galena crystals in so great abundance and in perfect crystals that show no signs of solvent action. It must be concluded, therefore, that the same solution that deposited the quartz and siderite was instrumental in etching the galena, the two processes being synchronous. Waters depositing quartz and siderite must have been alkaline or at least neutral. It is interesting to note that C. E. Siebenthal,[1] from his study of the lead and zinc ores of the Joplin district, in Missouri, concludes that slightly alkaline or neutral solutions have been active solvents of galena. The writer believes that the active solutions which produced these effects were ascending, probably thermal, and came from the same general source as the solutions which deposited the ore, though they were given off later and had a different composition.

DOWNWARD ENRICHMENT.

GENERAL FEATURES.

It is well known that when the superficial parts of ore deposits are attacked by the gases of the atmosphere and by water of surface origin and the dissolved substances it contains, some of the ore is carried away either mechanically or in solution and some remains behind. The metals carried away may become widely scattered and lost, so far as concerns the miner of to-day, or they may be concentrated elsewhere in ore deposits of different types, such as the gold-bearing gravels of the district here described or the copper ores found in surface sandstones in other districts. The metals that remain behind work their way downward into the ore body either mechanically or in solution; those carried mechanically do not penetrate far and those descending in solution are subject to reprecipitation through agencies that will be noted later.

Such processes as those outlined above must at their inception, as when erosion first exposes an ore body, result in a depletion in the value of the surficial ore, but as erosion progresses the metals left behind come in time to represent a residuum from tens, then hundreds, and perhaps thousands of feet of ore that has been eroded away. To use a commercial simile, the value of the ore in the upper part of a deposit may thus increase "at compound interest." Such a process is termed downward enrichment, the adjective being used to distinguish it from enrichment caused by ascending thermal solutions.

RELATION TO GROUND-WATER LEVEL.

In general the openings in rocks reach a maximum at the surface and gradually decrease downward, and the water-holding capacity of rocks, being dependent on the space available in openings, exhibits a corresponding decrease with increasing depth. There is reason to believe that at depths of a few thousand feet the openings in most rocks are so small and discontinuous that the rocks are essentially dry.[2] Between the dry rocks and the surface the rock openings are in some places entirely filled with water, but in most places the water filling extends only within a few tens or hundreds of feet of the surface. The upper limit of saturation is termed the ground-water level or the water table. Its depth below the surface is most variable in regions of high relief, like that under discussion. It is not absolutely fixed but rises and falls with climatic variations; it may also be lowered artificially by mine workings that afford deep drainage, as in parts of the region under discussion, and in such places its natural position must be inferred from the depth to which alterations attributable, in part at least, to the atmosphere (oxidation) extend, or from early records of the depth at which standing water was found in the first shafts sunk. In most parts of the Central City quadrangle its natural position appears to have been from 50 to 150 feet below the surface. Raymond, in an early report on the Gilpin County mines, states that oxidized ore in the California-Gardner vein extended 85 to 95 feet below the surface and that in a number of other veins oxidation extended to depths of 70 to 80 feet. In the Aurora vein oxidation extended to depths of about 150 feet. In the Little Giant mine, near Lawson, the original

[1] Oral communication.

[2] Evidence summarized by J. F. Kemp (The ground-waters: Am. Inst. Min. Eng. Trans., vol. 45, pp. 3-24, 1914).

ground-water level was within 60 feet of the surface.

In some of the ore deposits of the Central City quadrangle enrichment is practically confined to the zone between the surface and the ground-water level, which is subject to alternate wetting and drying and to the direct influence of oxygen and other atmospheric gases and which is known as the oxidized zone. In other ore deposits enrichment extends downward for over 600 feet into the zone below the ground-water level. Because the enriching minerals below the ground-water level are mainly sulphides, this lower zone has been called the zone of downward sulphide enrichment. For brevity it will be referred to in this discussion as the secondary sulphide zone, with the understanding that the secondary sulphides were deposited by downward-moving solutions.

CLASSES OF ORES AFFECTED.

Of the classes of ores represented in this region the tungsten ores of Boulder County have been somewhat enriched in the oxidized zone, owing to the fact that the tungsten minerals are heavy and are less readily decomposed than most of the associated ore minerals. These ores were not studied in detail by the writer. Oxidized ores of uranium were not exposed at any of the mines on Quartz Hill, but so far as could be learned there has been little, if any, enrichment of these ores in uranium either above or below the ground-water level. The copper ores of the Evergreen mine, near Apex, have been enriched in the manner usual in copper deposits, but on so small a scale that the value of the ore has not been greatly augmented. The iron ores of Caribou have not been enriched. It is in the predominant ores of the region, the gold-silver ores, that enrichment has been most effective. Enrichment in gold in the oxidized zone has occurred in all types of the gold-silver ores; enrichment in silver is largely confined to the secondary sulphide zone of the ores of the galena-sphalerite type; enrichment in copper, always on a small scale, has affected mainly the pyritic type of gold-silver ores. Enrichment in lead is insignificant, and enrichment in zinc was nowhere observed. The phenomena of enrichment will be further discussed with individual reference to gold, silver, copper, and other metals.

GOLD ENRICHMENT.

GENERAL CONDITIONS.

Gold-silver ores of all the types—the pyritic type, the galena-sphalerite type, the composite type, and the telluride type—have been notably enriched in gold in the oxidized zone. The effects of enrichment are most striking, however, in certain ores of the galena-sphalerite type which, where not oxidized, carry negligible amounts of gold, usually less than 0.1 ounce to the ton, and where oxidized may carry 1.5 to 3 ounces of gold to the ton. These are the so-called "silver veins," whose surface portions were worked by the pioneers for gold alone.

Although data showing in a systematic way the distribution of gold below the ground-water level are rather meager, such information as is available fails to indicate any considerable enrichment in gold below that level.

In the unaltered gold-silver ores the gold may occur (1) in particles of microscopic or submicroscopic size in the sulphides or gangue minerals; (2) in masses large enough to be seen with the unaided eye, embedded in quartz or more rarely in calcite or sulphides; or (3) as a gold-silver telluride. The first-named mode of occurrence is by far the most common, and in most of the gold ores of the region visible gold is a rarity. In the oxidized zone such ores suffered partial disintegration, which was accompanied by the conspicuous development of brown hydrous oxides of iron, an increase in porosity, and many other less conspicuous but very important changes. Among these changes was the partial freeing of the gold through the oxidation of its sulphide matrix, thus exposing it to the action of the solutions that entered the upper part of the lode.

SOLUTION AND REDEPOSITION OF GOLD.

Much of the gold that was partly or wholly freed from its matrix during the processes of oxidation probably remained unattacked by the solutions descending from the surface through the ore, and a large part of the enrichment in gold in the oxidized zone is doubtless due to the residual concentration of such gold during long-continued weathering. A part of the gold freed by oxidation, however, was unquestionably taken into solution. It has been generally assumed that chlorine was the agent which effected the solution of gold, but the paucity of chlorine in the surface waters of regions of crystalline rocks like that here under consideration suggests that if gold was dissolved at all some other solvent was the active agent. However this may be, it seems probable that if gold was taken into solution most of it was promptly reprecipitated within the oxidized zone itself or immediately below it. Palmer and Bastin [1] have shown that most of the metallic minerals common in ore deposits, including pyrite, chalcopyrite, and galena, are also effective precipitants of gold from chloride solutions. It is well known that ferrous sulphate is also an effective precipitant of gold from chloride solutions. Consequently, wherever ferrous sulphate is abundant gold is likely to be precipitated. It is doubtful, therefore, whether much gold in solution could travel far below the ground-water level without being precipitated. The available records of the early mining of oxidized gold ores show not only that the oxidized portions of the gold-silver veins were richer in gold than the unaltered ores below but appear to show also that the gold was on the average coarser, a fact explainable only upon the assumption that some of it was dissolved and redeposited. The oxidized gold ores were "free milling"—that is, most of the gold was recoverable by amalgamation, whereas the gold of the unaltered ores is only in small part recoverable by this process. It was indeed fortunate that the ore found at first, when elaborate mills and smelters were not available, was of a sort amenable to simple and inexpensive treatment.

EVIDENCE OF GOLD ENRICHMENT IN OXIDIZED ZONE.

Although enrichment in gold in the oxidized zone of the ores of this region is generally recognized to have been an important process, specific data exemplifying it are difficult to procure now that the oxidized ores have for many years been entirely worked out. The most striking examples are afforded by certain veins which, just below the oxidized zone, were valuable mainly for silver. In speaking of the condition in 1872 of certain mines on or near Seaton Mountain, Raymond [2] says:

> The mines in the eastern end of Clear Creek County have been worked to a greater extent than in any year since their surface ores were treated for the gold they contained. The ores still contain more or less gold, but notwithstanding this fact the lodes now carry mainly silver ores. * * * The principal mines are the Seaton, Crystal, Edgar, Whale, Hukill, Veto, Queen, and Franklin.

The Blue Ridge vein, near Dumont, is characteristically a silver vein, the primary ore in general carrying less than 0.1 ounce of gold to the ton. Oxidized ore from the surface, however, in places carried several ounces of gold and was characteristically poor in silver. Two shipments of such ore assayed respectively 1.60 and 2.55 ounces of gold and 3 and 6 ounces of silver to the ton.

In the gold-silver ores of the telluride type some primary gold is associated with the tellurides, but it is believed that much of the gold of the oxidized ore has been freed by oxidation from combination with tellurium.

PROBABLE UNIMPORTANCE OF GOLD ENRICHMENT BELOW GROUND-WATER LEVEL.

There were few opportunities for the study of gold-silver ores occurring not far below the oxidized zone, but such data as are available afford no certain evidence of notable enrichment in gold below the ground-water level. The records of careful sampling of all parts of a typical pyritic vein in the Iron mine, in Russell Gulch, for example, failed to show any systematic change in the gold content below the oxidized zone.

A specimen in the collections of the Colorado Bureau of Mines in the State House at Denver showed wires of gold on well-formed crystals of galena from the Prize vein, near Central City, but the depth from which the specimens came is not known. Another specimen in the same collection, from the Cook mine, showed wires of gold on crystals of chalcopyrite in a vug; the location in the mine was not given. At one point on the 392-foot level of the Aurora mine free gold occurred as small wires and grains on quartz crystals in a small watercourse entering the vein from its north wall, but undoubted primary gold intergrown with pyrite and chalcopyrite occurs near by in the same level. In all these cases, therefore, it is uncertain whether the gold was deposited by descending solutions or by ascending solutions belonging to the late stages of primary mineralization. Other relations noted in the Aurora vein are unfavorable to the idea of much enrichment in gold below the ground-water

[1] Palmer, Chase, and Bastin, E. S., Metallic minerals as precipitants of silver and gold: Econ. Geology, vol. 8, pp. 156-160, 1913.

[2] Raymond, R. W., Statistics of mines and mining in the States and Territories west of the Rocky Mountains for 1872, p. 276, 1873.

level. This vein was rich in its oxidized portion, between the surface and a depth of about 150 feet, assaying as much as $300 a ton; between 150 and 325 feet, however, the ore was of comparatively low grade; at still greater depth its value was locally increased by certain stringers that joined it from the hanging wall.

SILVER ENRICHMENT.

Silver enrichment contrasts strongly with gold enrichment in this district in that there is commonly impoverishment rather than enrichment of silver in the oxidized zone and notable enrichment below the oxidized zone. Furthermore, silver enrichment is practically confined to the ores of the galena-sphalerite type.

SOLUTION OF SILVER IN OXIDIZED ZONE.

THE SILVER MINERALS AND THE ACTIVE SOLUTIONS.

The silver minerals of the oxidized ores may be either primary or secondary. The primary minerals of this region are (1) silver alloyed with gold, which though locally visible is usually in particles of microscopic or submicroscopic size, and (2) silver-gold tellurides. Argentite has not been authoritatively reported, either as a primary or as a secondary mineral. Among the secondary silver minerals are native silver, cerargyrite, pearceite, polybasite, and proustite.

In the weathering of the ore in the zone of oxidation the silver finely disseminated through sulphides and gangue minerals is in part freed from its matrix and, with other silver minerals present, becomes exposed to the action of meteoric water and its dissolved substances. In most mine waters of surface origin the principal negative radicles present are chlorine (sometimes with bromine and iodine), carbonate, bicarbonate, and sulphate, the sulphate as a rule greatly predominating. As compounds of silver with all these radicles are known, it is customary to consider the dissolved silver as existing in distributed balance with as many of these radicles as may be present.

SILVER BALANCED BY THE SULPHATE RADICLE.

Silver sulphate is, as shown by the following table, by far the most soluble of all the silver salts of probable economic importance in nature, unless it is exceeded by the thiosulphate, whose possible presence in mine waters has not yet been investigated.

Solubilities of silver salts.[a]

Salt.	Solvent.	Temperature (°C.).	Solubility (grams per liter).
Silver bromide	Pure water	25	0.000137
Silver chloride	do	25	.002
Silver carbonate	do	25	.033
Do	do	15	.031
Do	Water saturated with CO_2.	15	.846
Silver sulphate	Pure water	25	8.01

[a] Cox, A. J., and Abegg, R., Zeitschr. physikal. Chemie, vol. 46, p. 11, 1903. Johnson, G. S., Chem. News, vol. 54, p. 75, 1886.

The solubility of the sulphate is slightly increased by the presence of free sulphuric acid. It is well known that the sulphate radicle is formed abundantly through the oxidation of sulphides and that the mine waters of the upper parts of sulphide ore bodies are characteristically "sulphate" waters; furthermore, H. C. Cooke [1] has shown that native silver and all the commoner silver compounds, except the chloride, are soluble in dilute sulphuric acid, especially in the presence of ferric sulphate. It is believed, therefore, that most of the silver in solution in such waters is in balance with the sulphate radicle.

SILVER BALANCED BY THE CARBONATE OR THE BICARBONATE RADICLE.

Silver carbonate, being a somewhat unstable compound, has never been certainly recognized in nature. It may, however, be readily prepared in the laboratory by the interaction at ordinary temperatures of solutions of silver nitrate and of an alkali carbonate, as shown by G. S. Johnson.[2] The writer has also obtained it at ordinary temperatures by precipitation from silver sulphate solution with either sodium carbonate or magnesium bicarbonate. The carbonate thus obtained is only slightly soluble in pure water, although more soluble than the chloride, but it is readily dissolved by water saturated with carbon dioxide, its solubility under these conditions being almost exactly that of calcium carbonate.[2] Carbonates are

[1] Cooke, H. C., The secondary enrichment of silver ores: Jour. Geology, vol. 21, pp. 10–15, 1913.
[2] Johnson, G. S., On silver carbonate: Chem. News, vol. 54, p. 75, 1886.

abundant as gangue minerals in certain of the gold-silver deposits of this region and are taken into solution mainly as bicarbonates. It is therefore probable that a portion of the silver dissolved in the oxidized zone of certain deposits was balanced by the bicarbonate radicle (HCO_3).

SILVER BALANCED BY CHLORINE.

The chlorine content of most surface waters, especially those in areas of crystalline rocks, is extremely small. In the river waters of the Piedmont Plateau region of Virginia, the Carolinas, and Georgia it ranges from 0.048 to 0.128 milligram to the liter; the average of three analyses of the waters of Lake Champlain, whose drainage basin is composed almost exclusively of crystalline rocks, shows only 0.034 milligram to the liter. These waters may be contrasted with normal sea water, which contains 19,350 milligrams to the liter. No similar determinations are available for the area under discussion, but it is almost certain that the chlorine content of the surface waters is of a correspondingly small magnitude. As the ores of this region carry no chlorine minerals, there is no reason why the waters of the upper parts of the ore bodies should be appreciably richer in chlorine than the surface waters. The few available analyses of waters of surface origin in the upper levels of mines in regions of crystalline rocks also show a low content of chlorine.[1] That some chlorine was present and entered into combination with silver is indicated, however, by the reported presence of cerargyrite (horn silver) in the oxidized zone of a few deposits. Compounds of silver with bromine and iodine have not been noted.

REPRECIPITATION OF SILVER IN OXIDIZED ZONE.

From the foregoing considerations it is evident that silver is readily taken into solution in the oxidized zone of sulphide ore bodies and that in the mine waters it is mainly in balance with the sulphate radicle but to some extent in balance with the carbonate, bicarbonate, and chlorine radicles. Cerargyrite is an extremely stable mineral under the conditions that prevail in the oxidized zone[2] and is very much less soluble than either the bicarbonate or the sulphate of silver. It may be readily precipitated in the laboratory by sodium chloride from solutions of either silver bicarbonate or silver sulphate. It is probable, therefore, that most of the silver balanced by chlorine is promptly precipitated within the oxidized zone as cerargyrite (horn silver). The rarity of this mineral in the region under discussion is attributable to the paucity of chlorine in its surface waters. It may be that a small amount of silver balanced by chlorine escaped precipitation in the oxidized zone and, descending below the water level, contributed to the formation of secondary silver sulphides.

Native silver as wires or small plates is occasionally found in the oxidized ores of this region. Some of it may have been deposited below the oxidized zone and merely have resisted complete oxidation, but some was probably deposited within the oxidized zone, either through the agency of ferrous sulphate[3] or of metallic sulphides. Unaltered residual chalcocite, enargite, and tennantite remaining in the lower part of the oxidized zone may also reprecipitate silver in part as native silver and in part as its compounds. Chalcopyrite may also reprecipitate silver from sulphate solution, not as the native metal, but as a compound whose exact nature has not been determined.

The preliminary experiments of Palmer and Bastin,[4] in which the formation of small amounts of silver on chalcopyrite immersed in silver sulphate solution was reported, must be corrected by later observations which show that perfectly clean surfaces of chalcopyrite do not precipitate metallic silver. The precipitations previously obtained were due to inconspicuous films of secondary copper minerals on parts of the chalcopyrite surface.

DEPOSITION OF SECONDARY SILVER MINERALS BELOW THE GROUND-WATER LEVEL.

GENERAL CONDITIONS.

Silver taken into solution in the zone of oxidation, if it escapes reprecipitation within that zone, descends into the ground-water zone, where in the presence of certain precipitating agents it is deposited either as the native

[1] See Emmons, W. H., The enrichment of sulphide ores: U. S. Geol. Survey Bull. 529, pp. 60-61, 1913.

[2] According to Cooke (op. cit.) silver chloride is the only one of the common silver minerals that is not appreciably attacked by sulphuric acid.

[3] H. N. Stokes (Econ. Geology, vol. 1, p. 649, 1906) showed that the reaction $Fe_2(SO_4)_3+2Ag=Ag_2SO_4+2FeSO_4$ was reversible, silver being dissolved on heating and reprecipitated on cooling.

[4] Econ. Geology, vol. 8, pp. 146-147, 1913.

metal or in compounds. In the absence of these agents it enters the general ground-water circulation and is lost so far as these ore deposits are concerned. In the ores of this region silver enrichment below the ground-water level exhibits an interesting dependence on the primary mineral composition of the ores. Furthermore, two contrasted types of silver enrichment were noted; in one the silver was redeposited as sulpho-compounds (proustite or ruby silver, pearceite, and polybasite) in association with secondary chalcopyrite; in the other it was redeposited as native silver in association with chalcocite, bornite, and covellite. In deposits of both types the secondary silver minerals are associated with carbonates and were not therefore deposited by strongly acid solutions.

DEPENDENCE ON PRIMARY MINERAL COMPOSITION.

A significant feature of silver enrichment as displayed in the Central City quadrangle is the fact that secondary silver minerals, with the exception of native silver, have never been recognized, so far as known, in the ores of the pyritic type, in spite of the fact that silver is fairly abundant as a primary constituent of these ores.

Native silver has been noted only in the oxidized upper portions of the ore deposits; its occurrence below the ground-water level in a finely divided form, expecially in association with rich copper minerals, must be recognized as possible and perhaps probable, but if present it is so inconspicuous as to have escaped recognition. Although silver is less abundant as a primary constituent in the ores of the pyritic type, in which it rarely exceeds 10 ounces to the ton, than in those of the galena-sphalerite type, in which a content of 20 to 30 ounces to the ton is common, the complete absence of secondary silver compounds is a fact demanding explanation.

The pyritic ores consist predominantly of pyrite in a gangue of quartz, sericite, or both, with subordinate amounts of chalcopyrite and tennantite (in part antimoniacal); enargite is abundant in some veins, and secondary chalcocite and bornite are present in certain deposits. (See p. 151.) Carbonates are commonly absent or if present are very minor constituents. In the galena-sphalerite ores galena and sphalerite are the predominant minerals, with subordinate amounts of pyrite, chalcopyrite, tennantite (in part antimoniacal), bornite, quartz, and calcite or siderite. Secondary chalcocite is generally not present. The ores of both types contain in their primary minerals all the elements necessary to the formation of compounds of silver with sulphur and arsenic or antimony, and in deposits of both types silver is undoubtedly taken into solution in the oxidized zone, probably through the agency of sulphuric acid and ferric sulphate.

The causes for this restriction of silver enrichment to veins of a certain mineral composition are undoubtedly complex, but the presence of carbonate gangue minerals in the ores that carry secondary silver sulphides is believed to be a most important factor.[1] Their presence has led to an early neutralization of the free sulphuric acid in the descending silver-bearing solutions.

Much of the carbonate in these veins is ferruginous (siderite and ferruginous calcite), and this by reaction with sulphuric acid yields ferrous sulphate, an effective silver precipitant. In a timely and suggestive paper Nishihara[2] has compared the neutralizing effect of various carbonates, silicates, and sulphides on sulphuric acid and their activity in reducing ferric sulphate to ferrous sulphate. It is very significant that pyrite, quartz, and chalcopyrite, the principal minerals of the ores of the pyritic type, were in Nishihara's experiments comparatively ineffective in neutralizing sulphuric acid and in reducing ferric to ferrous sulphate. Galena and sphalerite and, of course, the carbonates, are comparatively efficient in neutralizing sulphuric acid, and galena is fairly active in reducing ferric sulphate. Furthermore, galena and sphalerite in solutions of sulphuric acid or of ferric sulphate generate hydrogen sulphide, which may precipitate secondary sulphides. Nishihara has also shown that apparently pure galena from several localities, among them Idaho Springs, carries small percentages of manganese, which presumably occurs as the manganese sulphide alabandite in isomorphous mixture with the galena. Alabandite evolves hydrogen sulphide very actively when in contact with acid sulphate solutions and if present

[1] A large number of field tests of mine waters made by the writer in the San Juan Mountains of Colorado during the summer of 1913 showed that in many silver veins secondary sulpho-compounds of silver were present far below a level where all free acid in the descending mine waters had been neutralized.

[2] Nishihara, G. S., The rate of reduction of acidity of descending waters by certain ore and gangue minerals and its bearing on secondary sulphide enrichment: Econ. Geology, vol. 9, pp. 743-757, 1914.

in the enriched veins of this region may have exerted a considerable precipitative influence.

It appears, therefore, that the mineral composition of the galena-sphalerite veins that show enrichment is such as to favor ready neutralization of sulphuric acid of the silver-bearing sulphate solutions descending from the oxidized zone, the formation of ferrous sulphate at the expense of ferric sulphate and sulphuric acid, and the development of hydrogen sulphide. All these features favor silver precipitation. In the ores of the pyritic type, on the other hand, conditions favor the persistence of acidity and the retention of the iron in the ferric state; silver taken into solution in the oxidized zone is therefore likely to remain in solution and eventually to enter the general ground-water circulation and be lost so far as the local ore deposit is concerned.

Secondary silver minerals are not, however, equally abundant in all veins of the galena-sphalerite type. The variations in abundance are not due entirely to physical causes, such as the degree of fracturing of the ore, but appear to be dependent on differences in mineral composition. In certain of the veins near Cardinal, such as the Boulder County, Jack Pot, Pine Grove, and Gold King, silver enrichment appears to have been lacking or to have occurred only near the surface. Ore from a depth of 120 feet or less in the Gold King vein showed no silver minerals. None were found in ore from moderate depths on the Pine Grove and Jack Pot veins, and in the Boulder County mine they appear to have extended only to slight depths. Raymond,[1] writing in 1870, when development could hardly have extended to depths of more than 100 feet, says:

> As a greater depth was reached on this lode, the gold seemed gradually to be running out and the silver increasing in quantity. In much of the ore gold was found associated with large flakes of silver. Specimens had frequently been taken from the mine in which brittle silver and wire silver were visible in large quantities, with a smaller sprinkling of gold.

No silver minerals were noted by the writer in this vein as exposed in the Boulder County tunnel. The absence of carbonates seems to be the only important mineralogic difference between these veins and those in which silver enrichment is very prominent.

Silver enrichment seems to have been of slight value or at least to have extended to only slight depths in certain other veins of the galena-sphalerite type, such as the Albro, near Dumont; the Gladstone, near Idaho Springs; and the Topeka, near Russell Gulch. In these veins also carbonates are rare and chalcopyrite and in places pyrite are unusually abundant. It is likewise noteworthy that few ores of the composite type show much sulphide enrichment in silver. The scarcity of carbonates and the abundance of pyrite and chalcopyrite in the composite veins and those veins of the galena-sphalerite type in which there is little enrichment cause these veins to approach the pyritic ore type as regards susceptibility to downward sulphide enrichment.

RUBY SILVER AND CHALCOPYRITE TYPE OF ENRICHMENT.

Minerals.—The minerals recognized as formed secondarily in the more common type of silver enrichment are pearceite (in part antimoniacal), proustite (ruby silver), polybasite, native silver, chalcopyrite, and rarely galena. The primary sulphides are galena and sphalerite, with subordinate pyrite and chalcopyrite and rare tennantite (in part antimoniacal). The gangue minerals in fissure fillings are quartz, carbonates (usually siderite or calcite but in places rhodochrosite), and some barite. In ores formed by replacement the gangue minerals are quartz, sericite, and calcite or siderite, with remnants of unaltered wall-rock minerals.

Secondary minerals in fractures and vugs in primary ore.—Naturally the secondary galena and chalcopyrite can not always be differentiated from the primary, but where these minerals incrust primary minerals in vugs or open fractures or completely fill cracks traversing the primary ore their secondary origin is clear. The study of polished specimens of ore under the reflecting microscope shows that the secondary sulphides occur in two ways—as fillings or lining of fractures or vugs in the primary ore and as metasomatic replacements of primary sulphides and quartz. The second mode of occurrence, though familiar enough in copper enrichment, has seldom been noted in silver enrichment, not because it is a rare phenomenon, but because few secondary silver ores have been studied by the microscopic methods necessary to reveal it.

The deposition of secondary silver minerals along fractures was well shown in specimens from the Almaden mine, on Fall River, where

[1] Raymond, R. W., Statistics of mines and mining in the States and Territories west of the Rocky Mountains, 1870, pp. 327-328, 1872.

narrow fractures traversing the primary ore were coated with a mammillary deposit of pearceite and chalcopyrite, the latter in part intercrystallized with the pearceite and in part coating it as small crystals. Other fractures are coated with good-sized crystals of proustite associated with finely crystalline secondary chalcopyrite. One specimen from a depth of 200 feet showed a fracture one-quarter of an inch wide in galena entirely filled with pearceite. A few specimens from this mine are among the finest examples of rich silver ore that the district has produced. One in a mineral collection in the public library at Idaho Springs was a mass of pure ruby silver several inches across; another showed a width of 1 inch of ruby silver associated with a $\frac{1}{4}$-inch to $\frac{1}{2}$-inch band of

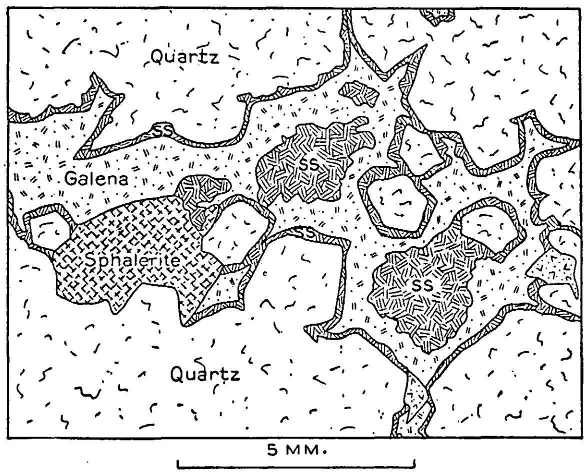


FIGURE 14.—Camera lucida drawing of polished surface of ore from the Princess of India tunnel, Lawson. The areas marked SS show a silver sulphide, probably pearceite developed by metasomatic replacement of quartz and of galena.

pearceite. Wires of native silver were common in vugs in the upper parts of the Almaden vein.

Pearceite and secondary chalcopyrite were noted in vugs in ore from the dump of the American Sisters mine, south of Lawson, and pearceite in vugs in the White vein, on Red Elephant Hill.

Secondary minerals as replacements of primary ore.—One of the best examples of enrichment by metasomatic replacement is furnished by ore from the Princess of India tunnel, near Lawson. Under the reflecting microscope with relatively low magnification portions of this ore present the appearance shown in figure 14. Between original quartz and galena there has developed a narrow band of a metallic mineral which is somewhat darker gray than galena. Larger irregular areas of the same mineral occur within the galena. The mineral upon testing proved to be a sulpharsenide of silver, proba-

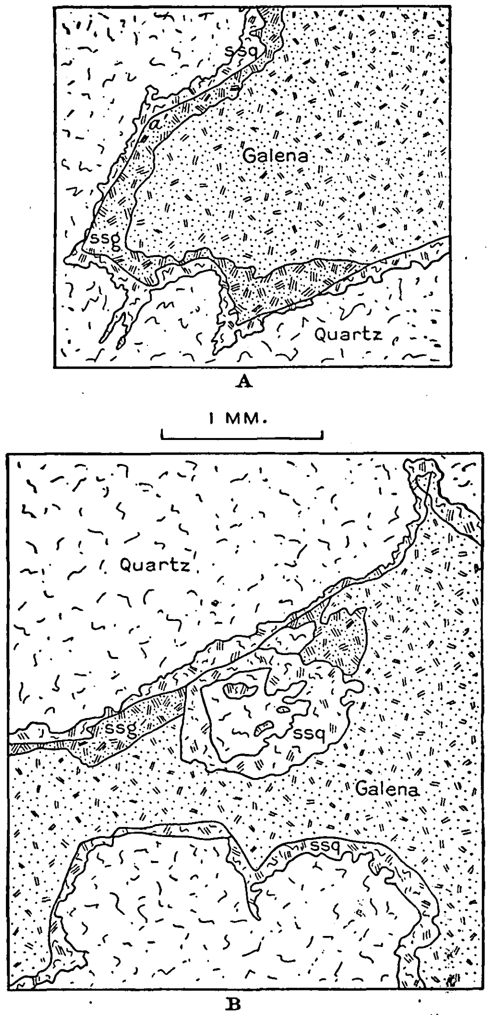


FIGURE 15.—Portions of specimen shown in figure 14, more highly magnified. Portions marked ssg and ssq are a silver sulphide, probably pearceite. Note the double character of the bands of silver sulphide locally, as at *a'* in A. The portions marked ssg have been formed by replacement of galena; those marked ssq by replacement of quartz.

bly pearceite,[1] carrying some antimony and copper.

[1] Fragments of the mineral were isolated from certain specimens. They were dark gray and somewhat sectile and reacted in the closed tube for arsenic, antimony, and sulphur. When dissolved in nitric acid, they reacted with hydrochloric acid for silver and with ammonia for copper. The freshly polished surface has much the appearance of chalcocite under the metallographic microscope, but, unlike chalcocite, it does not tarnish or etch readily when treated with nitric acid. When treated with concentrated nitric acid this mineral begins to show a tarnish at about the same time it appears on the chalcopyrite of the ore. When the chalcopyrite shows a faint peacock tarnish, the pearceite exhibits a yellowish-brown color, in places showing slight iridescence. In specimens where the pearceite is present in too small amounts to be isolated it may be identified with a considerable degree of probability in the polished section by its behavior with nitric acid.

The absence of any bands of pearceite between the sphalerite and any of the other minerals is noteworthy. Under higher magnification these borders present the appearance shown in figure 15, from which it may be seen that the bands of pearceite are in places single and in places double. Where the bands are single the pearceite has locally replaced quartz, as in the lower part of the specimen shown in figure 15, B, where the contact between quartz and pearceite is exceedingly ragged; elsewhere it has replaced galena, as in the lower part of the specimen shown in figure 14, where the original crystal faces of the quartz are still intact. Here also the pearceite has replaced larger areas in the interior of the galena mass. When the bands are double, as shown in figure 15, A, the two portions of the bands are separable because of a very slight difference in shade. The fairly regular boundary between the two parts of the bands is believed to represent the original boundary between the quartz and galena. One part of the double band appears to have been developed by the replacement of galena and the other by the replacement of quartz. Both are believed to be pearceite, but a slight difference in mineral structure or composition has resulted in a recognizable difference in shade. Probably some constituent of the original galena entered into the composition of pearceite during the replacement of that mineral.

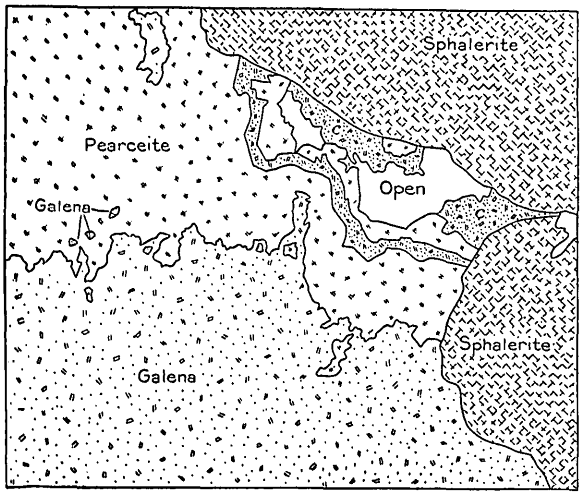


FIGURE 16.—Camera lucida drawing of polished surface of ore from Senator vein, near Lawson, showing metasomatic replacement of galena by pearceite and some chalcopyrite. c=chalcopyrite. Note the very irregular borders which characterize such replacement in some places.

The sulphides shown in figures 14 and 15 appear fresh, and there is no evidence that any of them represent fillings of fractures or cavities. There seems to be no way of accounting for the occurrence of the pearceite in this manner except by metasomatic replacement of the primary quartz and galena. The extremely irregular borders which it exhibits bear out this conclusion.

In a specimen of ore from the Senator mine, near Lawson, shown in figure 16, replacement of galena by pearceite is again illustrated. It is believed that the whole space represented in this figure was originally occupied by galena and sphalerite. The sphalerite, as in the specimen already described, has remained unaltered, while the galena has been extensively replaced by pearceite and a very ragged boundary has been developed between the two minerals. A little secondary chalcopyrite is associated with the pearceite. Unreplaced particles of galena occur within the pearceite.

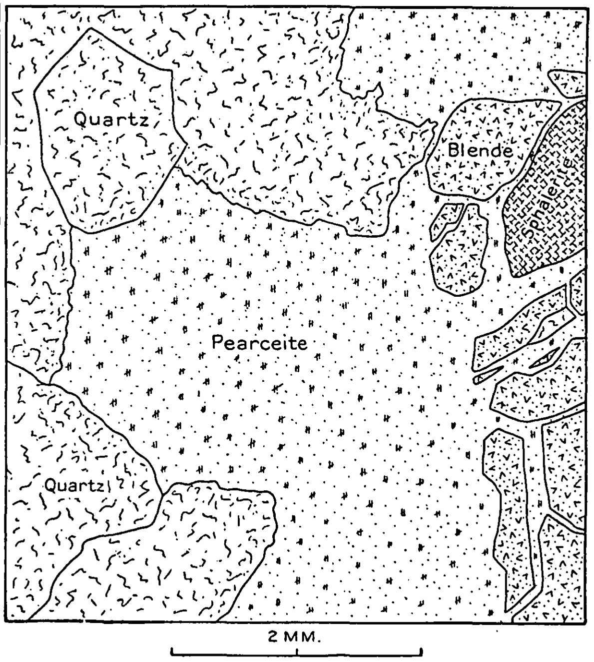


FIGURE 17.—Camera lucida drawing of polished section of ore from Maud S. mine, near Empire station. Shows pearceite filling fractures in brecciated sphalerite and metasomatically replacing quartz.

Figure 17 shows ore from the Maud S. mine, near Empire station. The silver mineral, apparently pearceite, is in part a replacement of quartz, as indicated by the ragged outline of some of the quartz, but is also in part a filling in a brecciated portion of the primary ore. The specimen illustrates particularly well the total absence of replacement of the sphalerite.

A small specimen of ore from the American Sisters mine, obtained through the courtesy of Mr. Philip R. Stanhope, proved of especial interest when polished and examined under the reflecting microscope. One face of this specimen is incrusted with a layer of secondary chalcopyrite showing a more or less mammillary surface. Intermixed irregularly with the chalcopyrite and plainly contemporaneous are minor amounts of pearceite, reacting strongly for silver, sulphur, and arsenic. The minerals of the primary ore are galena, sphalerite, siderite, gray quartz, pyrite, and chalcopyrite, the last two as a rule closely associated. All these appear to be essentially contemporaneous. Subsequent to the primary mineralization the ore has been fractured, and along the fractures secondary galena chalcopyrite and pearceite have been deposited. In the adjacent less-fractured portions secondary chalcopyrite and pearceite have metasomatically replaced primary galena. In the unfractured ore pearceite if present usually occupies a position similar to that shown in figure 14, being definitely related to the contact between galena and other minerals and representing a metasomatic replacement of the galena, similar to that observed in the Princess of India and Senator ores. The presence of very fine intergrowths of pearceite and galena that resemble eutectic intergrowths but can be conclusively shown to mark a stage in the gradual replacement of the galena by the pearceite is of much significance in the interpretation of ore textures. A true appreciation of their significance was not arrived at until this report was in proof, so that their detailed description can not be presented here. The writer hopes to describe and illustrate them later in a short paper.

Although some of the chalcopyrite in these specimens is contemporaneous with secondary galena and pearceite, some is distinctly later, occurring in cracks in them or replacing them metasomatically along their contacts with quartz or sphalerite.

Depth of silver enrichment.—General experience in the operation of the silver mines of this region has shown that the rich silver ores were reached at or near the ground-water level, attained their richest development in the first 100 or 200 feet below this level, and thence downward gradually decreased in abundance until at vertical depths of 500 to 600 feet evidences of enrichment were rare or absent and the metal values were essentially those of the primary ore. In the Seaton mine secondary silver minerals were noted to depths of 450 feet, and in the Senator vein locally to depths of 600 feet. In the Joe Reynolds vein the richest silver was found above the third level, although ore high in silver was obtained at intervals as far down as the eighth level, and some flakes of native silver in talclike material have been reported from the ninth level. The greatest vertical depth at which secondary silver minerals were observed by the writer was 700 feet, in the White vein, near Lawson. At that depth a few small crystals of pearceite were noted on the quartz of a small vug. The gradual disappearance in depth of the rich silver minerals, such as native silver, proustite, and pearceite, taken in connection with the occurrence of these minerals in fractures in the primary ore and as replacements of the primary ore minerals, forms conclusive evidence of their origin by downward enrichment.

Geographic distribution.—It has already been noted that enrichment in silver below the ground-water level has been recognized only in ores belonging to the galena-sphalerite type. In some of these—for example, the ores of the Topeka and Seaton veins—the primary ores are of workable grade, but in many others—for example, those near Lawson and on Silver Hill north of Blackhawk—only the ores that have been enriched in silver can be profitably mined. The latter form the typical silver ores of the miners of this region, their gold content being characteristically small. The primary ores that are workable usually have the primary gold content, rather than the primary silver content, above the average.

Veins in which silver enrichment of the type here discussed has taken place to a considerable extent occur principally in four localities—(1) near Lawson and Empire station, (2) on or near Seaton Mountain, north of Idaho Springs, (3) on Silver Hill, near Blackhawk, and (4) near Caribou, with scattered occurrences elsewhere. The characteristics of most of these veins are described in detail in Part III of this report. As most of the rich silver ores were worked out many years ago, the information concerning their occurrence has been gained mainly from specimens in collections, from old dumps, or from the records of early mining.

Silver content of enriched ores.—The silver content of the enriched ores shows much more variability than that of the primary ores. This is obviously due to the occurrence of the secondary silver minerals in fractures and as localized replacements rather than in even distribution through the ore. The silver content of ores of smelting grade varied from a few tens of ounces up to a thousand ounces to the ton, or even more in picked lots; 6½ tons shipped in 1870 from the Idaho mine, near Caribou, averaged 977.5 ounces of silver to the ton, and two lots of ore from the Almaden mine, on Fall River, gave on assay, according to the manager of the property, the following extraordinary results, in ounces to the ton:

	Gold.	Silver.
149 pounds	0.38	5,810.30
510 pounds	.487	4,084.92

In ore shipments aggregating 1 ton or more, the silver seldom exceeds 200 ounces to the ton. About 108 tons of enriched ore from the Murray vein near Lawson averaged 0.35 ounce of gold and 55 ounces of silver, and 150 tons shipped at a different period averaged 0.44 ounce of gold and 52 ounces of silver. The average precious-metal content of the ores between the third and ninth levels in the Jo Reynolds mine has been estimated by the management as 0.10 ounce of gold and 100 ounces of silver to the ton. Fuller details in regard to silver content is given in the individual mine descriptions.

The decrease in silver content of the enriched ores with increasing depth has been the prime factor in the decline in importance of the silver mines of this district, but a factor of subsidiary importance was the great decline in the market value of silver, from $1.32 an ounce in 1872 to 63 cents in 1894, a fall of about 50 per cent. In this connection the curve showing the average market price of silver from 1859 to 1915 shown in figure 18 (p. 148) is of interest.

The gold, copper, lead, and zinc content of the ores of this type seems to have been but slightly affected by enrichment below the oxidized zone; for information concerning these metals the reader is referred to the section on metal content of the primary ore (pp. 109–110).

NATIVE SILVER AND CHALCOCITE TYPE OF ENRICHMENT.

Specimens from the Dardanell No. 2 vein, obtained from the ore bins at the Up to Date tunnel, near Caribou, are of peculiar interest because in them silver occurs not in sulphocompounds but in native form and is contemporaneously intergrown with chalcocite, bornite, and a little covellite. Stephanite has been reported from some parts of the mine, but none was seen by the writer. Unfortunately the exposures in the mine were not especially good, and the observations are not as complete as might be wished in view of the unusual mineral relationships.

The rich silver ores studied occurred as replacements and to some extent as fissure fillings in altered pyroxenite. All thus far found were within 50 or 100 feet of the surface. Some of the rich veins are an inch or so in width and from this size they grade downward to exceedingly minute veinlets less than 1 millimeter in width. One of the latter, greatly magnified, is shown in figure 19.

A specimen of ore taken from the bins but said to have been obtained about 60 feet below the surface in stopes on the Dardanell No. 2 vein (see fig. 20) illustrates especially well the mode of silver occurrence. This specimen is 1½ to 2 inches thick and shows one wall of a small open fracture traversing altered pyroxenite. This fracture face is coated with an intergrowth of chalcocite, bornite, covellite, calcite, and native silver, one-fourth to one-half inch in thickness. The silver in places forms rough projecting knobs, and the chalcocite, bornite, and covellite are somewhat tarnished and not readily distinguishable from one another except in the polished section. When the polished section is examined under the microscope the chalcocite and bornite are seen to be about equally abundant and to be intimately and irregularly intergrown, showing beyond doubt that they crystallized contemporaneously. Covellite is present only in subordinate amounts and is in places inclosed by bornite and in places by chalcocite. It is irregularly associated with these minerals and appears to have crystallized contemporaneously with them, not being confined to the vicinity of vugs or fractures. Native silver is nearly as abundant as bornite; it occurs in very irregular masses, in some places inclosed in calcite,

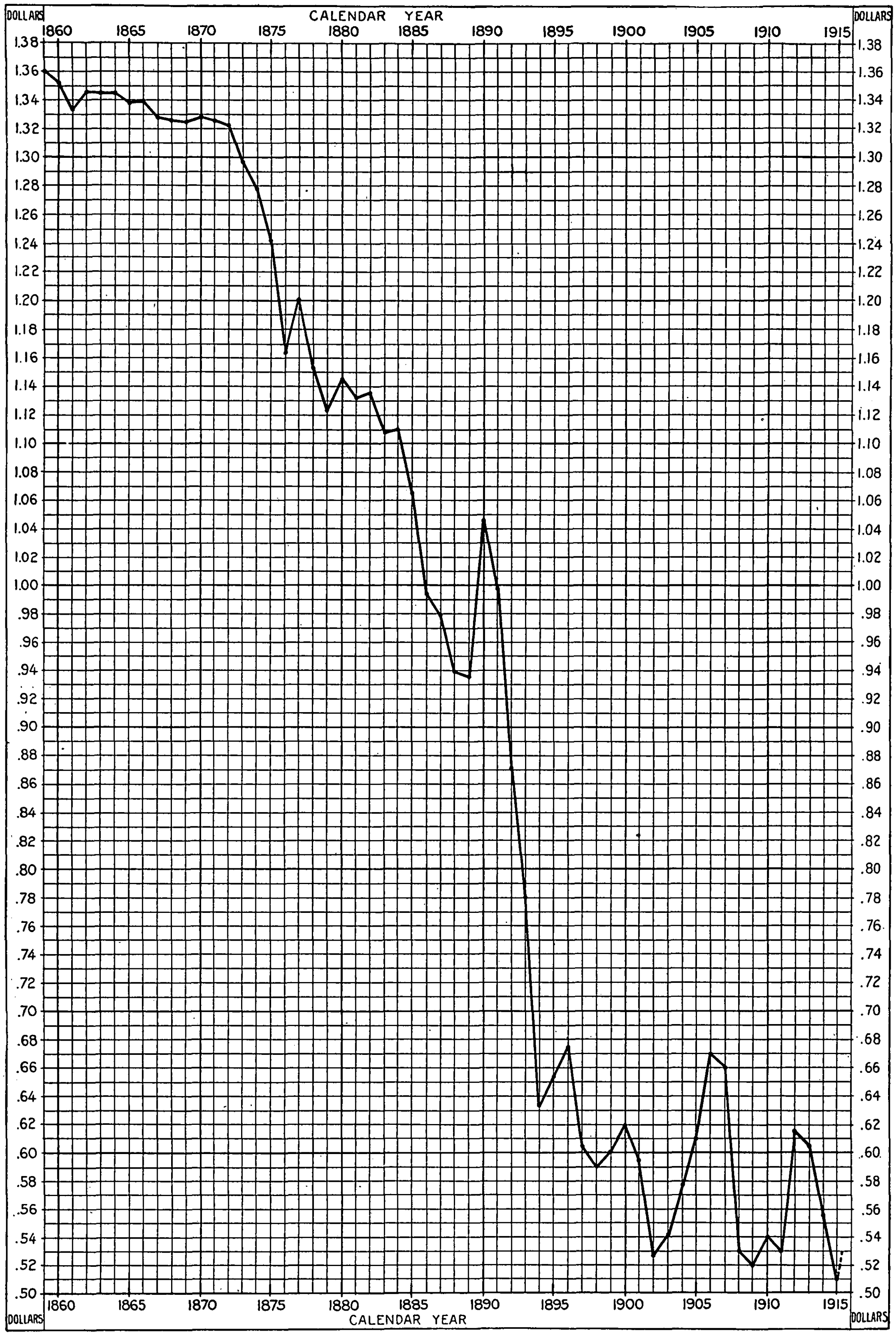


FIGURE 18.—Diagram showing average market price of silver in the United States for the years 1859 to 1915, inclusive. Figures taken from Annual Report of Director of the Mint for 1915.

but in others irregularly intergrown with the sulphides, so that there can be no question that it crystallized contemporaneously with them.

The pyroxenite bordering this vein has been extensively calcitized, and veinlets and small irregular masses of all the minerals described above are scattered irregularly through it. The irregular form of these veinlets and aggregates shows that they were developed by metasomatic replacement. The replacement veinlet shown in figure 19 illustrates also the contemporaneity of the silver and the copper sulphides.

In the absence of any opportunity to study the high-grade ore in place, its origin by downward enrichment can not be said to have been proved. Its position in the mine, between 50 and 100 feet below the present surface, and the fact that the silver is not associated with the usual primary ore minerals of this district but with rich copper sulphides that in other regions are commonly secondary point strongly to an origin by downward enrichment. The nature of the wall-rock alteration furnishes confirmatory evidence of such an origin, for calcite and quartz are the characteristic minerals developed in the wall rocks near the rich silver ores, whereas near the primary ores sericite is abundantly developed in rocks of similar type. An adequate source for the secondary minerals is found in ores of both the galena-sphalerite and pyritic types that occur in this mine. In the particular stope which yielded the rich silver specimens described pyroxenite heavily impregnated with galena was noted; in this material native silver had been deposited along minute fractures. The abundance of calcite in association with the silver of these ores shows that the solutions depositing the silver were neutral or alkaline.

It appears probable that whatever enrichment in silver takes place in the ores of the pyritic type is closely related to the sort of silver enrichment here described, much of the silver being deposited in native form in close association with secondary chalcocite and bornite.

RELATION BETWEEN THE TWO TYPES OF SILVER ENRICHMENT.

In recognizing two types of silver enrichment the writer's main purpose is to emphasize the marked dependence of the process on physical and chemical environment, one set of secondary minerals forming under certain conditions and an entirely different set under other conditions. What the controlling conditions are can not be definitely set forth in the present state of knowledge, but it should be sufficiently apparent from what has already been said that the composition of the primary ore is of the utmost importance. Both types of enrichment were effected by alkaline, neutral, or at most only slightly acid waters, as is shown by the abundant presence of carbonates. Some insight into the reason for the abundance of silver in the native state in association with chalcocite may be gained from the results of earlier studies by Chase Palmer and the writer,[1] which showed

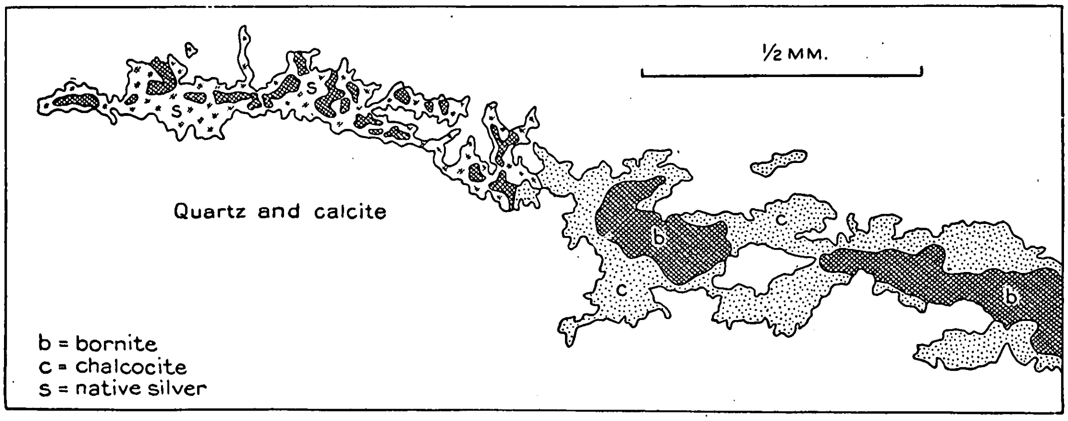


FIGURE 19.—Camera lucida drawing of replacement veinlet of silver, bornite, and chalcocite in altered pyroxenite from Up to Date tunnel, Caribou. The average width of this veinlet is 0.25 millimeter and its length 2 centimeters. A neighboring veinlet of similar character is traceable for a length of 8 centimeters.

[1] Palmer, Chase, and Bastin, E. S., Metallic minerals as precipitants of silver and gold: Econ. Geology, vol. 8, pp. 140-170, 1913.

that chalcocite is very efficient in reducing silver from a dilute solution of its sulphate, precipitating it mainly in the metallic form. It is not surprising, therefore, that where chalcocite and silver were deposited contemporaneously from the same solution most of the silver should occur native.

The two types are established merely to simplify description and facilitate discussion of the deposits of this region. They may not apply to other regions, and conditions intermediate between those here existing may produce transition types. What appeared to be secondary bornite was in fact observed by the writer intergrown with secondary chalcopyrite in rich ore of the ruby silver and chalcopyrite type from the American Sisters mine. It is clear, nevertheless, that the conditions which were favorable for the precipitation of the sulpho-compounds of silver also favored the precipitation of chalcopyrite, and that under conditions in which the copper was precipitated as the richer sulphides bornite and chalcocite the silver was more likely to be precipitated in native form. A determination of the conditions that favor the precipitation of copper secondarily as chalcopyrite rather than as bornite or chalcocite should be a material aid to the understanding of the phenomena of silver enrichment.

COPPER ENRICHMENT.

Downward enrichment in copper is not conspicuous in any of the mines of the Central City quadrangle and is of slight economic importance. Commonly it is restricted to the development of thin films of chalcocite or bornite on chalcopyrite in the upper parts of the ore bodies, but in some places small amounts of secondary chalcopyrite or very rarely native copper may be developed.

SOLUTION AND REDEPOSITION OF COPPER IN THE OXIDIZED ZONE.

In most sulphide ores the common sulphides of copper readily break down in the oxidized zone, the copper dissolved being balanced mainly by the sulphate radicle. If the common carbonates are abundant either as wall rocks or as gangue minerals, much of the copper dissolved may by reaction with them be temporarily fixed in the oxidized zone as the copper carbonates azurite and malachite; some copper may also by reaction with silicates become fixed in the oxidized zone as chrysocolla. If carbonates are rare or absent most of the copper in solution will be precipitated only below the oxidized zone, through the reducing influence mainly of the primary sulphides. In the region under discussion limestones are absent and carbonates as gangue minerals are abundant only in those ore types in which copper minerals are least abundant; as a consequence copper carbonates, though present in small amounts in most of the oxidized ores, are nowhere conspicuous. Chrysocolla was not observed. In a few of the old mine workings, such as those of the Kokomo mine, the copper has been temporarily checked in its downward progress by the process of evaporation and is deposited on the roofs, walls, and floors of old drifts as blue-green translucent stalactites, coatings, and stalagmites of a hydrous sulphate of iron and copper. In the Barnes mine waters carrying cupric sulphide descending from the oxidized zone have reacted with the iron rails on one of the levels and produced metallic copper. Films of native copper were also noted along seams in the pyrite-chalcopyrite ore of the Gladstone mine at depths of less than 75 feet. Copper oxides have been reported but are very rare.

REDEPOSITION OF COPPER BELOW GROUND-WATER LEVEL.

Copper may be secondarily deposited below the oxidized zone, either as chalcopyrite or as the richer copper sulphides chalcocite, bornite, and rarely covellite. The secondary copper minerals may line fractures or vugs in the primary ore or may metasomatically replace the primary ore minerals. In the section on silver enrichment attention has been called to the characteristic association of secondary chalcopyrite with the sulpho-compounds of silver, and chalcopyrite has also been noted in other veins of the galena-sphalerite type in which no silver minerals were recognizable. Nowhere is it sufficiently abundant to add greatly to the value of the ore.

The occurrence of chalcocite, bornite, and some covellite, probably secondary, in contemporaneous intergrowth with native silver in the Up to Date mine has been described (pp. 147, 149). In this occurrence all the copper minerals are contemporaneous.

The most notable instances of copper enrichment are found in veins of the pyritic type, particularly those that carry more than the average amount of primary chalcopyrite. Certain ores in the Pittsburgh vein, near Central City, furnish the best illustration. The ore of this vein is unusually rich in primary copper minerals, principally chalcopyrite, with some tennantite and enargite. It has undergone some fracturing subsequent to the primary mineralization, and the fractures have served as channels for copper-bearing solutions descending from the oxidized surface portions of the vein. Chalcocite was abundant only in the highest parts of the vein accessible—that is, a short distance above the 500-foot level—but minute amounts were noted to depths slightly greater than 700 feet. In a stope above the 500-foot level the vein consists of 5 inches of pyrite, chalcopyrite, tennantite, gray quartz, and chalcocite, and the texture is somewhat porous. Examination of a polished section with the reflecting microscope showed that the chalcocite was developed by the metasomatic replacement of chalcopyrite and to a lesser degree of pyrite. The replacement began along the contacts of chalcopyrite with quartz or pyrite or along minute fractures traversing the chalcopyrite. Portions of the ore not far away show much black pulverulent chalcocite in vugs, and in places the ore is honeycombed with irregular vugs one-eighth to one-fourth inch across. Ore from this stope averaged about 10 per cent of copper. In an underhand stope just below the 700-foot level the vein, which has a total width of only 2 to 2½ inches, consists of a central band made up of chalcopyrite and a little tennantite, 1 to 1½ inches wide, bordered on each side by half an inch of silicified granite gneiss carrying pyrite. Shearing movements along the vein have produced minute fractures in the chalcopyrite and tennantite, and these have been filled with gray quartz. Starting from the border of these minute quartz veinlets the chalcopyrite has been replaced by chalcocite, narrow rims of which border the quartz.

Black pulverulent chalcocite was noted on the chalcopyrite of pyritic ore in the 150-foot level of the Barnes mine. Films of chalcocite were noted on chalcopyrite in a stope 100 feet above the 300-foot level of the Egyptian mine in ore of the galena-sphalerite type, but in general chalcocite is not abundant in ore of this type.

In most of the ores copper enrichment manifests itself merely in the development of dark-gray films of chalcocite, mainly on chalcopyrite. In some places the films show colors suggestive of covellite or bornite rather than of chalcocite. Although such films effect only slight enrichment in copper, they may exert an important influence in the precipitation of silver and gold from descending solutions. (See p. 114.)

It is noteworthy that in the Evergreen copper mine, near Apex, where the principal metallic mineral of the ore is bornite, little enrichment seems to have taken place. This is doubtless attributable to the fact that the bornite, being a constituent of monzonite dikes, is comparatively little exposed to active water circulation.

In at least some places the secondary chalcocite, bornite, and covellite were deposited from solutions that were alkaline, neutral, or only faintly acid, for they are associated locally with abundant siderite or calcite.

ENRICHMENT IN OTHER METALS.

Sphalerite, the primary zinc mineral of the ores of this region, breaks down readily in the oxidized ores and is taken into solution mainly in balance with the sulphate radicle. In the scarcity of carbonates little of it is reprecipitated as zinc carbonate (smithsonite), and as sphalerite was nowhere observed to be clearly secondary, most of the zinc appears to enter the ground-water circulation and be lost so far as these ore deposits are concerned. It is noteworthy that in those veins in which secondary sulpho-compounds of silver are developed below the ground-water level as replacements of the primary ore minerals, galena is commonly replaced but sphalerite apparently is not.

Galena ordinarily oxidizes more slowly than sphalerite, pyrite, or chalcopyrite. The difficultly soluble lead sulphate anglesite was noted in a few ores, and the carbonate cerusite in a few others, but little opportunity was afforded for the study of oxidation in ores of the galena-sphalerite type. Secondary galena was nowhere observed.

In the few mines in which pitchblende occurs the oxidized ores have been wholly mined out. A sulphate of uranium whose exact composition is uncertain has been noted in some of the pitchblende ores, but in insignificant amounts.

SUMMARY OF ENRICHMENT.

The phenomena of enrichment in the Central City quadrangle are of economic importance mainly in the gold-silver ores, in which enrichment in gold and silver has been considerable, enrichment in copper of minor amount, and enrichment in lead and zinc negligible.

Enrichment in gold appears to be confined almost exclusively to portions of the ore deposits above or immediately below the ground-water level; it has affected all types of gold-silver ores and has caused a material increment in the value of the ore in the oxidized zone.

Enrichment in silver is confined mainly to the ores of the galena-sphalerite type. It appears probable that the relative scarcity of pyritic minerals in the galena-sphalerite ores and the presence of a carbonate gangue favoring neutral or alkaline rather than acid conditions in the secondary sulphide zone are important factors in restricting silver enrichment below the water table to ores of this type. Although in the oxidized zone of these ores there has been enrichment in gold, silver seems to have suffered impoverishment. Silver enrichment is confined to the ground-water zone and consists in the secondary deposition of pearceite and proustite and more rarely of native silver. It is most extensive in the first 100 or 200 feet below the natural ground-water level and shows a progressive decrease with increasing depth. The maximum depth at which secondary silver minerals were noted was 700 feet below the surface, or about 650 feet below the water level. Two types of mineral association were noted in the rich silver ores; in one secondary sulpho-compounds of silver were associated with secondary chalcopyrite, and in the other native silver was associated with abundant chalcocite and bornite and some covellite. The secondary silver minerals are deposited in fractures in the primary ore and also as metasomatic replacements of the primary minerals.

Enrichment in copper is nowhere conspicuous and is confined almost wholly to the ground-water zone of ores of the pyritic type. The oxidized ores underwent impoverishment in copper. Enrichment in copper is most extensive in those deposits whose ores are unusually rich in primary copper minerals. Chalcocite is the principal secondary copper mineral and is developed in part as a filling in fractures or a coating in vugs and in part by metasomatic replacement of chalcopyrite and pyrite.

Enrichment in lead or zinc was not observed.

Chapter XII.—ORE TREATMENT, LABOR AND ROYALTIES, FREIGHT RATES.

By E. S. Bastin, C. W. Henderson, and J. M. Hill.

ORE TREATMENT.

HISTORY.

Entering the mountains with little equipment beyond shovel, pick, and pan, the first miners in this district saved the gold by the usual pioneer methods of sluicing, cradling, and panning. These methods were fairly satisfactory when applied to the stream gravels and the oxidized surface ore of the veins, but the miners soon discovered that as depth was gained on the veins the yield of gold fell off rapidly. For this there is an excellent geologic reason, as the early workings were in the outcrops of the veins, in which the action of air and water had disintegrated the ore, freed much of the gold from its sulphide matrix, and converted it by solution and redeposition into a coarser form. In the deeper portions of the veins the ore was harder, and most of the gold being finely distributed through sulphides was much less readily amalgamated.

Appreciating the difficulty, even if not cognizant of its causes, the miners sought a remedy in various appliances for fine crushing of the ore. An early device consisted of a small mortar whose pestle was attached to a sapling, the spring of the sapling raising the pestle. Another device was the "woodpecker mill," which was an iron-shod wooden trip hammer, worked by water power, which fell in a wooden iron-lined trough. The arrastre early made its appearance, the first one being constructed near the mouth of Gregory Gulch in July, 1859. Five of them, each 6 feet in diameter and constructed of granite, may still be seen in the valley of Clear Creek just below Dumont. This device was followed the same summer by the first stamp mill, a homemade affair with six stamps, set up at the mouth of Chase Gulch and run by water power. It had wooden stems, shoes, and dies, but the dies were shod with iron plates. Its operation in the summer and fall of 1859 is said to have netted its owner about $6,000. The first imported mill appears to have been a little 3-stamp mill erected in 1859 by T. T. Prosser in Prosser Gulch.

During the first year of the development of the region near Central City the scarcity of water for ore treatment became troublesome, and a company was formed to bring water in from Fall River. The ditch built to accomplish this end had its head above the mouth of Silver Creek, at the base of the high peaks of the range, was 12 miles long, and traversed some rough country. The early miners, however, were deterred by no obstacles and had the work completed and water flowing at Russell Gulch, Nevadaville, and Blackhawk early in the spring of 1860. The ditch later came under the control of New York people, who, through shortsighted management, so antagonized the miners that the enterprise was of short usefulness.

During the summer of 1860 there were 60 stamp mills and 30 arrastres run by water power in operation between Nevadaville and Blackhawk. These were all working on oxidized ores, but by the end of that year the heavier sulphide ores were reached and the percentage of savings by the mills immediately dropped.

The year 1861 saw the construction of the first mill on South Clear Creek. In Gilpin County the savings from sulphide ores continued to diminish, and during 1861 it was found necessary to close mine after mine which could not be made to pay. Numerous experiments were tried, both with stamp mills and leaching processes, none of which was markedly successful. In fact, this change at so shallow a depth from free-milling ores to stubborn sulphides was a calamity that crushed the hopes of many prospectors and caused a suspension of operations by numerous companies operating in the district.

In 1861 Caleb S. Burdsall built the first smelter of the region at Nevadaville. This was a crude affair that was unfortunately destroyed too soon after its erection to prove its worth.

The difficulty in amalgamating the sulphide ores led to what Raymond[1] has called the "process mania."

> The process mania, commencing in 1864 and lasting till 1867, was one of the main causes which damaged the repu-

[1] Raymond, R. W., Statistics of mines and mining in the States and Territories west of the Rocky Mountains, 1869, pp. 347-348, 1870.

tation of the mines to such a degree that the country was nearly ruined by the reaction. Upon the first failure of the stamp mills, the people came to the conclusion that the ore must be roasted before the gold could be amalgamated. One invention for this purpose followed another; desulphurization became the abracadabra of the new alchemists, and millions of dollars were wasted in speculations based on sweeping claims of perfect successes put forward by deluded or deluding proprietors of patents.

In 1866 hope was revived by the successful experiments of Nathaniel P. Hill, of Blackhawk, on the smelting of Gilpin County ores. In 1867 several of the idle mines were reopened in anticipation of the opening of the Hill smelter, whose construction was started in the fall of that year. It was opened for business in January, 1868, and consisted of a calcining furnace and a small reverberatory. The fire brick were shipped by rail from St. Louis to the terminus of the road and then 600 miles by wagon. The iron cost 22 cents a pound and skilled labor $8 to $10 a day. The smelting charges were $20 to $45 a ton, and the matte was hauled to the Missouri and shipped by way of New York to Swansea, in Wales, for resmelting. The plant was in operation until 1878, when it was removed to Argo, near Denver.

A very complete description of this plant has been given by Egleston.[1]

MILLING OF GOLD ORES.

In Gilpin, Clear Creek, and Boulder counties, as in many other mining districts, the gold-silver ore as mined can be divided into two parts. The larger part is called concentrating ore, milling ore, or "mill dirt," and is of such character that its metal content is most economically saved by some form of amalgamation or concentration. The smaller part, called "smelting ore," is of such character that its metal content is best recovered by smelting. After the establishment of the Blackhawk smelter the mill men of the region were not idle, but continued to strive actively to improve methods of amalgamation and concentration. In May, 1869, over 800 stamps were dropping in Gilpin County. Supplies were necessarily expensive on account of the long wagon haul from Denver, but this difficulty was largely alleviated by the completion of the Colorado & Southern Railway to Blackhawk in 1872 and to Floyd Hill, on South Clear Creek, in 1873.

[1] Egleston, T., Boston and Colorado smelting works: Am. Inst. Min. Eng. Trans., vol. 4, pp. 276–298, 1876.

The mills now in use are of three principal types: (1) The old style Gilpin County stamp mill, in which battery amalgamation has been brought to a high degree of perfection, at the sacrifice of crushing efficiency; (2) the fast-drop stamp mill of the California type, depending on outside plate amalgamation, the inferior amalgamating efficiency being compensated for by more effective concentration; and (3) the plant in which amalgamation is wholly discarded and concentration may be supplemented by cyanidation or flotation.

The first stamp mills extensively used in the district were of the California pattern, and in the middle of 1860, according to T. A. Rickard, there were 60 stamp mills of this pattern in operation near Central City. While heavily oxidized surface ores were being milled, this type of stamp did fairly well, effecting savings as high as 75 per cent of the gold content. When the sulphide ores were reached, the extraction fell to an average of but 30 per cent of the gold content. To meet these changed conditions the California practice was modified, and what is now known as the Gilpin County practice was gradually evolved. In the following tabulation of data, published by T. A. Rickard, the California and Gilpin County practices are concisely contrasted, the figures in the table representing the extremes of both practices:

Comparison of Gilpin County and California stamp-mill practices.

	Gilpin County.	California.
Weight of stamps...lbs..	500–600........	750–850.
Number of drops per minute.	30.............	90–105.
Height of drop..inches..	18–20..........	4–6.
Size of mortars..........	Roomy.........	Small and narrow.
Amalgamation plates....	Inside and outside.	Outside.
Height of discharge, inches.	14.............	4.
Size of screens..mesh..	60–70..........	40.
Ore crushed in 24 hours per stamp......tons..	1..............	2½–3.
Pyrite in the ore, per cent.	15.............	1–2.
Gangue................	Altered granite gneiss, some quartz.	Quartz, some slate.
Distribution of gold....	Very fine and intimately associated with the sulphides.	Coarse and practically free.
Cost per ton with free water power...cents..	70.............	35.
Gold saved by amalgamation.....per cent..	75.............	70.

Reasons for the differences between California and Gilpin County practice lie in differences in the ores. In the California deposits the gold is usually free in quartz and amalgamates readily. In Gilpin County most of the gold is finely divided in sulphides and amalgamates much less readily. To effect a reasonable saving on Gilpin County ores it is necessary to prolong the period of amalgamation by holding the material longer in the stamp mortars, which are provided with amalgamating plates. This is accomplished by increasing the depth of the mortars, decreasing the size of the discharge screen, decreasing the weight of the stamps, increasing the height from which they drop, and decreasing the number of drops per minute. The Gilpin County stamps are therefore used both for crushing and for amalgamation, whereas the California stamps are used primarily for crushing, the principal amalgamation taking place subsequently on the plate tables.[1]

Many of the mills of the district are still of the old Gilpin County type, but with the improvement in concentrating devices there has been a tendency to depend more on concentration and less on amalgamation. This tendency has manifested itself in the adoption in some mills of heavier and faster stamps (a partial return to the California practice) and the addition of more concentrating machinery. In 1899, out of 600 stamps in 14 mills in Gilpin County there were 140 which had a rapid drop and medium discharge. The old Gilpin County practice, although yielding a high percentage of the precious-metal content in the readily marketable form of amalgam, produced large amounts of slimes from which there could not be a good saving by concentration. In the newer mills there is still some slime to handle, but the ore as a whole is not crushed so fine, and much better concentration is possible. In the early mills the pulp after leaving the amalgamation plates was usually run over Gilpin County bumping tables without any attempt at sizing, and a large part of the finely crushed sulphides, carrying valuable amounts of metals, went down the streams. In the mills constructed in the last 10 or 15 years the pulp after leaving the plates is classified, and the fragments of different sizes are concentrated on tables adjusted to these sizes.

Within the last few years amalgamation has been entirely discarded in a number of mills, and stamps if used at all are employed only for crushing. An example is the Frontenac mill, in which, according to Downey,[2] the recovery is about 85 per cent of the gold and 78 per cent of the silver content of the average ore, whose value is between $8 and $10 a ton.

Although it is hazardous to attempt to give any figure for the average extraction effected by the mills employing amalgamation and concentration, because of the variation in mill practice and in the character of the ores, it is probably not wide of the truth to say that it seldom exceeds 75 per cent of the gold and 40 per cent of the silver in ores having a value between $5 and $10 a ton. The ratio of concentration varies from 30 into 1 to 4 into 1. This saving may seem small compared with that obtained in some other districts, but it should be recalled that most of the mines of this region have always been dependent on custom mills and that these mills have of necessity been designed to suit a number of ores approximately rather than a single one exactly. When it is remembered that in a single mine ores of the pyritic type may predominate at one place and ores of the galena-sphalerite type at another, and that each of these types is itself somewhat variable, it is not surprising that the milling processes are not always closely adjusted to the ore being treated and that savings effected do not always compare favorably with those obtained elsewhere in ores of more uniform character. Some of the custom mills continue the former general practice of treating each lot of ore separately, at a certain rate (average, $9) per cord (8 to 9 tons), turning over to the miner the gold and silver bullion saved by amalgamation. The concentrates are also turned over to the miner, who moves them to the sampler or smelter. Sometimes the custom mill acts as agent for the miner, selling the bullion to the bank or to the United States Mint and selling the concentrates. Sometimes the mill acts also as agent for the ore hauler and distributes the proceeds from the sale of bullion and concen-

[1] The California and Gilpin County stamp-mill practices are discussed in the following papers, which have been freely drawn upon in this description: Rogers, A. N., The mines and mills of Gilpin County, Colo.: Am. Inst. Min. Eng. Trans., vol. 11, pp. 29-55, 1883. Rickard, T. A., The limitations of the gold stamp mill: Idem, vol. 23, pp. 137-147, 1893.

[2] Downey, C. J., A modern type of concentrator in Gilpin County: Min. Sci., vol. 64, p. 52, 1911.

trates between the miner, hauler, and mill. If the ore is mined by lessees the custom mill may also pay the royalty to the mine owner. Some of the newest custom mills purchase the ore outright from the miner, paying on the basis of the assay value.

The successful treatment of gold-silver ores in many districts by the cyanide process naturally led to experiments on the ores of this region. There have been a number of experimenters. The Collins brothers [1] from their work decided that it was not economically possible to cyanide concentrates, and that "the game was not worth the candle" for tailings. Later experiments by Alsdorf, Draper, and others on Gilpin County ores led them to conclude "that there was no particular difficulty in the cyanidation of the ores, and crude concentrates containing 2 per cent copper and only 10 to 12 per cent silica could be cyanided direct without undue cyanide consumption and with a high extraction." [2]

These experimenters were not in a position to install a mill to put their faith into practice, and it was left to the Hudson Reduction Co., of Idaho Springs, to demonstrate on a commercial scale the possibility of this metallurgic process. This company in 1911 rebuilt its amalgamation and concentration mill to include cyanidation. Parmelee [3] has described this mill in detail, giving the recovery in amalgam, concentrates, and cyanide precipitates as 88 per cent of the value of the ore. In 1913 the Argo mill, at the mouth of the Argo tunnel, was put into operation. In its construction the practice developed at the Hudson mill was followed closely, but changes have been made in details which have increased the extraction. This mill has been described by several writers,[4] including Roller and Curran, designers and first operators, and Heizer and Pearce, who had charge of the remodeling and subsequent operation. In the later part of 1913 this mill entirely discarded amalgamation.

The latest development in ore treatment in the district is the installation in 1915 and 1916 of flotation cells at the Hudson and Argo mills.

MILLING OF SILVER AND OTHER ORES.

Much of the rich silver ore mined in this region has been shipped direct to the smelter, but a few mills have been erected to treat the lower grades. One of the first silver mills was that erected by A. D. Breed at Nederland in 1871. This mill was equipped with Blake crusher, stamps for dry-crushing the ore, Bruckner cylinders for chloridizing roasting, and amalgamating pans. A few years later another mill, also employing chloridizing roasting, was erected at Caribou to treat the ores of the Native Silver mine. After long cessation of milling in the Caribou district the dump and stope fillings of the old Caribou mine are now being re-treated by concentration and cyanidation at the Cariman mill, of 25 tons daily capacity, at Caribou. A complete description of this mill has been given by Parmelee.[5]

The Jo Reynolds mill, erected between Dumont and Lawson in 1900 to treat the silver ores of the Jo Reynolds mine, is purely a concentrating mill, stamps being used only for regrinding. It has a capacity of 40 tons in 24 hours and yields a lead and zinc concentrate.

The treatment of the Boulder County tungsten ores is entirely one of concentration. Hills [6] has described the methods and has pointed out that the chief difficulty is the large loss due to excessive sliming. Parmelee [7] in 1911 further discussed the problems of tungsten concentration.

The Delano chlorination plant [8] for the treatment of Boulder County telluride ores was successfully operated for some years.

In the following table brief information is given in regard to most of the mills of the district. In consulting it the reader should remember that the equipment of many of the active mills is undergoing frequent modification.

[1] Collins, G. E., Lessons from Gilpin County practice: Min. and Sci. Press, vol. 101, pp. 366-371, 1910.

[2] Draper, M. D., Cyanidation in Colorado: Min. and Sci. Press, vol. 103, p. 684, 1911.

[3] Parmelee, H. C., Cyaniding by continuous decantation in Clear Creek County, Colo.: Met. and Chem. Eng., vol. 10, pp. 27-31, 1912.

[4] Goodale, S. L., Eng. and Min. Jour., vol. 96, pp. 385-389, 1913: Colorado State Bur. Mines Twelfth Bienn. Rept., p. 80, 1913.

Roller, A. H., and Curran, H. T., Ore treatment at the Argo mill: Eng. and Min. Jour., vol. 98, p. 1, 1914; idem, p. 217.

Pearce, J. A., Cyanidation of Clear Creek and Gilpin County sulphides: Min. and Sci. Press, vol. 109, pp. 833-837, 1914; Refining cupriferous precipitate: Min. and Sci. Press, vol. 112, pp. 270-272, 1916.

Heizer, O. F., Colorado State Bur. Mines Thirteenth Bienn. Rept., pp. 87-90, 1914.

Parmelee, H. C., Cyanidation of low-grade sulphide ores in Colorado: Met. and Chem. Eng., vol. 13, pp. 421-425, 1915.

[5] Parmelee, H. C., Caribou, Boulder County; cyaniding of low-grade sulphide ores in Colorado: Met. and Chem. Eng., vol. 13, pp. 477-479, 1915.

[6] Hills, V. C., Tungsten mining and milling: Colorado Sci. Soc. Proc., vol. 9, pp. 135-153, 1900.

[7] Parmelee, H. C., The problems of tungsten concentration: Met. and Chem. Eng., vol. 9, pp. 341-342, 409-411, 1911.

[8] Burger, C. C., Ore treatment in Boulder County: Eng. and Min. Jour., vol. 65, pp. 129-130, 1898.

Mills in Central City region treating gold-silver or silver ores.

Boulder County.

Name.	Location.	Capacity (tons in 24 hours).	Process.	Equipment.
Alton	North Beaver Creek, 2 miles west of Nederland.	25	Amalgamation and concentration. Expect to install cyanidation.	1 jaw crusher, 15 quick-drop 850-pound stamps, 3 outside amalgamation plates, 1 classifier, 2 Wilfley and 2 Card tables, 2 Monell slimers, 3 canvas tables, 1 Hartz jig.
Bailey	Middle Boulder Creek, 1¼ miles west of Eldora.	30	Cyanidation	Crusher, 2 sets rolls, tube mill, Portland filter press, 3 revolving barrels. Never operated.
Caribou (old mill)	¼ mile west of Caribou	40	Concentration	1 crusher, 10 stamps, classifier, 1 Wilfley table, 1 canvas table.
Caribou (new mill, 1914).	Caribou	100	Cyanidation	Crushers, screens, 2 Hardinge mills, Flood classifiers, Card tables, Dorr classifiers, leaching vats, 3 Dorr agitators, 1 Dorr thickener, Portland filter.
Boulder County	Cardinal	35	Amalgamation and concentration.	Blake crusher, 10 stamps, Wilfley tables, etc. Former gold-silver mill transformed to tungsten concentration and back to gold-silver.

Clear Creek County.

Name.	Location.	Capacity (tons in 24 hours).	Process.	Equipment.
Alice	Silver Creek, ¾ miles southwest of Alice.	20	Amalgamation and concentration.	Now dismantled. Equipment last used was 1 jaw crusher, 5 rapid-drop 950-pound stamps, outside amalgamation plates, patent amalgamator, 1 Gilpin County bumper, 1 classifier, 2 Card tables.
Gold Anchor	Silver Creek, ½ mile northwest of Alice.	40	Amalgamation	1 jaw crusher, 10 stamps.
Ninety Four	Silver Creek, ¾ mile northeast of Alice.	25	Dry concentration	1 jaw crusher, 3 sets rolls, 4 Waugh dry tables.
Lombard	Cumberland Gulch, 1 mile south of Yankee.	100	Amalgamation and concentration.	1 jaw crusher, 20 quick-drop 1,000-pound stamps, 3 outside amalgamation plates, 1 box classifier, 3 Wilfley tables, 3 Card tables.
Lalla	Silver Creek, 1 mile northeast of Alice.	25	.....do	5 stamps, 1 outside amalgamation plate, 1 Gilpin County bumper.
Standard	Fall River, 1 mile east of Hamlin Gulch.	30–40	.....do	1 jaw crusher, 20 quick-drop stamps, 1 box classifier, 2 outside amalgamation plates 4 Wilfley tables.
Phillips	Fall River, ½ mile northwest of York Gulch.	20	.....do	1 set rolls, 5 stamps, 1 outside amalgamation plate, 1 Wilfley table.
United Gold	Fall River, ¼ mile north of South Clear Creek.	50	.....do	1 jaw crusher, 10 quick-drop stamps, 2 outside amalgamation plates, 1 Gilpin County bumper, 1 Wilfley table.
Brighton	Mouth of Fall River	40	Concentration	1 jaw crusher, 1 set rolls, 1 Huntington mill, 4 trommels, settling box, 4 jigs, 3 Wilfley tables, 1 Card slimer, 1 Roberts belt table.
Silver Mountain	Empire Station	50	.....do	1 jaw crusher, 1 Huntington mill, 1 set rolls, 3 trommels, 1 classifier, 2 jigs, 3 Frue vanners, 1 Cammett table.

Mills in Central City region treating gold-silver or silver ores—Continued.

Clear Creek County—Continued.

Name.	Location.	Capacity (tons in 24 hours).	Process.	Equipment.
American Sisters	Silver Creek, 1 mile south of Lawson.	30	Amalgamation and concentration.	1 jaw crusher, 1 set rolls, 10 stamps, 3 trommels, 2 cone classifiers, 2 sand classifiers, 2 jigs, 2 Wilfley tables, 2 Card tables, 1 Frue vanner.
Jo Reynolds	South Clear Creek, 1 mile west of Dumont.	40	do	1 jaw crusher, 2 sets rolls, 10 rapid-drop stamps, 4 trommels, 3 Hartz jigs, 1 settling box, 1 Callow tank, 2 Card tables, 1 spiral plane table, 1 Frue vanner.
Blue Ridge	South Clear Creek, near Dumont.	40	do	Crusher, 2 sets rolls, 3 Card tables. Completed 1913.
Syndicate	do	100	Amalgamation and concentration.	30 stamps, tables.
Clear Creek and Gilpin.	Clear Creek, ½ mile east of Dumont.	40	Concentration	1 jaw crusher, 10 quick-drop stamps, 1 set rolls, 3 trommels, 3 Wilfley tables, 3 jigs.
Mountain Queen	South Clear Creek, Dumont.	5–8	Amalgamation and concentration.	1 jaw crusher, 10 stamps, 2 outside amalgamation plates, 1 Wilfley table.
Donelson	South Clear Creek, at mouth of Fall River.		do	1 jaw crusher, 4 trommels, 5 jigs, 50 slow-drop stamps, 10 outside amalgamation plates. Remainder dismantled.
Hoosac	South Clear Creek, ½ mile east of Fall River.	35	do	10 rapid-drop 1,050-pound stamps, 2 outside amalgamation plates, classifiers, 3 Wilfley tables. Built, 1912.
Stanley	South Clear Creek, ½ mile east of Trail Creek.	50	do	1 jaw crusher, 1 set rolls, 8 jigs, 10 stamps, 2 amalgamation plates, 3 trommels, 3 classifiers, 2 Cammett tables.
Argo	South Clear Creek, mouth of Argo tunnel.	100	Cyanidation and concentration. Flotation added in 1916.	1 gyratory crusher, 20 1,050-pound stamps, 6 Dorr classifiers, 7 Dorr thickeners, 9 Card tables, Parrall and Dorr agitators, Portland filter.
Combination (Staley)	South Clear Creek, Idaho Springs.	50	Amalgamation and concentration.	15 1,050-pound stamps with outside and inside amalgamation plates, classifier, 1 tube mill, 4 Wilfley and 2 Card tables, 1 Deister slimer.
Lincoln	South Clear Creek, ½ mile east of Trail Creek.	50	do	10 stamps, etc.
Mixsell	South Clear Creek, Idaho Springs.	20	do	1 jaw crusher, 10 stamps, 2 outside amalgamation plates 3 Gilpin County bumpers, 1 Card table.
Waltham	Chicago Creek and South Clear Creek.	30	do	Partly dismantled. 10 slow-drop stamps remain.
Idaho Springs Reduction Co.	South Clear Creek, Idaho Springs.	20	do	5 stamps and tube mill left of former equipment of 30 stamps (1,050-pound), 3 ball mills, amalgamation plates, 8 Wilfley tables, 3 Frue vanners. Dismantled.
Jackson	Chicago Creek and South Clear Creek.	50	Concentration	1 jaw crusher, 1 set rolls, 2 Huntington mills, 3 trommels, 3 jigs, 3 classifiers, 3 Card tables, 1 Roberts buddle, 1 belt table, 2 Callow cones.
Hudson	do	88	Amalgamation, concentration, and cyanidation; flotation added in 1915–16.	1 jaw crusher, 20 stamps and outside amalgamation plates, 3 Card tables, 2 Wilfley tables, 2 Aiken classifiers, 3 Dorr thickeners, 2 Callow cones, agitators, etc.

Mills in Central City region treating gold-silver or silver ores—Continued.

Clear Creek County—Continued.

Name.	Location.	Capacity (tons in 24 hours).	Process.	Equipment.
Gem (Newton), east section.	Chicago Creek and South Clear Creek.	150	Concentration..........	1 jaw crusher, 1 set rolls, 10 quick-drop stamps, 3 trommels, 3 jigs, 5 Wilfley tables, 4 cone classifiers, 1 Frue vanner.
Gem (Newton), west section.	.....do..................	....	.....do..................	1 jaw crusher, 1 set rolls, 10 quick-drop stamps, 3 trommels, 3 jigs, 1 box classifier, 5 Wilfley tables, 1 Frue vanner.
Gem (Newton annex), east section.	.....do..................	Not used.	Amalgamation and concentration.	10 stamps with amalgamation plates, 3 Wilfley tables, 1 Wilfley slimer.
Gem (Newtonannex), west section.	.....do..................	250	Concentration..........	1 jaw crusher, 1 set rolls, 40 quick-drop stamps, 3 trommels, 6 jigs, 8 Wilfley tables, 1 Wilfley slimer.
Bertha..............	South Clear Creek, mouth of Virginia Canyon.	20	Amalgamation and concentration.	1 jaw crusher, 3 Kinkaid (Virginia City, Nev.) mills, 5 quick-drop stamps, 2 outside amalgamation plates, 3 Gilpin County bumpers, 2 Wilfley tables; idle for years; partly dismantled.
Wilkie..............	South Clear Creek, 1 mile below Idaho Springs.	40	Concentration..........	Crusher, stamps, jigs, Wilfley tables; partly dismantled.

Gilpin County.

Name.	Location.	Capacity (tons in 24 hours).	Process.	Equipment.
Black Hills and Denver.	South Boulder Creek, 1½ miles east of Tolland.	50	Amalgamation and concentration.	1 Sampson crusher, 1 Elspass roller mill, 1 Pierce amalgamator, 6 Dixon tables.
Golden Sun.........	South Boulder Creek 1 mile east of Boulder Park.	50	Concentration..........	1 jaw crusher, 2 sets rolls, 1 King classifier, 2 box classifiers, 2 Wilfley tables, 2 Frue slime tables.
Smuggler...........	South Fork Moon Gulch, 2 miles south-southwest of Rollinsville.	30	Amalgamation and concentration	1 jaw crusher, 10 stamps (60 drops a minute) with amalgamation plates, 2 Gilpin County bumpers, 1 Wilfley table.
Mountain Monarch...	Gamble Gulch, 2 miles south-southwest of Rollinsville.	30	.....do..................	1 jaw crusher, 10 quick-drop stamps, 2 outside amalgamation plates, 4 Gilpin County bumpers, 1 Bartlet table.
Penobscot...........	Gamble Gulch, 2½ miles south-southwest of Rollinsville.	30	.....do..................	1 jaw crusher, 10 quick-drop stamps, 2 outside amalgamation plates, 4 Gilpin County bumpers, 1 Standard table.
Perigo...............	Gamble Gulch at Perigo.	100	.....do..................	1 jaw crusher, 30 stamps with outside amalgamation plates, 12 Gilpin County bumpers.
Golden Flint.........	.....do..................	100	Cyanidation............	25 stamps, amalgamation plates, Pierce amalgamator, Card tables. This mill abandoned in 1912 and new mill with rolls, tube mill, Card tables, and cyanide agitation tank commenced 1913.
Gettysburg...........	¾ mile southwest of Gilpin.	....	Concentration..........	3 rolls, 3 air concentrators.
Reform..............	Silver Creek, 2½ miles north of junction with North Clear Creek.	....	Amalgamation and concentration.	10 stamps, King-Darrough table.
Pine Cone...........	Missouri Creek, ½ mile south of Wide Awake.	30	.....do..................	20 stamps, 4 outside amalgamation plates, 2 Gilpin County bumpers.

Mills in Central City region treating gold-silver or silver ores—Continued.

Gilpin County—Continued.

Name	Location.	Capacity (tons in 24 hours).	Process.	Equiptment.
Annie H.	Elk Creek, 2 miles west of Apex.	30	Amalgamation and concentration.	1 jaw crusher, 10 stamps, 3 Gilpin County bumpers, 3 Frue vanners.
Mackey	.....do		Amalgamation and cyanidation.	10 stamps, cyanide tanks, etc.
Pioneer	Junction North Clear Creek and Pine Creek, 2 miles south of Apex.	40	Amalgamation and concentration.	10 1,000-pound stamps. In construction 1912.
Booster	South of Evergreen mill, Apex.	?	.....do	15 stamps with outside amalgamation plates, 1 Gilpin County bumper.
Evergreen	½ mile south of Apex	60	Concentration (copper ore).	1 jaw crusher, 2 sets rolls, 2 trommels, 1 Callow cone, 1 Richards classifier, 3 Card tables.
North Star	Pecks Flat, 1¼ miles east of Yankee Hill.		Amalgamation and concentration.	10 stamps.
Wheeler	North Clear Creek, 1¼ miles northwest of Blackhawk.		.....do	25 slow-drop stamps with outside amalgamation plates, 5 Gilpin County bumpers. Mill partly dismantled.
Brooklyn	North Clear Creek, 1 mile northwest of Blackhawk.		.....do	1 jaw crusher, 10 stamps with outside amalgamation plates, jigs, and Gilpin County bumpers.
Hidden Treasure	North Clear Creek, ¼ mile north of Blackhawk.		.....do	10 stamps (originally 40) 2 outside amalgamation plates, 2 Wilfley tables.
Polar Star	North Clear Creek, mouth of Chase Gulch.	49	.....do	40 slow-drop 500-pound stamps with amalgamation plates, 8 Gilpin County bumpers.
"Fifty"	North Clear Creek, mouth of Gregory Gulch.	350	.....do	80 stamps with outside amalgamation plates, concentrating tables.
Rocky Mountain	North Clear Creek, ¼ mile east of Blackhawk.		Concentration	Machinery removed. New process to be installed in building in 1916.
Frontenac	North Clear Creek, ⅜ mile east of Blackhawk.	250	.....do	1 jaw crusher, 3 sets rolls, 3 trommels, 3 jigs, 3 cone thickeners, 9 Flood classifiers, 20 Card tables, 4 Deister tables.
Tucker	Chase Gulch, ¾ mile northwest of Blackhawk.	50	.....do	1 jaw crusher, 1 set rolls, 3 trommels, 5 Hartz jigs, 10 stamps, 3 Wilfley tables.
U. P. R. (Buell) Mill.	Gregory Gulch, east end of Central City.	150	Amalgamation and concentration.	1 jaw crusher, 45 rapid-drop stamps with outside amalgamation plates, 5 Gilpin County bumpers, 3 Wilfley tables, 1 Standard table.
Gilpin-Eureka	Prosser Gulch, ¾ mile west of Central City.	50	.....do	1 jaw crusher, 1 set rolls, 10 stamps with outside amalgamation plates, Pierce amalgamator, 2 Wilfley tables, 2 Callow cones, 1 Deister slimer, 1 Frue vanner.
Casto	Winnebago Hill, north of Teller House, Central City.	30	.....do	1 jaw crusher, 10 stamps with outside amalgamation plates, 1 classifier, 2 concentrating tables, 1 Horn slimer.
Pleasant Valley	Elkhorn Gulch, 3 miles southeast of Blackhawk.		.....do	1 jaw crusher, 2 sets rolls, 20 stamps with outside amalgamation plates, 4 Gilpin County bumpers.
Avon	Nevada Gulch, east end of Nevadaville.	60-100	.....do	1 jaw crusher, 30 stamps with outside amalgamation plates, 6 Gilpin County bumpers, 1 Wilfley table.
Gold Coin	Nevada Gulch, south of Nevadaville.		.....do	25 stamps, 18 amalgamation pans. Partly dismantled.

Mills in Central City région treating gold-silver or silver ores—Continued.

Gilpin County—Continued.

Name.	Location.	Capacity (tons in 24 hours).	Process.	Equipment.
Clear Creek Mining & Milling Co.	Blackhawk		Concentrate mill waste	48 canvas tables, 2 Frue vanners, 2 Wilfley tables.
Eagle	....do		Amalgamation and concentration.	25 stamps, Gilpin County bumpers.
Oliver	....do		....do	Stamps, amalgamation plates, tables.
New York	....do	150	....do	70 stamps and amalgamation plates, 20 Gilpin County bumpers.
Randolph	....do	100	....do	Originally 50 stamps, 10 plates, 10 bumping tables, water power. In 1914 operating part of mill consisted of crusher, Challenge feeders, 10 750-pound stamps (53 drops a minute), amalgamation plates, 2 Gilpin County bumping tables, 6 Wilfley tables; electric power.
Iron City	North Clear Creek, ⅜ mile east of Blackhawk (immediately adjacent to Frontenac).	75	Concentration and subsidiary amalgamation.	1 jaw crusher, 25 rapid-drop stamps, Flood classifiers, 5 Card tables, 2 Deister tables, regrinding pan, 2 Callow cones.

SMELTING.

HISTORY.

After two unsuccessful attempts to smelt the ores of Gilpin County in 1861 and 1866,[1] a successful smelter was opened for business in January, 1868, at Blackhawk by Nathaniel P. Hill,[2] with two reverberatory furnaces, one for calcining and one for smelting.[3] In 1869 the works consisted of two reverberatories for roasting and two for smelting, together with roast heaps in the open air. There was also a terrace furnace, not used. Early in 1871 the plant consisted of two calcining furnaces for tailings, which are too finely pulverized to be roasted in heaps, two Gerstenhofer or terrace furnaces for calcining (never satisfactorily operated), and two reverberatory smelting furnaces.[4] The plant was enlarged during the summer of 1871 by one smelting furnace, a reverberatory of the same type as the two older ones. In 1872 a blast furnace was added for reworking slags obtained by the treatment of zinciferous silver ores.

From the beginning of operations this company had shipped its copper matte to Swansea, Wales, for separation, but in the summer of 1873 Richard Pearce [5] built separating works at Blackhawk for this smelter, and the first silver bullion, 0.998 fine, was turned out early in November. The residue was shipped to Boston for the recovery of the gold and copper.[6]

In 1875 Mr. Pearce invented a process for the separation of the gold, silver, and copper, at Blackhawk.[7] This process [8] was not made

[1] Raymond, R. W., Lyon's smelting works: Statistics of Mines and Mining in the States and Territories west of the Rocky Mountains, 1869, p. 359, 1870.

[2] Hill smelter or Boston & Colorado Smelting Co. organized in 1867; first experimental plant erected at Blackhawk in June, 1867; establishment opened for business January, 1868; first shipment of matte June, 1868.

[3] Bain, H. F., Matte smelting at Denver: Min. and Sci. Press, vol. 100, p. 251, 1910.

[4] For detailed description of process, see Raymond, R. W., Metallurgical processes (smelting): Statistics of mines and mining in the States and Territories west of the Rocky Mountains, 1869, pp. 362–363, 1870; 1870, pp. 368–370, 1872; also Hague, J. D., Mining industry: U. S. Geol. Expl. 40th Par. Rept., vol. 3, pp. 577–586, 1870.

[5] In April, 1872, Richard Pearce, of Swansea, Wales, built the Swansea smelter (capacity 8 tons in 24 hours) near Empire, Clear Creek County, similar in design to the Hill smelter. Owing to the deficiency of iron pyrite the smelter was operated steadily only about one month in 1872, but in 1873 it was operated intermittently, the deficiency being supplied from Gilpin County. No mention of the Swansea smelter is made in reports subsequent to 1874, and it was probably closed when Mr. Pearce took over the superintendency of the plant at Blackhawk and lead smelters were erected at Golden. Mr. Pearce apparently started at the Swansea smelter his experiments for the extraction of silver from the matte and carried the results of these experiments to Blackhawk.

[6] Raymond, R. W., op. cit., 1874, p. 361, 1875.

[7] For description of the Blackhawk plant and process, smelting charges, capacity, etc., see Egleston, T., The Boston and Colorado smelting works, in Raymond, R. W., Statistics of mines and mining in the States and Territories west of the Rocky Mountains, 1873, pp. 294–295, 379–394, 1877; Am. Inst. Min. Eng. Trans., vol. 4, pp. 276 et seq., 1876.

[8] The revelation of a metallurgical secret: Eng. and Min. Jour., vol. 87, pp. 464, 963, 1909. Pearce, H. V., Am. Inst. Min. Eng. Trans., vol. 39, pp. 722–734, 1908.

public until after the decision in 1908 to close and dismantle the smelter at Argo, a suburb of Denver to which the smelter had been removed in 1878 from Blackhawk, because of the expansion of business and the need of closer accessibility to fuel supplies. The refinery at Argo was destroyed by fire in 1906 and was not rebuilt. The fires of the smelting furnaces were finally "out" on March 17, 1910.

It was at the Argo smelter that Richard Pearce developed the smelting of copper ore in reverberatories, gradually working up from 5-ton to 100-ton furnaces. The works at one time included five furnaces, later reduced to two, and finally to one (1909–10). In 1900 the Argo works were the only works in the United States that smelted gold and silver ores to matte exclusively in reverberatory furnaces. Copper at Argo was merely a vehicle, and only sufficient cupriferous ore was employed to make sure of thoroughly collecting the precious metals, the average charge smelted containing less than 2 per cent copper. The ores treated comprised pyritic (auriferous) ores and concentrates from Gilpin County and elsewhere, barytic silver ores from Aspen and Creede, siliceous telluride and other gold ores from Cripple Creek, and any and every kind of ore containing gold and silver and not too rich in lead.[1]

While the Hill smelter at Blackhawk had the distinction of being the first successful smelter of the district and with its successor at Argo played a most important part in the development of this region, several other smelters were also in operation at different times. In 1872 there were in operation the Swansea matte smelter at Swansea, near Empire; a matte smelter at the Whale mill (now a part of the Stanley mill), near Idaho Springs; and a lead smelter at Golden (Bayley & Sons or Golden City Smelting Works). In 1873 a lead smelter (Denver Smelting Works) was established at Denver. In 1875 the Collom Co., which already had separating and concentrating works at Idaho Springs and Blackhawk, completed a lead smelter at Golden. The Golden Smelting Co.'s plant was constructed at Golden in the same year. This plant, which started in September, was first operated as a lead smelter, but as the supply of galena proved inadequate, it was altered to a copper-matte smelter. Golden became for a short time a smelting center of some importance. In 1880 three plants were in operation there, but from 1884 to 1888 inclusive, only one was in operation. In 1901 the Golden semipyritic plant was built by F. R. Carpenter according to plans developed at Rapid City and Deadwood, S. Dak., for the purpose of treating highly pyritic ores from Gilpin and Clear Creek counties. The smelter, operated for several years by the Clear Creek Mining & Reduction Co., smelted large quantities of ore from the Saratoga mine, which the company controlled, also ore bought in the open market. In April, 1910, this plant, after the addition of a reverberatory, was reopened as the North American semipyritic plant for the treatment of copper and pyritic ores of Gilpin, Clear Creek, and other counties, and was operated intermittently until November, 1911. Its building is still intact, but none of the other plants at Golden are standing.

About the time the owners of the Argo plant were planning to go out of business, a new matte smelter, styled the Modern, with McDonald furnace, went into blast on October 22, 1909, at Utah Junction, a short distance from Globeville, on ores purchased in the market from Clear Creek, Gilpin, Lake, and other counties, but it was closed in April, 1910, and was never operated again, being dismantled in 1915–16.

The American Smelting & Refining Co.'s Globe plant, at Denver, now treats most of the ores of this region. Some ore from Georgetown and Rollinsville goes to the Ohio & Colorado Smelting & Refining Co.'s plant, at Salida. Zinc ores and concentrates from Georgetown and Idaho Springs go to the United States Zinc Co.'s plant, at Blende, and to spelter plants in Kansas and Oklahoma.

EARLY SMELTING AND MILLING CHARGES.

The smelting and milling charges in the early days of the development of the region seem prohibitive compared with those now in vogue. The prices paid by the Blackhawk smelter previous to January 1, 1870, are shown in the following schedule, which was not, however, invariably adhered to.

[1] Collins, H. F., Silver, pp. 181, 299-303, 314-315, 1900.

Prices paid by Blackhawk smelter before 1870.

Ounces of fine gold per ton of 2,000 pounds.	Percentage of the value of the gold and copper paid.	Ounces of fine gold per ton of 2,000 pounds.	Percentage of the value of the gold and copper paid.
10	60	5	45
9	58	4	40
8	55	3	30
7	52.5	2	20
6	50		

In calculating the value of ore according to the above scale, the ounce of fine gold was reckoned at $20 coin, and the unit (1 per cent) of copper at $2. The copper unit, however, was reckoned on the English ton; and as the ores were assayed and purchased by the short ton, a deduction of 12 per cent was made from the copper assay. Thus, if an ore was found to contain 8 per cent (or 8 units) of copper, worth according to the above scale $16, a deduction of 12 per cent was made, to adapt it to the English ton. Moreover, the copper was determined by wet assay, from which 1.5 per cent was deducted for working loss, so that if the percentage of copper contained in an ore did not exceed 1.5, no account was taken of it in paying for the ore. The silver in the ore was paid for at the rate of 75 cents an ounce, after deducting 1 ounce of silver for each unit or per cent of copper present.

Raymond,[1] in discussing the smelter charges at this time, says:

The complicated system of prices, perquisites, and deductions employed by smelters in calculating their payment for ores is justly complained of by the miners, as serving merely to bewilder the seller and conceal the profits of the buyer. Many items might be simplified in the interest of fair dealing. The theory, however, is correct that the prices paid for ores must be graduated not merely according to their actual contents in valuable metals, but with reference also to the grade and character of ore, as influencing the cost of reduction. It is probable that on the foregoing schedule Prof. Hill lost something in the purchase of the lowest grades and made it up on the rich ores. Indeed, he would doubtless refuse to purchase 2-ounce gold ores, did he not require them, in the absence of cheaper fluxes, to mix with the others. * * * At the time of my visit, in the autumn of 1870, I was told that no regular schedule was followed. I heard of instances in which $5 a ton was paid for tailings, containing from 1 to 1¼ ounces of gold. The developments in Grand Island district [Caribou] having made silver ores an important part of the supply of the works, the prices paid for silver had been advanced, possibly to prevent shipments of ore to the East. For 100-ounce silver ores 80 cents per ounce was paid, and for very rich ores as high as $1.30 currency—a deduction of $50 per ton being made, however, for the cost of reduction. Probably these works, being well established and commanding large capital, could afford to advance prices still further, if competition should require it—a consideration full of warning to the eager projectors of rival establishments.

The precious metals in the ores were up to 1874 never paid for below a certain minimum, which for silver was 40 ounces and for gold 1½ ounces. In July, 1874, an arrangement was adopted whereby the Blackhawk smelter paid for gold ores at the rate of 85 per cent of the total value of the gold and silver contained after deducting $35 (currency) a ton for treatment. The gold was estimated at $20 an ounce and the silver at $1.25 (gold) an ounce, with the premium (3 per cent below New York quotations) added.

Schedules for silver ores are given in the table below, the minimum of 40 ounces still holding. The prices are based on the premium on gold in New York, ranging between $1.10 and $1.15.

Schedule of prices paid for silver ores by Blackhawk smelter July, 1874.

Silver content of ore (ounces per ton).	Price paid (in currency) per ounce of silver.	Silver content of ore (ounces per ton).	Price paid (in currency) per ounce of silver.
40	$0.34	300	$1.01
50	.44	350	1.03
60	.52	400	1.05
70	.60	450	1.06
80	.66	500	1.07
90	.70	600	1.08
100	.74	700	1.09
125	.82	800	1.10
150	.89	900	1.11
175	.93	1,000	1.12
200	.97	2,000	1.16
250	.99		

Copper was paid for at $1.50 currency for each unit by the dry Cornish assay.

SAMPLING WORKS.

DEVELOPMENT.

While not confined to this district nor to the State of Colorado, public sampling works for the purchase of ores were probably first established in this district and to this day have

[1] Raymond, R. W., Statistics of mines and mining in the States and Territories west of the Rocky Mountains, 1870, p. 372, 1872.

continued to be a vital factor in its mining industry. These works in the early days served as agents or brokers for smelters at Swansea, Wales, in Germany, and in the middle Western and Eastern States of this country. Later they acted as agents for or sold ores to the Blackhawk smelter, and still more recently have acted as agents or middlemen for smelters at Denver, Pueblo, and other localities within and without the State. The Chamberlain sampling works at Blackhawk was built on the site of the Hill smelter soon after its removal to Argo in 1878 and has been operated continuously since that time, selling the purchased ores both to the Argo smelter and to other smelters, according to the character of the ore. The Chamberlain sampling works at Idaho Springs was opened in 1883. At the present day the Chamberlain sampling works at Georgetown, Idaho Springs, and Blackhawk are the only ones remaining in operation, although during the time of the operation of the North American smelter at Golden the smelter company had its own sampling works at Idaho Springs, and for some time previous to 1910 the Santiago Mining Co. operated a sampling plant at Georgetown.

PAYMENT FOR ORES.

The sampling works pays the miner for his ore according to certain schedules or contracts based on the assay of the ore for the precious metals, the base metals, and other components that aid or interfere with smelting, the charges for sampling, freight, and smelting being deducted. An attempt is made to crush, sample, assay, and pay for the ore in one or two days, and in this promptness of payment lies the great advantage of the sampling works to the small producer. The miner can, if he so desires, watch all the operations of the sampler, and he has his own or a public assayer check the assaying of the sampler. If the ore is shipped direct to the smelter a much longer time elapses before payment for it can be received, and as a rule only the larger producers can brook this delay; moreover, the smelters do not handle less than carload lots. A considerable quantity of the ore received by the samplers is delivered irregularly in small lots, by the wagon load, with no contract as to grade, tonnage, price, or time of delivery, and in acting as a purchasing agent for ore of this class the sampler serves perhaps its most useful purpose. The engineer may use the sampler as a testing plant for small lots of ore of questionable grade; if those small lots do not carry sufficient quantities of metals to pay freight and treatment charges, he is out only the price of sampling, and the ore or rock can be transferred to an amalgamating or concentrating mill or thrown on the dump.

At present the Chamberlain sampling works act almost exclusively as agents for the American Smelting & Refining Co., although they have recently disposed of certain lead-zinc sulphide ores and uranium ores to other concerns. The sampling works have many contracts with mining companies whereby the latter can ship their ore either to the sampling works or direct to the American Smelting & Refining Co.; any contracts made with the American Smelting & Refining Co. will be fulfilled by the sampling works if the ore is shipped to the latter. The bulk of the ore from this district goes through the sampling works before going to the smelter. For the purchase of ores in this district the following publicly posted or "open" schedules were in use in February, 1916. The smelting charges given include sampling. If a contract is made to deliver a certain monthly tonnage, the smelting charge is $1 a ton less than the "open" schedule. If less than carload lots are delivered at the sampler, an additional $1 a ton is charged for sampling. Of the several schedules, payment is made in accordance with the one most favorable to the miner.

General schedule for all classes of ores and concentrates, Clear Creek, Gilpin, and Boulder districts, effective July 1, 1912.

[All rates f. o. b. cars Denver. Lots to contain not less than one carload. Subject to change without notice.]

Upon all classes of ore:

- Gold, $19 per ounce if 0.05 to 2 ounces per ton; $19.50 if over 2 ounces per ton.
- Silver, 95 per cent of the New York quotation on date of assay, when ore assays 2 ounces or over per ton.
- Copper, for dry copper (1.5 per cent off wet assay) up to and including 5 per cent, 6 cents off Western Union quotation for casting copper. Over 5 per cent to 10 per cent dry, 5 cents off quotation; over 10 per cent dry, 4 cents off quotation.
- Zinc, limit 10 per cent: Penalty 50 cents for every unit over 10 per cent.
- $14 gross value and under, $5 treatment charge.

Upon all classes of ore—Continued.

Over $14 to $20 gross value, $6 treatment charge.
Over $20 to $25 gross value, $6.50 treatment charge.
Over $25 to $30 gross value, $7 treatment charge.
Over $30 to $35 gross value, $7.50 treatment charge.
Over $35 to $40 gross value, $8 treatment charge.
Over $40 to $45 gross value, $8.50 treatment charge.
Over $45 to $50 gross value, $9 treatment charge.
Over $50 gross value, $10 treatment charge.
Pay 25 cents per unit for lead if 5 per cent or over.
Apply to lead ores "neutral schedule" or "flat schedule" of July 1, 1912, if either figures better for shipper than above schedule.
Apply to dry ores, $7 treatment charge, neutral basis, 10 cents added or subtracted for each unit of variation up or down from the neutral basis, when this figures better for shipper than the "flat schedule."

Dry concentrates:

Gold, silver, and copper as above.
Silica (insoluble matter), 10 per cent limit; penalty of 10 cents for every unit above 10 per cent.
Zinc, 5 per cent limit; penalty of 30 cents for every unit over 5 per cent.
$35 gross value and under, $3.50 treatment.
$36 to $80 gross value, $4 treatment charge.
Over $80 gross value, $4.50 treatment charge.

The maximum treatment charge upon concentrates, including silica penalty but not zinc penalty, shall not exceed the maximum charge upon crude ores of the same grade.

Special schedule for lead ores and concentrates: Clear Creek and Gilpin counties, effective July 1, 1912.

[All rates f. o. b. cars Denver. Subject to change without notice. Lots to contain not less than one carload.]

Lead ores:

Gold, $19.50 per ounce if 0.05 ounce or over per ton.
Silver, 95 per cent of the New York quotation on date of assay.
Lead, prices based upon $4 per 100 pounds and based on dry lead (1.5 per cent off wet assay).
Copper, for dry copper (1.5 per cent off wet assay) 6 cents off Western Union quotation for casting copper.
Zinc, 10 per cent limit; penalty 50 cents for every unit over 10 per cent.

Neutral schedule.

Per cent of lead (dry).	Price paid (cents per unit of lead).	Working charge per ton.
5 to 10, inclusive	40	$6.00
Over 10 to 15, inclusive	43	5.00
Over 15 to 20, inclusive	45	4.00
Over 20 to 25, inclusive	47	3.00
Over 25 to 30, inclusive	49	3.00
Over 30 to 35, inclusive	51	2.00
Over 35 to 40, inclusive	52	1.50
Over 40 to 45, inclusive	52	1.00
Over 45 to 50, inclusive	53	1.00
Over 50 to 55, inclusive	54	1.00
Over 55	55	1.00

Neutral basis; 10 cents added or subtracted for each unit of variation up or down from the neutral basis.

Flat schedule.

Per cent of lead (dry).	Price paid (cents per unit of lead).	Working charge per ton.
5 to 10, inclusive	40	$10.00
Over 10 to 15, inclusive	43	8.50
Over 15 to 20, inclusive	45	7.00
Over 20 to 25, inclusive	47	5.50
Over 25 to 30, inclusive	49	4.50
Over 30 to 35, inclusive	51	3.50
Over 35 to 40, inclusive	52	2.00
Over 40 to 45, inclusive	52	1.00
Over 45 to 50, inclusive	53	1.00
Over 50 to 55, inclusive	54	1.00
Over 55	55	1.00

"Neutral schedule" to be used when it figures better for shipper.

Lead concentrates:

Gold, $19 per ounce if 0.05 ounce to 2 ounces per ton; $19.50 if over 2 ounces.
Silver and copper, as in lead ores.
Lead, prices based on $4 per 100 pounds.
Silica, limit 10 per cent; penalty of 10 cents for every unit over 10 per cent.
Zinc, limit 10 per cent; penalty of 50 cents for every unit over 10 per cent.

Per cent of lead (dry).	Price paid (cents per unit of lead).	Working charge per ton.
5 to 10, inclusive	40	$3.75
Over 10 to 15, inclusive	43	3.00
Over 15 to 20, inclusive	45	2.50
Over 20 to 25, inclusive	47	2.25
Over 25 to 30, inclusive	49	2.25

Upon concentrates assaying over 30 per cent lead, apply "neutral schedule" or "flat schedule," whichever figures better for shipper; gold, $19 per ounce up to 2 ounces; $19.50 if over 2 ounces per ton.

LEAD QUOTATION.

The prices paid per unit for lead in all ores and concentrates are based upon a quotation of $4 per 100 pounds, 1 cent up or down for each change of 5 cents in the quotation.

The quotation used as a basis of settlement shall be figured as follows from the New York sales price of the American Smelting & Refining Co. on date of settlement. When the sales price does not exceed $4 per 100 pounds take 90 per cent of the sales price. When it does exceed $4, add to $3.60 per 100 pounds one-half of the excess of the New York sales price above $4.

As the name implies, the neutral schedule refers to the balance between iron and silica, and "neutral basis, 10 cents up or down" means that 10 cents per unit is paid for the iron excess over silica and 10 cents is deducted per unit of silica excess over iron.

The use of the schedules given above may be illustrated by the following examples.

Example I.

Calculation of the net value of a sulphide ore carrying 0.3 ounce of gold and 29 ounces of silver to the ton, 26 per cent of dry lead, 12 per cent of zinc, 18 per cent of silica, and 11 per cent of iron. Date, October 1, 1914.

A. Under neutral schedule.

	Credit.	Debit.
Gold, 0.3 ounce at $19.50 per ounce	$5.85	....
Silver, 29 ounces at 95 per cent of the New York quotation for the date of assay (which was 52$\frac{3}{8}$ cents per ounce)	14.43	....
Lead, 27.50 per cent wet assay, 26 per cent dry (26 units). Lead quotation $3.75 per 100 pounds; 90 per cent of $3.75 is $3.375; $4.00 less $3.375 is $0.625. For each change of 5 cents in the quotation, 1 cent up or down, so subtract 12.5 cents from 49 cents, making 36.5 cents per unit. 26 times 36.5 is	9.49	....
Smelting charges	....	$3.00
Silica excess over iron	....	.70
Zinc excess	....	1.00
	29.77	4.70
	4.70	....
Net value per ton	25.07	....

B. Under flat schedule.

	Credit.	Debit.
Credits as in neutral schedule	$29.77	....
Smelting charges	....	$4.50
Silica (no premium or penalty)	....	....
Zinc excess	....	1.00
	29.77	5.50
	5.50	....
Net value per ton	24.27	....

As this is a lead ore the general schedule for all classes of ore would not be best, for there would be a smelting charge of $7 alone for an ore of gross value between $25 and $30, and in addition there would be a penalty of $1 for zinc excess; moreover, gold would be paid for at $19 an ounce instead of $19.50. In this case, therefore, the neutral schedule for lead ores figures best for the shipper and is the one adopted.

Example II.

Calculation of the value of ore carrying 45 per cent silica and 15 per cent iron, the other constituents being as in Example I.

A. Under neutral schedule.

	Credit.	Debit.
Credits as under neutral schedule in Example I	$29.77	....
Smelting charges	....	$3.00
Penalty for silica excess over iron	....	3.00
Penalty for zinc excess	....	1.00
	29.77	7.00
	7.00	....
Net value per ton	22.77	....

Under flat schedule the net value would be $24.27, as in Example I under the flat schedule. In this case, therefore, the flat schedule figures better for the shipper and is the one adopted.

SETTLEMENT SHEET.

If a producer shipped to the sampler a lot of 12,720 pounds (6.36 tons), gross weight (4 per cent moisture, net weight 12,221 pounds, 6.11 tons), of the ore shown in Example I the sampler settlement sheet would be as follows, $1.50 a ton being charged for freight and $1 a ton for sampling (the shipment being less than a carload; see p. 164). The value of the ore is figured on the net weight.

.... Ore Sampling Co.,

Blackhawk, Colo., October 1, 1914.

.... mine.

Mine lot No.	Sampler lot No.	Gross weight.	Per cent H_2O.	Net weight.	Assay.				Gross per ton.	Net per ton.	Total net.
					Au.	Ag.	Pb.	Cu.			
1	4360	12,720	4.0	12,211	0.03	29.00	26.0	....	$29.77	$25.07	$153.06
										Freight....	9.54
											143.52
										Sampling..	6.36
											137.16

Quotations.	Fe.	SiO_2.	Zn.	S.
Ag. 52$\frac{3}{8}$....	11.00	18.00	12.00	[a] Sul.
Pb. 3.75...	....	....	....	....

Signed ....
Manager.

[a] "Sul" means over 6 or 7 per cent sulphur.

Zinc from this district goes to the smelter mostly in the form of concentrates, although a small quantity of zinc ore is produced in Clear Creek County. The ore runs 36 to 54 per cent in zinc, and the zinc concentrates from Gilpin County seldom exceed 25 per cent in zinc. The following schedule was in use in October, 1914:

Special schedule for Clear Creek and Gilpin counties for zinc ore and concentrates of smelting grade.

Base, f. o. b. Denver, carloads, $16.50 per ton.	Unit variation for 1 per cent or 1 ounce up or down from base.	Premium or penalty with variations in market price.
Spelter, St. Louis ..... $5 a hundredweight.	....	5 cents per ton for each variation of 1 cent from $5.
Lead, New York ..... $4 a hundredweight.	....	None.
Zinc, 40 per cent	$1.00	
Wet lead, 6.50 per cent.	.30	
Silver, 10 ounces	.40	
Gold, 0.05 ounce	19.00	
CaO+MgO, 1 per cent.	1.00	

EXAMPLE III.

Calculation of the value of an ore carrying 0.42 ounce of gold, 12.50 ounces of silver, 8.70 per cent of wet lead, 45 per cent of zinc, and 1 per cent of CaO. For this ore the zinc schedule would be the most advantageous, the calculation being as follows:

Base.	Assay and market values.	Variation from base.	Credit.	Debit.
$16.50	....	....	$16.50	......
Spelter, $5	Assume $4.90.	−$0.10 at 5 cents.	......	$0.50
Lead, $4	....	None	None.	None.
Zinc, 40 per cent.	45 per cent	+ 5.00 at $1..	5.00	......
Wet lead, 6.50 per cent.	8.70 per cent.	+2.20 at 30 cents.	.66	......
Silver, 10 ounces.	12.50 ounces	+2.50 at 40 cents.	1.00	......
Gold, 0.05 ounce.	0.42 ounce.	+0.37 at $19.	7.03	......
CaO+MgO, 1 per cent.	1 per cent..	None at $1...	None.	......
			30.19	0.50
			.50	......
Net value per ton.	....	....	29.69	......

EXAMPLE IV.

Calculation of the value of an ore carrying no gold, 112 ounces of silver, 13.50 per cent of wet lead, 32 per cent of zinc, 10 per cent of silica, and 10 per cent of iron.

A. Under zinc schedule.

Base.	Assay or market values.	Variation from base.	Credit.	Debit.
$16.50	....	....	$16.50	......
Spelter, $5	$6	+$1 at 5 cents	5.00	......
Lead, $4	$5.10	No variation.	......	......
Zinc, 40 per cent.	32 per cent.	−8 at $1	......	$8.00
Wet lead, 6.50 per cent.	13.50 per cent.	+ 7 at 30 cents.	2.10	......
Silver, 10 ounces.	112 ounces.	+102 at 40 cents.	40.80	......
Gold, 0.05 ounce.	None	−0.05 at $19.	......	.95
	Iron, 10 ..	....	......	......
	Silica, 10 ..	....	......	......
			64.40	8.95
			8.95	......
Net value per ton.	....	....	55.45	......

B. Under neutral lead schedule.

[Assumed market values, silver $0.64, lead $5.10.]

	Credit.	Debit.
Gold, 0.05 ounce, not paid for	......	......
Silver, 112 ounces, at $0.608 (95 per cent of $0.64) per ounce	$68.10	......
Lead, 12 per cent dry assay, at $0.46 per unit	5.52	......
NOTE.—The lead price is arrived at as follows: To $3.60 add $\frac{\$5.10-\$4.00}{2}$, or $0.55, making $4.15. To the 43 cents per unit shown in the schedule for ores with 10 to 15 per cent lead, add 3 cents, or 1 cent for each 5 cents difference between $4.15 and $4.00.		
Smelting charge	......	$5.00
Penalty for zinc (22 excess over 10 per cent)	......	11.00
	73.62	16.00
	16.00	......
Net value of ore per ton	57.62	......

For this ore the neutral lead schedule is more advantageous to the shipper than the zinc schedule and is the one adopted.

Had silver been 52 cents and lead $3.50, the credits under the neutral lead schedule would have been $55.33 for silver and $3.12 for lead, a total of $58.45 credits, from which the debit of $16 leaves a net credit of $42.45. In this case the zinc schedule would be better, with zinc market at $6. It is possible that for the ore represented above some reduction would be made in the $11 zinc penalty.

On October 14, 1914, the sampler had no schedule for zinc ore, concentrates, and middlings that must be reconcentrated, but for any such material a special price can be obtained on request.

On January 24, 1916, the following zinc schedule was issued:

United States Zinc Co.'s publicly posted zinc schedule January 24, 1916, for Georgetown, Idaho Springs, and Blackhawk, Colo.

Base: $20 f. o. b. Blende ($1 per ton additional freight Denver to Blende).
- 6.11 ounces gold.
- 13 ounces silver.
- 30 per cent zinc.

No regard for spelter quotations.

Premiums or penalties for variations up and down from base:
- Gold $19 per ounce.
- Silver $0.45 per ounce.
- Zinc $1.50 per unit over 30 per cent; $2 per unit under 30 per cent; no zinc less than 29 per cent.
- 1 per cent lime allowed, penalty of $1 per unit for excess.

The ores and concentrates purchased by the sampling works are kept in separate bins, and after the metal content of each lot has been calculated they are mixed in such proportion as to make the best charge for the blast furnace. The small quantity of copper ores produced in this region is not sent to copper plants, for there are no exclusively copper smelters in Colorado; such ore is mixed with the other ores and sent to the lead smelters. Copper, lead, and siliceous or dry ores are smelted at Denver, Pueblo, and Salida. The zinc and lead-zinc ores are treated at zinc smelters at Pueblo and at different localities in Kansas, Oklahoma, and Illinois. Formerly zinc-lead middlings were treated at the Western Chemical Co.'s sulphuric acid, wet concentration, and dry magnetic separation plant.

The following schedule of the Argo mill at Idaho Springs for the purchase of gold-silver ores from Gilpin and Clear Creek counties was still in effect February 21, 1916. The ores treated in 1914–15 ranged from strictly gold ores from Empire to silver-lead-gold, silver-gold-copper, and other complex ores from mines near the line of the Argo tunnel.

Schedule D, The Argo Reduction & Ore Purchasing Co., Idaho Springs, Colo., purchase of ores f. o. b. Argo Mill, November 10, 1914.

[Subject to change without notice.]

Gold: Pay $19 per ounce, if 0.05 to 1.5 ounces per ton; $19.50 per ounce if over 1.5 ounces per ton.

Silver: Pay New York quotation, date of assay, for 60 per cent of the silver assay, if 1 ounce or over per ton.

Lead: Deduct 2 units from the fire assay and pay 25 cents per unit for the balance.

Copper: Deduct 1.5 per cent from the wet assay and pay $1 per unit for the balance.

Zinc: No pay; no penalty.

Sampling: No charge.

No lots less than 10 tons received.

Treatment charges.

Gross value per ton.	Treatment charge per ton.	Gross value per ton.	Treatment charge per ton.
Up to $5.......	$3.50	Over $20 to $25.	$6.25
Over $5 to $6....	3.75	Over $25 to $30.	7.50
Over $6 to $7....	4.00	Over $30 to $35.	8.00
Over $7 to $8....	4.25	Over $35 to $40.	9.00
Over $8 to $9....	4.50	Over $40 to $45..	9.50
Over $9 to $10...	4.75	Over $45 to $50.	10.00
Over $10 to $11..	5.00	Over $50 to $75.	11.00
Over $11 to $14..	5.25	Over $75.......	12.00
Over $14 to $20..	5.50		

LABOR AND ROYALTIES.

For many years[1] the leasing system has been prevalent in mining in this region, and at one time or another has been operative in nearly every mine of the region. Under this system certain portions of a mine or more rarely the entire mine are leased for short terms to a miner or group of miners who assume the costs of operation and pay to the owners a royalty on the ore extracted. An effect of this system has been to give a large number of the miners of the region the status of independent operators and to exempt the region from the labor troubles that have afflicted many camps whose mines were under company operation. It has also permitted a large number of mines that might otherwise have been closed to continue operation, though rarely to their full capacity. On the other hand, the methods employed have not been as economical and far-sighted from the standpoint of the mining technologist as they might have been under company management, lessees naturally being more concerned in obtaining a quick and sure return on their investment than in safeguarding the interests of the owners or of future lessees. This difficulty has been obviated in some mines by the maintenance of a certain amount of company supervision over the operations of lessees, the com-

[1] As early as 1871 Raymond recorded that the larger number of the older claims which had been idle for several years had been taken up under lease by miners, almost every one of whom made good money, and some of them small fortunes.

pany under some contracts operating the hoists and furnishing rails and certain other equipment and maintaining through a superintendent some inspection of the methods of mining.

On ores of fairly uniform character, such as those of the Old Town and Saratoga mines, a flat royalty based on the net returns is charged. In many mines this amounts to 25 per cent for smelting ore, but in the Old Town, where the company hoists the ore and furnishes rails, etc., a royalty of one-third is charged. In the Perigo mine 25 per cent is charged on smelting ore and 10 to 15 per cent on concentrating ore. In the Ophir-Burroughs 10 per cent is charged on concentrating ores. In mines where the ore is more variable in metal content the charges are graded to the value of the ore. In the San Juan mine, for example, the royalties are as follows:

Net return on ore.	Royalty (per cent).
$40 or over	25
$25 to $40	20
Less than $25	15

In the Gem mine there is a graded royalty of 25 to 60 per cent, depending on the value of the ore, on ore mined through the shaft, and a flat rate of $1.25 a ton on smelting ore and $1 on concentrating ore taken out through the Argo tunnel, the company in the latter case paying the haulage charges.

Occasionally the royalties are graded according to the difficulties of mining. Thus in the Chase mine 15 per cent is charged on smelting ore and 10 per cent on concentrating ore when development work is necessary and 20 to 30 per cent on smelting ore taken from portions of the veins already opened.

Although wages are of course subject to much variation the following figures approximate the average: Hand-drill men, $2.75 to $3 a day; machine stoper men, $3 to $3.50; drifting-machine drill men, $3.50 to $4; engineers, $3.25 to $3.50; and muckers, trammers, etc., $3. The wages paid commonly increase somewhat with the distance of the mine from the principal towns.

FREIGHT RATES.

The freight rates on the Gilpin Tramway, a road of 24-inch gage that connects the principal mines of Gilpin County with Blackhawk, range from 35 to 75 cents a ton for smelting ore and concentrates, depending on the distance of the mine from Blackhawk. Minimum charges of $3 to $6 a car (holding about 9 tons) are fixed to prevent the shipment of only small lots in a car. For concentrating ore the rates are somewhat lower, ranging from $2.50 to $5 a car according to distance from Blackhawk.

Hauling charges in the Argo tunnel in February, 1916, were as follows: Waste 51 cents a car (of about 51 cubic feet capacity), or approximately 17 to 20 cents a ton; concentrating ore (under $20 in value) 60 to 75 cents a ton, according to quantity.

Switching charges from the mouth of the Argo tunnel to mills or sampling works at Idaho Springs are 15 cents a ton for lots of 20 tons or over.

Freight rates over the Colorado & Southern Railway are proportioned to the value of the smelting ore or concentrate. From the principal shipping points to either Golden or Denver they are as follows:

Freight rates to Golden or Denver by Colorado & Southern Railway.

From Blackhawk and Idaho Springs.

Ore value.	Charges per ton.
$9 or less	$0.75
$9 to $20	1.00
$20 to $30	1.50
Over $30	2.00

From Dumont.

Ore value.	Charges per hundredweight.
$9 or less	$0.05
$9 to $20	.06¼
$20 to $30	.08¾
$30 to $100	.11¼

From Empire station and Lawson.

Ore value.	Charges per hundredweight.
$9 or less	$0.05¾
$9 to $20	.07
$20 to $30	.09½
$30 to $100	.13

When the value exceeds $100 the above rates are doubled.

The freight rates for carload lots over the Denver & Salt Lake Railroad are as follows:

Freight rates from Tolland or Rollinsville to Denver by Denver & Salt Lake Railroad.

Ore value.	Charges per ton.
$20 or less	$1.00
$20 to $30	1.50
$30 to $40	2.00
$40 to $100	2.75
Over $100	5.50

Chapter XIII.—PRODUCTION.

By Charles W. Henderson.

The following tables of production have been compiled from the best sources available and revised to date. Footnotes show the exact source of each figure used. These data are taken from a report showing similar data for the State of Colorado, by counties, the statistical part of which is completed. Figures for the total production of the State, particularly for lead and copper, have always been more reliable than county figures, and where there are discrepancies the county figures have been prorated on a basis of the State total. For many items the aggregate of all counties was much more than the total for the State as a whole.

Metals produced in Clear Creek County, Colo., 1859–1914.

Year.	Ore (short tons).	Gold (value).			Silver.			Copper.			Lead.			Zinc.			Total value.
		Placer.	Lode.	Total.	Quantity (fine ounces).	Value.		Quantity (pounds).	Value.		Quantity (pounds).	Value.		Quantity (pounds).	Value.		
						Average per ounce.[a]	Total.		Average per pound.[a]	Total.		Average per pound.[a]	Total.		Average per pound.[a]	Total.	
1859-1865	....	b$2,000,000	....	bc$2,000,000	....	....	....	....	....	....	....	....	....	....	....	....	$2,000,000
1866	....	d 50,000	....	c d 50,000	15,123	$1.339	b $20,250	....	$0.3425	....	....	$0.07	....	....	....	....	70,250
1867	....	d 50,000	....	c d 50,000	15,226	1.33	b 20,251	....	.2537	....	....	.065	....	....	....	....	70,251
1868	....	d 50,000	....	d 50,000	106,953	1.326	b 141,820	....	.23	....	....	.065	....	....	....	....	191,820
1869	....	d 50,000	....	d 50,000	377,359	1.325	d 500,000	d 2,000	.2425	$485	d e 100,000	.06	$6,000	....	....	....	556,485
1870	f 2,000	d 80,000	....	d 80,000	362,465	1.328	b 481,354	d 2,500	.2118	530	de 2,000,000	.06	12,000	....	....	....	573,884
1871	....	b 20,000	....	b 20,000	640,790	1.325	b 849,047	d 3,000	.2412	724	d e 550,000	.06	33,000	....	....	....	902,771
1872	g 5,888	b 25,000	....	b 25,000	1,118,299	1.322	b 478,391	d 4,000	.3556	1,422	de 1,000,000	.064	64,000	....	....	....	1,568,813
1873	h 5,421	b 34,000	....	b 34,000	902,668	1.297	b 170,760	d 10,000	.28	2,800	de 1,000,000	.06	60,000	....	....	....	1,267,560
1874	i 9,490	b 42,500	....	b 42,500	d 1,634,434	1.278	2,088,807	d 15,000	.22	3,300	dej 803,983	.06	48,239	....	....	....	2,182,846
1875	k 12,000	b 68,960	$3,448	b 72,408	d 1,343,610	1.24	1,666,076	d 15,000	.227	3,405	de 1,300,000	.058	75,400	....	$0.07	....	1,817,289
1876	....	b 40,000	55,161	b 95,161	d 1,421,104	1.16	1,648,481	d 15,000	.21	3,150	d e 819,672	.061	l 50,000	....	.072	....	1,796,792
1877	....	b 20,000	76,500	b 96,500	d 1,534,560	1.20	1,841,472	d 15,000	.19	2,850	2,236,364	.055	l 123,000	....	.06	....	2,063,822
1878	....	b 10,000	124,000	b 134,000	d 1,759,652	1.15	2,023,600	d 25,000	.166	4,150	2,722,222	.036	l 98,000	....	.049	....	2,259,750
1879	....	d 10,000	110,000	m 120,000	m 1,546,875	1.12	1,732,500	d 100,000	.186	18,600	1,951,219	.041	l 80,000	....	.052	....	1,951,100
1880	....	d 5,000	191,000	n 196,000	n 1,902,656	1.15	2,188,054	d 200,000	.214	42,800	d 517,500	.05	25,875	....	.055	....	2,452,729
1881	....	o 5,000	195,000	o 200,000	o 1,546,875	1.13	1,747,969	d 200,000	.182	36,400	d 815,000	.048	39,120	....	.052	....	2,023,489
1882	....	o 6,000	214,000	o 220,000	o 1,299,375	1.14	1,481,288	o 300,000	.191	57,300	d 815,000	.049	39,935	....	.053	....	1,798,523
1883	....	d 10,000	240,000	o 250,000	o 1,222,031	1.11	1,356,454	d 300,000	.165	49,500	d 815,000	.043	35,045	....	.045	....	1,690,999
1884	....	o 12,551	587,449	o 600,000	o 1,314,844	1.11	1,459,477	d 300,000	.13	39,000	d 1,038,273	.037	38,416	....	.044	....	2,136,893
1885	....	d 10,000	490,000	p 500,000	p 1,356,000	1.07	1,450,920	d 200,000	.108	21,600	q 1,038,273	.039	40,493	d 25,000	.043	$1,075	2,014,088
1886	....	d 10,000	599,070	r 609,070	r 1,396,364	.99	1,382,400	d r 200,000	.111	22,200	d 1,630,000	.046	74,980	d 25,000	.044	1,100	2,089,750
1887	....	d 15,000	302,214	r 317,214	r 1,284,083	.98	1,258,401	d r 200,000	.138	27,600	r 1,847,930	.045	83,157	d 25,000	.046	1,150	1,687,522
1888	....	d 20,000	399,821	r 419,821	r 1,148,190	.94	1,079,299	d r 200,000	.168	33,600	r 3,761,246	.044	165,495	d 75,000	.049	3,675	1,701,890
1889	....	o 25,000	496,909	r 521,909	r 1,770,875	.94	1,664,623	r 91,731	.135	12,384	r 5,357,906	.039	208,958	d 75,000	.05	3,750	2,411,624
1890	....	o 24,336	418,032	r 442,368	r 1,819,682	1.05	1,910,666	r 124,102	.156	19,360	r 12,029,217	.045	541,315	d 75,000	.055	4,125	2,917,834
1891	....	d 22,875	415,692	r 438,567	r 1,771,055	.99	1,753,344	r 57,572	.128	7,369	r 7,947,786	.043	341,755	d 75,000	.05	3,750	2,544,785
1892	....	o 5,340	308,701	r 314,041	r 1,691,579	.87	1,471,674	d 40,424	.116	4,689	r 7,916,672	.04	316,667	d 250,000	.046	11,500	2,118,571
1893	....	d 5,000	579,187	r 584,187	r 2,218,377	.78	1,730,334	r 40,000	.108	4,320	dr 8,000,000	.037	296,000	d 400,000	.04	16,000	2,630,841
1894	....	d 5,000	657,649	r 662,649	r 2,228,846	.63	1,404,173	r 40,000	.095	3,800	dr 8,000,000	.033	264,000	d 200,000	.035	7,000	2,341,622
1895	....	o 5,000	669,210	r 674,210	r 1,585,483	.65	1,030,564	r 44,168	.107	4,726	r 6,415,936	.032	205,310	s 200,000	.036	7,200	1,922,010
1896	....	o 5,000	787,631	r 792,631	r 1,626,828	.68	1,106,243	r 204,519	.108	22,088	r 6,438,672	.03	193,160	d 400,000	.039	15,600	2,129,722
1897	....	o 50,000	732,649	t 782,649	t 1,442,583	.60	865,550	t 516,034	.12	61,924	t 5,263,116	.036	189,472	d 300,000	.041	12,300	1,911,895
1898	....	d 5,000	600,528	t 605,528	t 1,569,012	.59	925,717	t 317,423	.124	39,360	t 5,843,769	.038	222,063	d 300,000	.046	13,800	1,806,468
1899	....	d 5,000	541,825	t 546,825	t 1,502,900	.60	901,740	t 292,966	.171	50,097	t 7,216,260	.045	324,732	d 300,000	.058	17,400	1,840,794
1900	....	d 5,000	460,447	t 465,447	t 1,358,143	.62	842,049	t 244,092	.166	40,519	t 4,994,263	.044	219,748	d 300,000	.044	13,200	1,580,963
1901	....	d 5,000	535,975	t 540,975	t 1,271,227	.60	762,736	t 374,534	.167	62,547	t 3,890,216	.043	167,279	d 300,000	.041	12,300	1,545,837
1902	....	d 5,000	925,481	t 930,483	t 1,279,050	.53	677,897	t 473,754	.122	57,798	t 3,282,270	.041	134,573	t 317,705	.048	15,250	1,815,999
1903	....	d 5,000	467,061	t 472,061	t 851,638	.54	459,885	t 289,876	.137	39,713	t 3,451,849	.042	144,978	t 656,000	.054	35,424	1,152,061
1904	u 62,661	u 2,398	634,217	t 636,615	t 873,949	.58	506,890	t 401,180	.128	51,351	t 3,913,976	.043	168,301	t 906,705	.051	46,242	1,409,399
1905	u 58,775	u 1,881	501,817	u 503,698	u 692,437	.61	422,387	u 235,669	.156	36,764	u 3,270,211	.047	153,700	t 1,102,301	.069	65,036	1,181,585
1906	u 64,774	u 1,568	528,185	u 529,753	u 652,796	.68	443,901	u 235,375	.193	45,427	u 3,307,001	.057	188,499	t 1,733,477	.061	105,742	1,313,322
1907	u 79,548	u v 11,511	511,385	u 522,896	u 518,364	.66	342,120	u 171,340	.20	34,268	u 2,804,172	.053	148,621	t 2,771,960	.059	163,546	1,211,451
1908	u 109,672	u 2,610	656,506	u 659,116	u 503,551	.53	266,882	u 264,994	.132	34,979	u 2,015,010	.042	84,630	u 836,411	.047	39,311	1,084,918
1909	u 116,753	u 3,846	532,561	u 536,407	u 448,535	.52	233,238	u 299,546	.13	38,941	u 3,254,675	.043	139,951	u 758,074	.054	40,936	989,473
1910	u 109,954	u 3,678	518,846	u 522,524	u 475,174	.54	256.594	u 595,795	.127	75,666	u 2,434,476	.044	107,117	u 1,247,389	.054	67,359	1,029,260
1911	u 105,774	u 1,754	517,453	u 519,207	u 437,841	.53	232,056	u 650,368	.125	81,296	u 3,325,222	.045	149,635	u 1,417,544	.057	80,800	1,062,994
1912	u 102,892	u 331	445,463	u 445,794	u 373,940	.615	229,973	u 449,401	.165	74,151	u 3,523,733	.045	158,568	u 1,734,493	.069	119,680	1,028,166
1913	u 104,892	(u)	432,489	u 432,489	u 408,527	.604	246,750	u 426,393	.155	66,091	u 3,999,614	.044	175,983	u 1,489,518	.056	83,413	1,001,726
1914	u 101,366	....	495,275	u 495,275	u 345,387	.553	190,999	u 367,790	.133	48,916	u 2,435,692	.039	94,992	u 1,067,314	.051	54,433	884,615
	....	2,851,139	17,958,837	20,809,976	54,967,315	....	49,946,056	9,555,546	....	1,389,960	155,293,394	....	6,532,162	19,363;891	....	1,062,097	79,740,251

[a] McCaskey, H. D., Prices of silver, copper, lead, and zinc, 1850–1913, U. S. Geol. Survey Mineral Resources, 1913, pt. 1, p. clxxiii, 1914.

[b] Director Mint Rept. for 1887, p. 153, value of gold and silver. Gold and silver prorated by Charles W. Henderson on basis of subsequent figures or from reports of R. W. Raymond on States and Territories west of the Rocky Mountains for 1869 to 1875.

c From placers at Idaho Springs and surface workings of lode deposits at Empire.
d Estimated by Charles W. Henderson.
e Represents lead in ores shipped to Eastern States, to England, and to Germany.
f Raymond, R. W., op. cit., 1870, p. 316, 1872.
g Idem, 1872, pp. 277-278, 1873.
h Idem, 1873, p. 287, 1874.
i Idem, 1874, p. 365, 1875.
Idem, 1874, p. 365.
k Idem, 1875, p. 295, 1877.
l U. S. Geol. Survey Prof. Paper 63, p. 175, 1908.
m Burchard, H. C., Director Mint Rept. for 1880, p. 156.
n Idem, p. 157.
o Director Mint reports.
p Interpolation by Charles W. Henderson to agree with total for State in Director Mint reports.
q U. S. Geol. Survey Mineral Resources, 1885, p. 257, figuring 15 per cent reduction correctly.
r From reports of the agents of the mint, the gold and silver being prorated to correspond with the corrected figures of the total production of the State by the Director of the Mint, the lead production being prorated to correspond with the total production of the State in annual volumes of U. S. Geol. Survey Mineral Resources, and any "unknown production" of the State being distributed proportionately to the several counties. Copper treated similarly to lead, but as Mineral Resources figures for copper included copper from matte and ores treated in Colorado smelters from other States, the copper figures are subject to revision.
s Ore receipts of American Zinc-Lead Co., Canon City.
t Colorado State Bureau of Mines, figures being smelter and mint receipts.
u U. S. Geol. Survey Mineral Resources, being figures collected from mines.
v Includes $7,628 "unknown gold," probably stamp gold not placer.

Metals produced in Gilpin County, Colo., 1859–1914.

Year.	Ore (short tons).	Gold, lode and placer (value).[a]	Silver.			Copper.			Lead.			Zinc.			Total value.
			Quantity (fine ounces).	Value.		Quantity (pounds).	Value.		Quantity (pounds).	Value.		Quantity (pounds).	Value.		
				Average per ounce.[b]	Total.		Average per pound.[b]	Total.		Average per pound.[b]	Total.		Average per pound.[b]	Total.	
1859		c $241,918	5,943	$1.36	c $8,082		$0.22			$0.55					$250,000
1860		c 870,903	21,553	1.35	c 29,097		.23			.055					900,000
1861		c 725,753	18,231	1.33	c 24,247		.22			.05					750,000
1862		c 1,161,204	28,738	1.35	c 38,796		.22			.06					1,200,000
1863		c 1,548,272	38,460	1.345	c 51,728		.34			.06					1,600,000
1864		c 1,741,806	43,267	1.345	c 58,194		.47			.07					1,800,000
1865		c 1,451,505	36,272	1.337	c 48,495		.3925			.066					1,500,000
1866		c 725,753	18,108	1.339	c 24,247	(d)	.3425			.07					750,000
1867		c 967,670	24,308	1.33	c 32,330	(d)	.2537			.065					1,000,000
1868		e 1,640,000	93,311	1.326	e 123,730	f 50,000	.23	$11,500		.065					1,775,236
1869		e 2,690,000	86,340	1.325	e 114,400	f 100,000	.2425	24,250		.06					2,828,650
1870		e 2,120,000	65,910	1.328	e 87,528	f 180,000	.2118	38,124		.06					2,245,652
1871		e 3,237,346	59,229	1.325	e 78,478	f 180,000	.2412	43,416		.06					3,359,240
1872		e 2,083,611	52,911	1.322	e 69,948	f 200,000	.3556	71,120		.064					2,224,679
1873		c 1,393,931	35,907	1.297	c 46,571	f 200,000	.28	56,000	f 25,000	.06	$1,500				1,498,002
1874		g 1,525,447	g 39,418	1.278	50,376	g 252,050	.22	55,451	f 50,000	.06	3,000				1,634,274
1875		h 1,395,566	h 62,670	1.24	77,711	i 193,665	.227	43,962	f 50,000	.058	2,900		$0.07		1,520,139
1876		j 1,990,002	j 89,365	1.16	103,663	f 250,000	.21	52,500	f 50,000	.061	3,050		.072		2,149,215
1877		j 2,086,871	j 93,714	1.20	112,457	f 300,000	.19	57,000	f 50,000	.055	2,750		.06		2,259,078
1878		j 2,155,708	j 96,806	1.15	111,327	f 300,000	.166	49,800	f 50,000	.036	1,800		.049		2,318,635
1879		k 2,260,000	k 232,031	1.12	259,875	f 300,000	.186	55,800	f 100,000	.041	4,100		.052		2,579,775
1880		l 2,380,000	l 232,031	1.15	266,836	f 300,000	.214	64,200	f 100,000	.05	5,000		.055		2,716,036
1881		m 1,850,000	m 201,094	1.13	227,236	f 300,000	.182	54,600	f 100,000	.048	4,800		.052		2,136,636
1882		n 1,600,000	n 201,094	1.14	229,247	f 400,000	.191	76,400	f 100,000	.049	4,900		.053		1,910,547
1883		o 1,650,000	o 154,688	1.11	171,704	f 200,000	.165	33,000	f 100,000	.043	4,300		.045		1,859,004
1884		p 1,950,000	p 278,438	1.11	309,066	f 600,000	.13	78,000	f 128,411	.037	4,751		.044		2,341,817
1885		q 2,051,000	q 300,000	1.07	321,000	f 300,000	.108	32,400	r 128,411	.039	5,008		.043		2,409,408
1886		s 1,337,061	s 101,784	.99	100,766	f 300,000	.111	33,300	t 200,000	.046	9,200		.044		1,480,327
1887		s 1,134,476	s 266,281	.98	260,955	f 600,000	.138	82,800	s 228,622	.045	10,288		.046		1,488,519
1888		s 1,250,756	s 174,364	.94	163,902	f 400,000	.168	67,200	s 1,288,825	.044	56,708		.049		1,538,566
1889		s 1,054,065	s 313,071	.94	294,287	s 250,110	.135	33,765	s 1,411,926	.039	55,065		.05		1,437,182
1890		s 805,236	s 292,495	1.05	307,120	s 620,927	.156	96,865	s 1,130,453	.045	50,870		.055		1,260,091
1891		s 938,016	s 232,001	.99	229,681	s 558,298	.128	71,462	s 779,837	.043	33,533		.05		1,272,692
1892		s 1,358,157	s 134,462	.87	116,982	s 538,988	.116	62,523	s 2,232,158	.04	89,286		.046		1,626,948
1893		s 1,218,626	s 135,850	.78	105,963	t 600,000	.108	64,800	t 2,000,000	.037	74,000		.04		1,463,389
1894		s 1,915,863	s 228,927	.63	144,224	t 400,000	.095	38,000	t 2,200,000	.033	72,600		.035		2,170,687
1895		s 1,196,319	s 190,256	.65	123,666	q 209,414	.107	22,407	s 844,037	.032	27,009		.036		1,369,401
1896		s 1,534,358	s 295,182	.68	200,724	q 435,838	.108	47,071	s 1,948,756	.03	58,462		.039		1,840,615
1897		u 2,086,471	u 374,417	.60	224,650	u 1,018,595	.72	122,231	u 2,007,698	.036	72,277		.041		2,505,629
1898		u 1,983,514	u 305,687	.59	180,355	u 633,707	.124	78,580	u 1,216,338	.038	46,221		.046		2,288,670
1899		u 1,996,061	u 340,652	.60	204,391	u 1,037,421	.171	177,399	u 1,312,312	.045	59,054		.058		2,436,905
1900		u 1,655,502	u 236,400	.62	146,568	u 799,478	.166	132,713	u 735,773	.043	32,374		.044		1,967,157
1901		u 1,638,966	u 271,638	.60	162,983	u 731,194	.167	122,109	u 670,018	.043	28,811		.041		1,952,869
1902		u 1,551,035	u 303,638	.53	160,928	u 765,516	.122	193,393	u 497,366	.041	20,392		.048		1,925,748
1903		u 1,346,113	u 375,238	.54	202,629	u 611,988	.137	83,842	u 945,975	.042	39,731		.054		1,672,315
1904	v 109,557	v 1,403,865	v 318,406	.58	184,675	v 638,945	.128	81,785	v 859,293	.043	36,950		.051		1,707,275
1905	v 182,873	v 1,450,033	v 340,901	.61	207,950	v 512,276	.156	79,915	v 519,841	.047	24,433	u 33,090	.059	$1,952	1,764,283
1906	v 114,662	v 1,115,902	v 242,478	.68	164,885	v 638,002	.193	123,134	v 510,791	.057	29,115	u 46,000	.061	2,806	1,435,842
1907	v 87,887	v 938,488	v 209,347	.66	138,169	v 874,060	.20	174,812	v 611,060	.053	32,386		.059		1,283,855
1908	v 120,761	v 1,075,808	v 187,030	.53	99,126	v 636,371	.132	84,001	v 538,143	.043	22,602		.047		1,281.532
1909	v 111,118	v 887,311	v 172,010	.52	89,445	v 499,146	.13	64,889	v 664,581	.043	28,577		.054		1,070,225
1910	v 83,631	v 687,902	v 132,635	.54	71,623	v 534,244	.127	67,849	v 575,477	.044	25,321		.054		852,695

1911	[v] 103,038	[v] 778,774	[v] 292,659	.53	155,109	[v] 950,240	.125	118,780	[v] 1,239,356	.045	55,771	[v] 23,088	.057	1,316	1,109,705
1912	[v] 118,652	[v] 904,505	[v] 316,205	.615	194,466	[v] 1,025,770	.165	169,252	[v] 1,351,600	.045	60,822	[v] 25,377	.069	1,751	1,330,796
1913	[v] 94,156	[v] 687,101	[v] 273,207	.604	165,017	[v] 837,974	.155	129,886	[v] 1,210,341	.044	53,255	[v] 8,589	.056	481	1,035,740
1914	[v] 52,839	[v] 573,553	[v] 145,237	.553	80,316	[v] 726,579	.133	96,635	[v] 499,718	.039	19,489	[v] 12,980	.051	662	770,655
	....	81,998,103	9,812,295	....	7,957,924	22,990,796	....	3,613,921	31,262,117	....	1,272,461	149,124	....	8,968	94,856,377

[a] How much of the early gold production should be credited to placers can not be estimated. While the greater part for the first few years was taken out by placer methods, the bulk of the material treated was the oxidized decomposed portion of the lodes, and not placer deposits in the true sense of the word. In later years no placer gold worth mentioning has been taken out, although there are placer deposits worthy of exploration near Perigo and Rollinsville.

[b] McCaskey, H. D., Prices of silver, copper, lead, and zinc, 1850–1913, U. S. Geol. Survey Mineral Resources, 1913, pt. 1, p. clxxiii, 1914.

[c] Director Mint Rept., 1887, p. 151, value of gold and silver. Gold and silver separated by Charles W. Henderson on proportion of figures for 1874.

[d] O. J. Hollister, The mines of Colorado, p. 357, 1867, credits J. E. Lyons smelter with 100 to 200 tons of matte on hand. R. W. Raymond, op. cit., 1869, credits J. E. Lyons smelter with 80 to 100 tons of matte produced in 8 months, beginning in the summer of 1866, and with the discovery of 100 tons additional, which was found later when plant was torn down. No record of assay of copper in this matte or record of sale of this matte is given.

[e] Increased by Charles W. Henderson to agree with R. W. Raymond's figures for Colorado for these years.

[f] Estimated by Charles W. Henderson, from U. S. Geol. Survey Mineral Resources, 1881–82, p. 228, and subsequent volumes; and Raymond, R. W., op. cit., 1870, p. 372. Raymond's figures for 1868, 1869, and 1870 are stated to be estimates which he himself thinks high. From Raymond's 1874 and 1875 data, said to be a statement from the Blackhawk smelter, it is seen that the small plant of 1868, 1869, and 1870 could not have produced more than the enlarged plant of 1874–75. In 1868, 1869, and 1870 Raymond estimates matte averaged 40 per cent copper. In 1875 Egleson gives more authentic data, including matte 25 to 30 per cent copper.

[g] Raymond, R. W., Statistics of mines and mining in the States and Territories west of the Rocky Mountains, 1874, p. 360, 1875.

[h] Idem, 1875, p. 289, 1877.

[i] Idem, p. 294.

[j] Director Mint Rept., 1887, p. 151, value of gold and silver. Gold and silver separated by Charles W. Henderson on proportion of figures for 1879.

[k] Burchard, H. C., Director Mint Rept., 1880, p. 156.

[l] Idem, p. 157.

[m] Idem, 1881, p. 355.

[n] Idem, 1882, p. 394.

[o] Idem, 1883, p. 240.

[p] Idem, 1884, p. 177.

[q] Director Mint Rept., 1887, p. 151, value of gold and silver. Gold and silver prorated to correspond with total production of State.

[r] U. S. Geol. Survey Mineral Resources, 1885, p. 257, figuring 15 per cent reduction correctly.

[s] From reports of the agents of the mint in annual reports of the Director of the Mint, the gold and silver being prorated to correspond with the corrected figures of the total production of the State by the Director of the Mint, the lead production being prorated to correspond with the total production of lead in the State in annual volumes of U. S. Geol. Survey Mineral Resources, and any "unknown production" of the State being distributed proportionately to the several counties. Copper treated similarly as lead, but as Mineral Resources figures for copper include copper from matte and ores treated in Colorado smelters from other States, the copper figures are subject to revision.

[t] Estimated by Charles W. Henderson.

[u] Colorado State Bureau of Mines figures, being smelter and mint receipts.

[v] U. S. Geol. Survey Mineral Resources, being figures collected from mines.

PART III.—THE MINES.

By Edson S. Bastin and James M. Hill.

Chapter XIV.—BOULDER COUNTY.

CARIBOU, NEDERLAND, AND VICINITY.

GENERAL FEATURES.

Some prospecting for gold had been done in the Caribou, or Grand Island district (as it was called in the early sixties), but the early prospectors were not on the lookout for silver ores and it was not until 1869 that the presence of this metal was recognized. In that year Samuel Conger discovered the outcroppings of a vein which he called the Poor Man; and William Martin and George Lytle found a lode a little farther up the hill which they named the Caribou. Assays showed that both veins contained large amounts of silver, and before winter a wagon load of ore had been mined and sent to the smelter at Blackhawk. In the succeeding summer (1870) a wagon road was constructed to the mine and regular shipments were begun to Blackhawk, 20 miles away. The success of these ventures caused a rush to the district and resulted in the discovery of numerous other veins, including the Boulder County, Idaho, Sherman, No Name, and Seven-Thirty, and led to the founding of the town of Caribou, which in November, 1870, had about 30 houses and 125 voters. The great development of mining at Caribou may be said to date from the completion in 1871 of a mill at Nederland (then called Middle Boulder) for the treatment of the silver ores from the Caribou mine. This mill was built by A. D. Breed, who had purchased the western portion of the Caribou lode from its discoverers.

The essential features of the milling process were chloridizing roasting in Brüchner cylinders, followed by pan amalgamation, and the capacity of the works was 18 to 20 tons per day. The bullion recovered had a fineness in silver of 0.850 to 0.950. Shortly after the completion of this mill Breed obtained control of the whole Caribou lode and sold it to a Dutch company for the exorbitant amount of $3,000,000. According to Raymond[1] Caribou was very active in 1875, its gross production amounting to $450,000, an increase of more than $100,000 over the figures for 1874. The Caribou mine was the largest producer, other mines operated being the Sherman, No Name, Poor Man, Grand View, Native Silver, Seven-Thirty, Idaho, Potosi, and Sovereign People. In the winter of 1875–76 the Dutch company operating the Caribou mine failed, causing a temporary setback that was offset in a measure by the completion at Caribou of a new mill, operated on the same principle as that at Nederland, for the treatment of ore from the Native Silver mine.

The silver ores yielded by the camp in early days were very rich. For instance, assorted lots of from 1 to 7 tons sent to the smelter from the Caribou mine are said to have assayed from 235 to 666 ounces of silver to the ton, and 39 tons to have averaged over 300 ounces. Raymond[2] gives the following table of assays of silver ore shipped from the Idaho mine to the Blackhawk smelter in 1870:

Assays of shipments of silver ore from the Idaho mine, 1870.

Tons.	Ounces per ton.
3. 25	874
. 56	103
6. 5	977. 5
4. 35	922. 4
1. 28	618. 2
15. 94	3, 115. 1

Aveiage per ton, 195.4 ounces.

Up to July, 1880, the total yield of the Caribou mine is said to have been about $1,168,000.

[1] Raymond, R. W., Statistics of mines and mining in the States and Territories west of the Rocky Mountains, 1875, pp. 306–307, 1877.
[2] Idem, p. 327.

SILVER VEINS OF BALD MOUNTAIN AND CARIBOU HILL.

UP TO DATE MINE.

The Up to Date mine is at the southeast base of Bald Mountain, about a mile northwest of the small mining camp of Caribou. The main development consists of a tunnel about 1,900 feet in length. The principal geologic features are shown in figure 20, to which the lettering used below refers.

Vein A: A highly oxidized vein 2½ feet in width, carrying some white quartz.

Vein B: A 1½-inch veinlet of calcite.

Dardanell No. 1: A vein 4 feet in width, composed of small subparallel veinlets of calcite locally carrying some chalcopyrite.

Dardanell No. 2: A vein which, at the face of the north drift, contains in a width of 8 feet numerous veinlets of calcite, most of them less than three-quarters of an inch wide. At the face of the south drift monzonite is traversed by a single 1-inch veinlet of calcite, locally carrying a little galena. In the stope on this vein, just south of the line of the tunnel, the vein is more or less oxidized, being only about 60 feet from the surface, and shows much calcite and some vugs lined with quartz. The vein here shows no metallic minerals, but a specimen taken from the ore bin and reported to have come from this stope showed numerous small veinlets, consisting predominantly of bornite and chalcocite, with subordinate calcite and native silver. Another specimen from this stope shows pyroxenite heavily impregnated with galena and traversed by minute fractures along which native silver has been deposited. This rich silver ore is believed to have been formed by downward enrichment. (See pp. 147–149.)

Vein C: A 1 to 2½ inch calcite vein.

Vein D: A calcite veinlet three-quarters of an inch wide.

Vein E: A zone of altered monzonite 1 foot wide traversed by several narrow stringers of calcite.

Eureka vein: An indefinite zone of fracturing characterized locally by sharp-walled veinlets of quartz and chalcopyrite or of calcite. In a stope north of the line of the tunnel level a 1½-foot zone of soft much-altered pyroxenite is traversed by numerous small calcite stringers. At another place in this stope the fractured zone is 3 feet wide and, in addition to calcite stringers, contains lens-shaped masses of white quartz, carrying pyrite and chalcopyrite and a

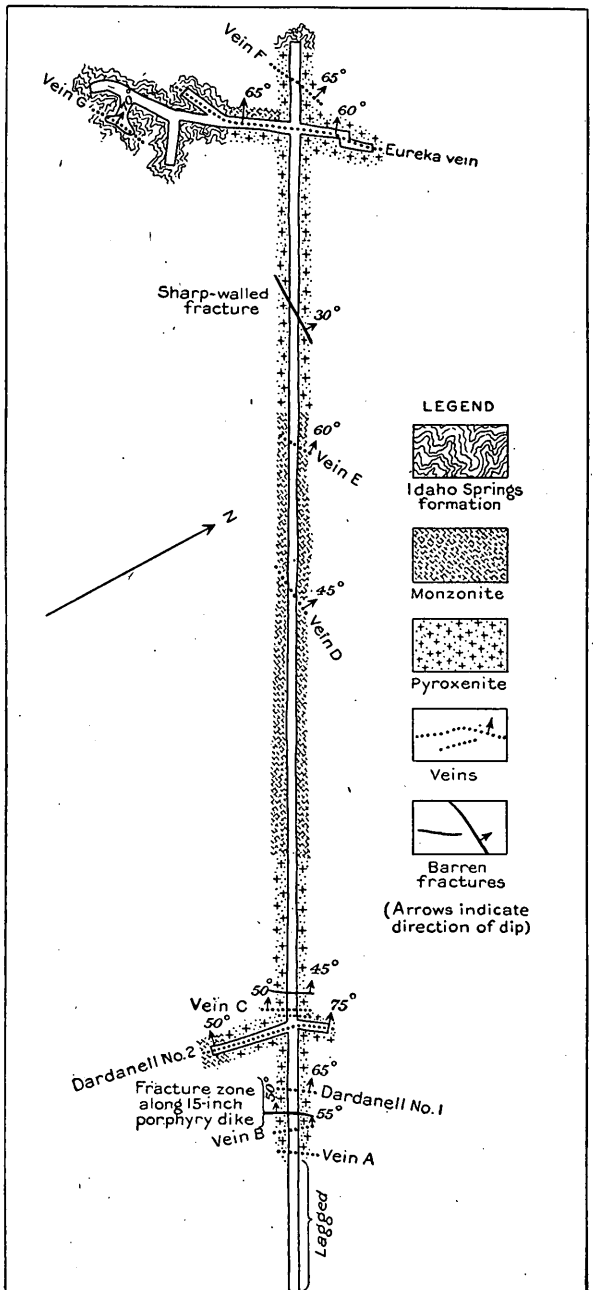


FIGURE 20.—Geologic plan of Up to Date tunnel, Caribou. Surveyed by hand compass and pacing.

few flakes of molybdenite. In places the calcite stringers cut sharply across the quartz-pyrite-chalcopyrite masses. In the tunnel a few feet beyond the Eureka vein the pyroxenite carries abundant disseminated pyrite.

Vein F: A network of calcite veinlets, which is reported to carry locally some chalcopyrite.

Vein G: A vein exposed in a short crosscut, which shows 7 feet of schist traversed by subparallel stringers of quartz and pale-pink calcite, some of which carry sphalerite, galena, and a little chalcopyrite.

In general the ore taken from the veins in the Up to Date tunnel as well as that obtained in the past from shallow workings now long abandoned in the Eureka and neighboring veins was valuable principally for its silver content. Chalcopyrite ore from the Eureka vein is said, however, to carry in places as much as 2 ounces in gold. Most of the silver occurs native and one mass of silver measured 6 by 8 inches by one-fourth to 1 inch thick. What appeared to be polybasite or pearceite, although no opportunity was afforded for testing it, was associated with native silver in one specimen seen by the writer. Stephanite is also reported to have been observed in the ore. All these silver minerals, as well as the bornite, covellite, and chalcocite locally associated with the native silver, are believed to have been formed through the process of downward enrichment. (See pp. 147–149.) Galena and chalcopyrite are sufficiently abundant to form by their weathering in the gossan an adequate source for the rich ores, especially when the original extension of the veins above the present surface is taken into account.

The predominant metasomatic alteration in the wall rocks next the primary ore is the development of sericite, as is well shown in the walls of the Eureka vein. The alteration of pyroxenite carrying abundant disseminated galena, as seen in a stope on the Dardanell No. 2 vein, is instructive. This rock consisted originally of biotite, pyroxene, apatite, and titaniferous magnetite. The biotite has been bleached and small grains of iron oxide have been developed in it so that it is nearly colorless and shows only faint pleochroism. In small part it has been replaced by calcite. Original pyroxene has been replaced by a mixture of calcite and sericite—in some areas wholly by sericite. Titaniferous magnetite has wholly disappeared, its place being apparently taken by a mixture of carbonate and red oxide of iron. Secondary quartz forms irregular aggregates of small grains. Irregular masses of galena and some sphalerite appear to replace indiscriminately all the original constituents except apatite, which remains wholly unaltered. In short, in these places, in addition to the development of calcite, sericitization is an important metasomatic process.

In contrast, the wall rock near veinlets of chalcocite, bornite, and native silver and calcite show no sericite. The rock studied was similar to that last described and was taken from another part of the same stope in the Dardanell vein No. 2; it has been altered to an association of calcite and quartz, through which chalcocite, bornite, and native silver are distributed as isolated irregular patches or as irregular replacement veinlets. (See fig. 19, p. 149.) In the portions in which these sulphides are most abundant sericite is entirely absent. The absence of sericitization, so characteristic of galena-sphalerite mineralization, is additional evidence that the deposition of the native silver and the rich copper minerals was not a phase of the primary mineralization but was a distinct process, probably attributable to descending surface waters. The abundant intergrowth of calcite with the native silver, chalcocite, and bornite of these veins shows conclusively that the depositing waters were not acidic in character.

Mining through the Up to Date tunnel had up to the time of this survey been mainly exploratory in character, and the total output had as yet been small.

CARIBOU MINE.

All the workings of the famous Caribou mine, on the north side of Caribou Hill, were inaccessible at the time of this survey, the mine having been idle for many years. From the discovery of the property in 1869 until 1880 the mine was in almost constant operation; in 1873 its main shaft was 370 feet deep; at the close of 1875 it was a little over 500 feet deep; and at present it is said to be about 800 feet deep.

Lawrence Thompson[1] describes the appearance of the vein in 1871 as follows:

> The vein does not show well-defined walls. A hanging wall especially can never be recognized, while a footwall

[1] Raymond, R. W., Statistics of mines and mining in States and Territories west of the Rocky Mountains, 1872, p. 359, 1873.

shows itself in spots, being separated from the vein by a very thin selvage. But in the greater part of the workings there was nothing found to define the vein sharply. The gangue is a very hard and tough quartz. There is sometimes only one pay streak, from one-half to 4 or 5 inches wide, and in these cases this is exceedingly rich. At other times there are a great many thin seams of high-grade ore running through the vein. But very rarely is the quartz interspersed with silver-bearing minerals throughout its width, or even its greater part.

Writing in 1872, Thompson [1] says further:

There are in this mine 11 shafts, aggregating 1,248 feet in depth. The main or working shaft is 329 feet deep, another is 229, a third is 129, and eight others are from 20 to 100 feet deep. There are also four levels, aggregating 1,678 feet in length. The crevice may be stated to be from 6 to 8 feet in width, and the paying part of the vein from 6 inches to 4 feet wide. The ores of this mine are sulphurets of silver, argentiferous galena, brittle and native silver, with but little zinc blende.

Examination of the dump shows galena, sphalerite (in part resinous), chalcopyrite, pyrite, quartz, and barite as primary vein minerals, and native silver in wire and leaf form, malachite, azurite, limonite, and hematite as secondary minerals. One specimen showed jasper developed in vugs with iron-stained quartz and in one place inclosing a wire of native silver. Argentite, pyrargyrite, and cerusite have been reported.

The Caribou mine has in the past yielded large amounts of very rich silver ores, most of which were a product of downward enrichment. According to Raymond [2] a falling off in silver content in depth, characteristic of such enrichment, was noted as early as 1874. The unenriched primary ore appears not to be of workable grade.

The ore mined from near the surface was very rich. Twenty-six tons shipped in 1869 had an average assay value of about $124, and 425 tons of smelting ore extracted in 1870 had an average value of about $173.[3]

According to a statement made by Mr. A. D. Breed, then owner of the mine, the number of tons mined and milled between September 21, 1870, and October 1, 1872, was 3,650¾, and the net profit was $90 a ton. Most of the ore obtained during 1874 is said to have carried 60 to 90 ounces of silver to the ton.

Recently reworking of the old dump and stope fillings by cyanidation has been undertaken in a new mill which was constructed in 1914. The equipment of this mill is given in the table on page 157.

The total production of the mine is not accurately known but is believed to be somewhat more than $1,000,000.

[1] Raymond, R. W., Statistics of mines and mining in States and Territories west of the Rocky Mountains, 1872, p. 291, 1873.

[2] Idem, 1874, pp. 370-371, 1875.

[3] Idem, 1870, p. 326, 1872.

WIGWAM MINE.

The Wigwam mine is on the east side of Caribou Hill. The development consists of a shaft 215 feet deep, with levels at 75, 125, and 200 feet. The vein strikes about N. 75° E. At the surface it dips steeply north, but in depth shifts to southerly. Work was temporarily suspended at the time of this survey and the mine could not be entered, but specimens taken from a depth of about 200 feet were obtained from the ore bin and showed very well the character of the mineralization. The primary minerals of this ore are galena, sphalerite (in part resinous), very minor amounts of chalcopyrite and pyrite, quartz, and pink and white calcite and barite. Along fracture seams and in small vugs in this ore secondary deposits of very finely crystalline chalcopyrite, proustite or ruby silver, and pearceite were recognized. Where high silver values are present they are evidently the result of downward enrichment.

A small shipment from this mine in 1911 assayed gold 0.02 ounce, silver 31.33 ounces, lead 7.58 per cent, and copper 0.1 per cent.

COMSTOCK MINE.

The Comstock mine, which was in operation at the time of this survey, is in Caribou village and is developed by a shaft 212 feet deep. Only the 45-foot level was accessible for inspection. On this level the vein, which strikes nearly east and west and dips about 70° S., has been drifted upon for 112 feet west and 20 feet east of the shaft. West of the shaft the wall rock is monzonite, but just east of the shaft it is dark-green gabbro. The highest values are reported to have been found in the gabbro, but the drift in this rock was boarded up and could not be inspected.

The Comstock vein may be described as a zone of fracturing from 1½ to 6 feet in width, within which galena and calcite and chalcopyrite have been sparsely deposited in small irregular veinlets and disseminated through the rock. Few of the veinlets exceed one-fourth inch in width, but one an inch wide was observed.

About 80 feet west of the shaft on the 45-foot level the Comstock vein is joined by another, said to be the No Name vein, which consists of three subparallel veinlets of fine-grained galena and calcite separated from each other by 3 feet of wall rock. The junction of the two veins is also exposed in the shaft at a depth of about 65 feet, the combined vein there having a width of about 10 feet.

While none of the rich ore could be seen, it is practically certain that like the ore of neighboring mines it owed its high silver value largely to downward enrichment. Ore from a depth of 212 feet in the shaft is said to have assayed 700 ounces of silver to the ton.

SHERMAN VEIN.

The Sherman vein[1] was in 1874 developed by a shaft 160 feet deep, from which levels had been run to a total length of 310 feet. Its production for 1874 was 220 tons of first-class ore of an estimated value of $40,000. Early in 1874 this vein was cut by the Caribou tunnel and was found to be productive at that depth. It was not accessible for study at the time of this survey.

NO NAME VEIN.

The No Name vein had in 1874 been more extensively developed than any other of the region except the Caribou.[1] The main shaft in 1874 was 320 feet deep, and the total length of shafts and drifts was nearly 800 feet. The product for the year was estimated at 4,000 tons, one-half of which was low-grade concentrating ore that was not then available, and the remainder higher grade ore, which was shipped to the smelter at Blackhawk or to the Caribou mill at Nederland. The total value of the ore mined up to that time was estimated by the owner at $400,000.

In 1873 a very rich shoot carrying silver and horn silver was opened.[2] First-class ore from this mine had been sold for more than $1,300 per ton, second-class for $250 to $400, and third-class for $30 to $75.

[1] Raymond, R. W., Statistics of mines and mining in the States and Territories west of the Rocky Mountains, 1874, p. 370, 1875.
[2] Idem, 1873, p. 299, 1874.

CROSS LODE TUNNEL.

The Cross Lode tunnel, just east of Caribou, was inaccessible at the time of this survey. Ore on the dump showed pyrite, chalcopyrite, galena, and sphalerite of the resinous variety in a quartz and calcite gangue.

GOLD ORES OF IDAHO MOUNTAIN.

ST. LOUIS MINE.

The St. Louis mine is on the southwest slope of Idaho Mountain, near Caribou, at an elevation of about 10,000 feet. It was discovered in the early seventies, but was not worked until many years later. The mine has been idle since 1905 and the workings could not be entered. The vein, which appears to strike about N. 60° W., is developed by a shaft 335 feet deep. The ore seen on the dump shows predominant pyrite and quartz, with subordinate galena, sphalerite, and a little siderite. Most of the ore mined was treated in a near-by mill equipped with 10 stamps and Wilfley tables.

The ore treated was free milling and the value was mainly in gold. Sixteen tons shipped in 1905 are said to have shown an average content of gold, 3.28 ounces; silver, 9 ounces; and silica, 17 per cent. Two tons shipped in 1904 are said to have assayed gold, 5.81 ounces; silver, 8.5 ounces; silica, 41.7 per cent. Sampling-works assays of several lots of smelting ore shipped in 1908 are as follows:

Assays of ores from the St. Louis mine, 1908.

Ore.	Gold.	Silver.	Silica.
Net tons.	*Ounces.*	*Ounces.*	*Per cent.*
5. 435	1. 82	3. 60	79. 50
1. 830	3. 06	6. 50	26. 50
. 884	5. 59	5. 20	42. 90

The fineness of the gold ranges from 0.582 to 0.655.

BOSTON AND IDAHO TUNNEL.

The portal of the Boston and Idaho tunnel is near the St. Louis mill, just east of Caribou. The tunnel was inaccessible and the dump showed only pyritic ore and brecciated pegmatite.

EAGLE BIRD MINE.

The Eagle Bird mine is near Caribou, in the south slope of Idaho Mountain. The vein appears to strike about N. 65° W. and to dip about 65° NE. Ore seen on the dump was oxidized and of the pyritic type. The mine was idle and could not be entered.

GREAT NORTHERN MINE.

The Great Northern shaft, now abandoned, is on the east side of Caribou Park, about a mile north of the town of Caribou. The shaft house is just east of the contact between monzonite porphyry and Idaho Springs formation; most of the rock on the dump is porphyry. The vein apparently strikes east and west. The greater part of the ore on the dump is oxidized and consists of iron-stained porphyry cut in many directions by narrow stringers of limonite containing some sphalerite in their centers. Some ore shows massive white quartz, with some limonite-coated pyrite and sphalerite, and here and there some copper carbonates. A small part of the ore consists of veins of white quartz carrying pyrite, chalcopyrite, and subordinate sphalerite and galena. In general the massive pyrite ore carries very little of the other sulphides, but where chalcopyrite appears the lead and zinc sulphides are also present. Some specimens seem to show that the lead and zinc were deposited later than the chalcopyrite in small seams that in places cut masses of that mineral.

GOLD-SILVER VEINS OF BOULDER COUNTY HILL AND SHERWOOD CREEK.

The ores of Boulder County Hill and the upper valley of Sherwood Creek belong to the galena-sphalerite type of gold-silver ores, but differ from those of Caribou Hill in being practically devoid of carbonates and in containing a great abundance of gangue quartz. They show much less downward enrichment in silver than the Caribou Hill group. Ore from a depth of only 120 feet in the Gold King vein, for example, showed no evidence of enrichment.

BOULDER COUNTY MINE.

The Boulder County vein was discovered by S. P. Conger about 1870 and was mined intermittently until a few years ago. The early development was through a shaft 400 feet deep on the south side of Boulder County Hill at an elevation of about 9,500 feet. These workings, which include about 5,000 feet of drifts on three levels, have been abandoned for many years and are now inaccessible. According to Mr. Charles Sherman, a former owner,[1] there were in 1872 eight shafts on the Boulder County vein, aggregating 250 feet in depth, and 225 feet of levels and tunnels.

The present management, which assumed control in 1901, operated exclusively through a crosscut known as the Boulder County tunnel, whose portal is in the valley of Coon Trail Creek, a short distance above Cardinal station. This tunnel, which was accessible for study, trends about N. 18° W. and intersects the Boulder County vein about 3,200 feet from the portal. The west drift on the vein, which is about 1,500 feet long, was unsafe, but the east drift was studied for its entire length of about 650 feet. Near its east end it is connected by a 500-foot raise with the shaft workings.

The Boulder County tunnel cuts no veins of importance until the Boulder County vein is reached, and is of interest mainly because of the number and variety of the porphyry dikes which it exposes. The dikes and minor veins intersected are described briefly below. The distances are from the portal and were determined by pacing.

At 142 feet: A 3-foot dike of fine-grained, very dark gray biotite diorite. Strike, N. 60° E.; dip, 80° N.

At 382 feet: A barren fault zone in schist of the Idaho Springs formation. Wet. Strike, N. 70° E.; dip, 80° N.

At 409 feet: A 4-foot dike, probably of hornblende andesite. Strike, N. 65° E.; vertical.

At 700 feet: A 4-foot dike of fine-grained and sparsely porphyritic hornblende andesite.

At 725 feet: A 6-inch dike of black biotite diorite showing biotite phenocrysts, some of which are 5 millimeters across, though most of them are under 2 millimeters. This dike cuts sharply through a 15-foot dike of gray porphyry, which is shown by the microscope to be much altered, but which was probably originally a hornblende-biotite andesite. The biotite diorite is finer grained and nonporphyritic for one-

[1] Raymond, R. W., Statistics of mines and mining in the States and Territories west of the Rocky Mountains, 1872, p. 291, 1873.

fourth inch next its "frozen" contact with the andesite.

At 890 feet: A nearly east-west vertical dike of biotite diorite, 2 feet in width.

At 1,120 feet: A barren fracture zone 4 feet wide. Strike, N. 75° W.; vertical.

At 1,130 feet: A 4-foot vertical dike of hornblende latite. Strike, N. 75° W.

At 1,220 feet: An open vein of white quartz with a little pyrite, having a maximum width of 6 inches. Strike, N. 60°–75° W.; dip, 60°–80° N. The vein was followed by drifts till it pinched out at points 115 feet east and 30 feet west of the tunnel.

At 1,270 feet: An 8-foot dike of altered hornblende-biotite andesite carrying some quartz. Strike, N. 80° W.; vertical. The dike is cut by a narrow dike of black biotite diorite porphyry, which is finer grained and nonporphyritic next its contact with the andesite.

At 1,340 feet: A 10-foot dike of typical hornblende-andesite porphyry. Strike, N. 60° W.

At 1,730 feet: Fracture zone, unmineralized. Strike, N. 55° E.; vertical.

At 1,870 feet: A 4-foot dike of a nearly black rock, probably hornblende-biotite diorite. Strike, N. 80° E.; vertical.

At 1,900 feet: A 1-foot dike of biotite diorite. Strike, N. 60° E.; vertical.

At 2,490 feet: A 1-foot dike which is much altered but appears to be diorite porphyry showing altered feldspar phenocrysts. This dike is parallel and in contact with a 6-inch light-gray dike, which is also much altered but is probably an andesite porphyry. The dike of diorite (?) is finer and nonporphyritic next the andesite, which it appears to intrude.

At 2,920 feet: A 14-inch dike of biotite diorite. Strike, N. 65° W.; vertical.

The exposures in this tunnel are the only ones found in the district that clearly show the age relations between the diorite and andesite dikes. The repetition of the same relations in several exposures in this tunnel unquestionably determines the diorites as somewhat younger than the andesites.

The strike of the Boulder County vein as exposed in the tunnel workings is about N. 70° W., and its dip is 60°–70° N. Its width varies from 1 inch to 3 feet and in one place to 4½ feet; it shows many abrupt enlargements, in one place widening from 4 inches to 4 feet within a distance of 10 feet.

The following statement regarding the appearance of the upper part of the vein is taken from Raymond:[1]

> As it appeared in August, 1870, it presented a 2½-foot crevice, one side of which was rich in gold and the other still richer in silver. As a greater depth was reached on this lode, the gold seemed gradually to be running out and the silver increasing in quantity. In much of the ore gold was found associated with large flakes of silver. Specimens had frequently been taken from the mine in which brittle silver and wire silver were visible in large quantities, with a smaller sprinkling of gold.

As now exposed on the tunnel level, the vein is, in general, highly quartzose, quartz in places constituting the whole vein and commonly forming over half of the ore. In a few places, however, quartz is practically absent, the vein at one point consisting of 3 inches of solid galena and chalcopyrite with only a little quartz and pyrite next the walls. Where widest the vein consists of a 6-inch border of white quartz on both footwall and hanging wall and a core of 3½ feet of altered wall rock which is cut by a network of quartz veinlets not more than 1 inch in width and which carries irregular masses of sulphides not more than 2 inches across. In general the minerals of the vein in order of abundance are white quartz, galena, sphalerite, pyrite, and chalcopyrite. Vugs are common and are usually lined with crystals of galena and transparent quartz. No carbonates were observed.

No evidence of downward enrichment was apparent in the vein at the level of the tunnel; enrichment was probably operative near the surface (see p. 139), but does not seem to have been extensive far below the oxidized zone or to have produced ore extraordinarily rich in silver, the ore mined in 1872 being valued, according to a former owner, at $20 to $150 per ton in gold and silver.

The nature of the wall-rock alterations near the Boulder County vein has already been discussed. (See p. 52.)

The ore mined by the present company was treated in a mill located at the mouth of the tunnel which has since been remodeled for the treatment of tungsten ores. The richest ore yielded $400 per ton and the average between $15 and $18. The average gold content is placed at about 0.6 ounce, and the usual lead content at 3 to 4 per cent, occasionally reaching

[1] Raymond, R. W., Statistics of mines and mining in the States and Territories west of the Rocky Mountains, 1870, pp. 327-328, 1872.

16 to 18 per cent. Zinc was present only in minor amounts. There has been no production since 1906.

JACK POT TUNNEL.

The Jack Pot tunnel is on the southwest slope of Idaho Mountain about one-fifth mile southeast of the Boulder County shaft. At the time of this survey it had been idle for some time but was accessible throughout. It is about 670 feet long and develops two nearly parallel veins.

The first vein, which is tapped by the tunnel 200 feet from the portal and is followed by it for 150 feet, strikes slightly north of west and is about vertical. It is for the most part barren, but in one place it shows 1½ inches of gray quartz carrying some pyrite. There has been postmineral movement along this vein.

The main vein is tapped by the tunnel 400 feet from the portal and is followed by it to the face, a distance of about 270 feet. The vein strikes about N. 70° W., and dips 35°–70° N. It varies in width from 5 inches to 2 feet and is mainly in granite, though it traverses some Idaho Springs schist. In some places the vein shows several subparallel sharp-walled veinlets of quartz and sulphides, between which the wall rock has been only slightly mineralized. In other places the rock between small fracture planes has been entirely replaced by quartz and sulphides which form lenses of ore 6 to 8 inches in width. Elsewhere the only mineralization consists in the development of quartz and disseminated sulphides in the granite immediately adjacent to fracture planes.

The ore minerals are pyrite, galena, chalcopyrite, and quartz. The ore is of the same type as that from the Boulder County vein, being chiefly characterized by the predominance of quartz gangue over sulphides and the abundance of vugs.

PINE GROVE MINE.

The Pine Grove mine is in the valley of Sherwood Creek about 1¾ miles west-northwest of Nederland and about one-half mile northeast of Cardinal station. The shaft, which connects with at least three levels, could not be entered, the mine being idle at the time of this survey.

As shown by specimens on the dump and in the ore bin the ore is very similar to that of the Boulder County vein, consisting predominantly of white and gray quartz, through which sphalerite, galena, and chalcopyrite are scattered. Vugs are very common and are usually lined with crystals of quartz and sphalerite. A few crystals of calcite and siderite were observed on the quartz crystals of some vugs, and in one vug a little secondary chalcopyrite deposited on galena was seen. One specimen shows 5 inches of such vein material bordered by 5 inches of altered wall rock traversed by numerous small branches from the main vein. Locally the vein proper is bordered by a breccia of fragments of wall rock in a matrix of quartz and sulphides. No evidence of postmineral fracturing or of downward enrichment was observed. The wall-rock alterations are sericitization and, close to the vein, silicification.

The average metal content of smelting ore shipped from this mine from 1906 to 1908 was as follows:

Metal content of smelting ore from Pine Grove mine, 1906–1908.

	Gold.	Silver.
	Ounce.	*Ounces.*
1906	0.24	35
1907 and 1908	.28	24

The total production is not known.

GOLD KING MINE.

The Gold King mine is about 1½ miles northwest of Nederland, just north of Sherwood Creek, and only a short distance northeast of the Pine Grove shaft. The vein has been developed by a shaft 120 feet deep, now idle and inaccessible. The ore fragments in the shaft house show that the vein locally attained a width of at least 10 inches. The ore is highly quartzose and full of vugs and closely resembles that from the neighboring Pine Grove and Boulder County veins. Sphalerite is the principal sulphide with galena subordinate; pyrite and chalcopyrite were not observed. The sulphides form from 10 to 60 per cent by volume of the ore. Quartz is the only gangue observed. No evidence of postmineral movement or of downward enrichment was observed in this ore, which appeared very fresh even though it could not have come from a depth greater than 120 feet. At the time of survey a crosscut tunnel was being driven to intersect the vein at a depth of 100 to 200 feet.

MINES NEAR NEDERLAND.

BLUE BIRD MINE.

The Blue Bird vein is on the west side of North Boulder Creek 2¾ miles west of Nederland. The workings consist of three drift tunnels, but as the vein is unusually flat, with dips of 2° to 17°, the workings bear little resemblance to those on most of the metalliferous veins of the district. The tunnels are 380, 150, and 370 feet long and connect with numerous drifts and stopes.

The country rock is a rather coarse-grained biotite granite, porphyritic in places, which is intruded by granite pegmatite and which contains several lenses of schist of the Idaho Springs formation near its borders. North of the Blue Bird tunnels a small dike of gray fine-grained biotite andesite porphyry crops out; and the same porphyry is cut by the third level of the north tunnel. The dike was intruded after the formation of the Blue Bird vein and distinctly cuts the latter at the third level of the north tunnel. The relation of this andesite to the other andesites of this region is not known.

The vein strikes north-northwest and dips 2°–17° SW. The steeper dips are seen in the north tunnel, the dips in the lower south tunnel being in places scarcely noticeable. In the third level of the north tunnel there is a saddle over which the vein curves. At the north end of the third level the vein dips 7° NW., and near the tunnel it dips about 7° SW.

The vein varies from 2 inches to 3 feet in width but commonly measures 4 to 6 inches. In some places it is a single fissure filling and in other places it splits into several narrow subparallel veinlets. The ore is generally "frozen" to the walls but here and there breaks free, though the parting is hardly noticeable. No gouge was seen in any part of the vein.

The gangue minerals are barite and white quartz. Most of the quartz is opaque, but some crystals of it in vugs are transparent. In places quartz is the sole gangue, but where barite also occurs the two minerals are irregularly intergrown. In places barite forms fully half of the vein material, being particularly abundant on the second and third levels in the north tunnel. In all parts of the vein druses are common. Metallic minerals, though in few places wholly absent, are generally much subordinate to quartz and barite; rarely, however, galena constitutes over half the vein. The sulphides (galena, chalcopyrite, and rarely gray copper) usually form irregular bands or bunches. Specularite was observed in one place intergrown with clear hexagonal quartz in a vug in the vein and is probably primary. Much of the ore is oxidized. Limonite, malachite, and azurite were observed in seams and cavities. Films of native silver occur on fractures in quartz in oxidized ore, and small irregular masses of the metal appear in cavities. Small wires of native gold were observed in cavities in quartz; and cerargyrite was noted in oxidized ore.

The stopes on this vein are low, roomlike, and very irregular, following the more heavily mineralized parts of the vein and leaving the leaner parts as pillars. They are all near the surface. The vein with increased depth under the mountain is apparently narrower and not so well mineralized. This was particularly noticeable at the face of the incline tunnel.

Development work on the Blue Bird property was in progress in 1875, when some ore was shipped that yielded over $200 a ton in mill returns.[1] The high value of some of the ore was evidently due to downward enrichment. The property has now been idle for many years.

ALTON TUNNEL.

The mouth of the Alton tunnel is on the north side of Coon Trail Creek, about one-half mile east of Cardinal station. It is a crosscut tunnel, running due north for about 2,060 feet. For the first 1,800 feet the tunnel traverses the Idaho Springs formation, cutting numerous lenses of granite pegmatite, the largest of which forms the wall for 420 feet in the central part of the tunnel. (See fig. 21.) Beyond 1,800 feet the tunnel is driven in coarse porphyritic biotite granite (Silver Plume granite). At 2,060 feet the tunnel turns northwest and by the fall of 1911 had been driven about 100 feet toward the Pine Grove shaft.

Four porphyry dikes are cut by the tunnel. The first is 410 feet from the mouth and has

[1] Raymond, R. W., Statistics of mines and mining in the States and Territories west of the Rocky Mountains, 1875, p. 307, 1877.

also been followed for about 80 feet by the west Skipper drift. It varies from 14 inches to 2 feet in width and is nearly vertical. It is a fine-grained dark biotite andesite containing a few feldspar phenocrysts about one-eighth

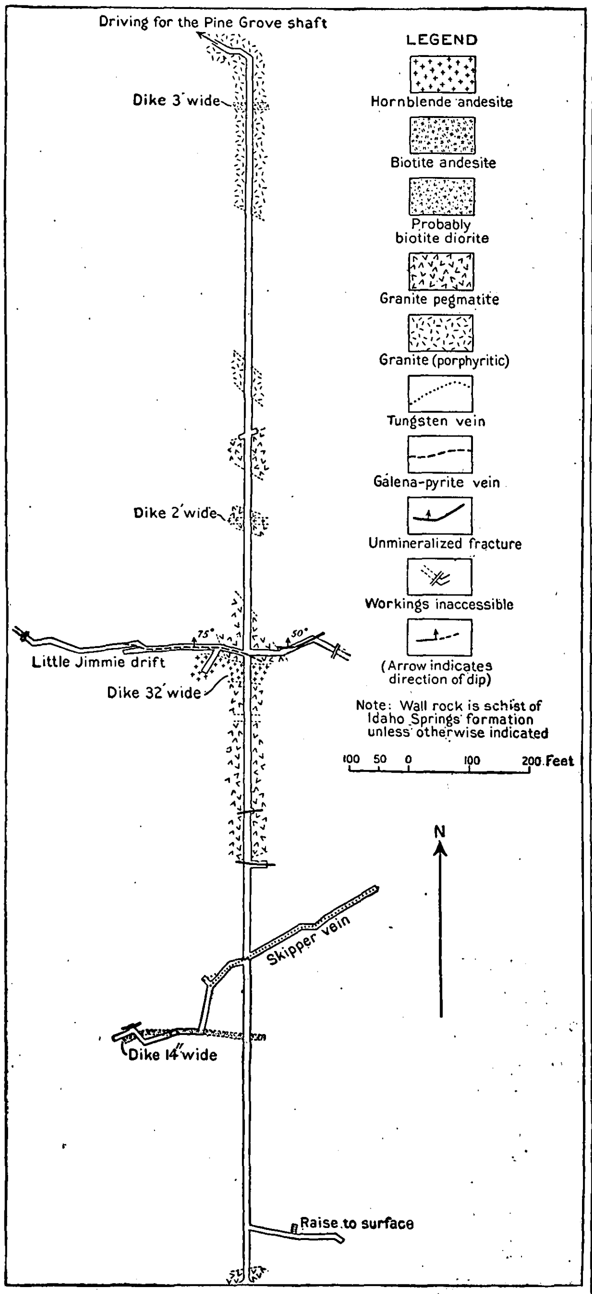


FIGURE 21.—Geologic plan of Alton tunnel.

inch in maximum diameter. The second dike, 32 feet wide, is cut 1,000 feet from the mouth of the tunnel and is also exposed in a crosscut to the south from the west Little Jimmie drift. The rock is a much-altered hornblende andesite; it lies a few feet south of the Little Jimmie vein and is somewhat mineralized. The third dike, about 2 feet wide, is cut 1,270 feet from the mouth of the tunnel, where it traverses granite pegmatite. It is a very fine grained light-gray much-altered porphyry containing a little disseminated fine-grained pyrite and is probably a hornblende andesite. The fourth dike, about 3 feet wide, trends east and west, cutting granite 1,960 feet from the mouth and 100 feet south of the turn of the tunnel. It is a dark-gray, fine-grained, highly altered rock, probably originally a biotite diorite. Its outcrop was not located.

There are only three drifts of consequence from this tunnel. The first starts 85 feet from the mouth and extends east for 150 feet about parallel to the foliation of the schist walls. About 80 feet east of the crosscut there is a 70-foot raise, from which a small pocket of tungsten ore is said to have been taken, though no ore and nothing that resembled a vein was seen in the drift.

The Skipper vein is cut 540 feet from the mouth of the tunnel and has been followed east for 250 feet and west for 80 feet. This vein strikes N. 63° E. and is about vertical, traversing Idaho Springs formation. In most places it is a barren fracture zone 2 to 4 inches wide, containing gouge, brecciated schist, and in some places small lenses and stringers of gray and buff cherty silica. Eighty feet west of the tunnel the fracture splits on entering a small lens of granite pegmatite. In this place the pegmatite is iron stained and contains small pockets and seams of ferberite which form the matrix of a breccia of pegmatite and chert fragments. West of this ore pocket the drift did not follow the fracture but turned south for 80 feet, then west along the 14-inch andesite dike mentioned above, and finally north. A little brecciated pegmatite and schist along a northeast-southwest fracture at its end may be the continuation of the Skipper vein, but so far as seen it is barren at this place.

The Little Jimmie vein, which is cut 1,050 feet from the mouth of the tunnel, strikes N. 88° W. and dips 75° N. In the tunnel it cuts granite pegmatite but enters schist 50 feet to the west. The west drift is caved 370 feet from the tunnel, and its last 150 feet are south of the vein. The east drift is north of the vein but exposes a nearly parallel barren fracture. In the west drift the vein, which varies from a few inches to a foot in width, consists of narrow stringers of gray cherty silica about one-fourth inch wide running about parallel to the foliation of the schists. These stringers are nearly barren in the schist, but in the pegmatite near the tunnel a small stope, showing some ore, consists of stringers of gray and buff chert carrying pyrite, chalcopyrite, galena, and light-colored sphalerite. A small quantity of ore taken from this place is said to have assayed $100 a ton, principally silver with a little gold.

Although both lead-silver veins and tungsten veins are cut in this tunnel the production from all of them has been small.

The Alton mill is near the mouth of the tunnel and can be used for treating either gold, silver, or tungsten ores. It is equipped with a crusher, 15 quick-drop stamps, amalgamation plates, concentrating tables, and canvas tables.

ELDORA AND VICINITY.

GENERAL FEATURES.

As most of the mines in the vicinity of Eldora were idle at the time of this survey and as admission was denied to the only one that was in operation the data collected in regard to the district are not extensive. Most of the veins belong to a different type from those about Caribou, their distinguishing character being the presence of tellurides of gold. In regard to the relative ages of the telluride and sulphide veins Lindgren says:[1]

> 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 present writer was not able to obtain any evidence bearing upon this point. As no rich portions of the telluride veins were exposed at the time of this survey, Lindgren's description of them may here be quoted at length.[2]

> 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,[3] is believed to be the rare mineral, ilsemannite, a compound of the oxides of molybdenum ($MoO_2.4MoO_3$).
>
> 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,[4] 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 is 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 toward 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 chalcedonic silica. The intimate relationship to the Cripple Creek

[1] Lindgren, Waldemar, Some gold and tungsten deposits of Boulder County, Colo.: Econ. Geology, vol. 2, p. 453, 1907.

[2] Idem, pp. 458–460.

[3] Lindgren, Waldemar, and Ransome, L. F., Geology and gold deposits of the Cripple Creek district, Colo.: U. S. Geol. Survey Prof. Paper 54, pp. 114, 123, 1906.

[4] Rickard, T. A., The veins of Boulder and Kalgoorlie: Am. Inst. Min. Eng. Trans., vol. 33. p. 558, 1903.

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.

A specimen of rich ore from the Village Belle mine in the collections of the State Bureau of Mines in Denver shows specks of sylvanite with a maximum width of one-sixteenth inch in a matrix of porous gray quartz. Another specimen shows a silvery-looking telluride coating fracture seams in cherty-looking silica.

ENTERPRISE MINE.

The Enterprise vein outcrops at an elevation of about 9,400 feet on the north side of Spencer Mountain and is developed by a shaft which could not be safely entered at the time of this survey. The shaft is 400 feet deep, with five levels and about 1,200 feet of drifting. At greater depths what is believed to be the Enterprise vein is cut by both the Mogul and Swathmore tunnels.

Rickard[1] has published an instructive sketch and a description of the Enterprise vein. Where studied by him it was a zone of fractured and crushed wall rock about 5 feet wide traversed in its central portion by numerous subparallel threads of dark flinty silica. He says: "The dark quartz carries finely disseminated tellurides, chiefly petzite, which renders a width of 2 to 2½ feet sufficiently rich to yield an average of 2 ounces of gold per ton."

Only a part of the drifts on the so-called Enterprise vein in the Mogul tunnel was accessible, and in this part no mineralization was observed. The vein was not studied in the Swathmore tunnel.

About 1,800 tons taken from the Enterprise shaft in 1896 and 1897 and treated by chlorination in the Bailey mill at Eldora are said to have averaged about $10.80 a ton, mainly in gold.

MOGUL TUNNEL.

The portal of the Mogul tunnel is near Eldora station. No mining through it was being done at the time of survey, but it was entered and all the accessible workings examined. Its general direction for about 835 feet from the portal is southwesterly; beyond that it trends approximately S. 18° E. for 530 feet to a point where it is caved. In this distance three fracture zones occur.

The Little Charlie vein, which strikes nearly east and west, is cut about 680 feet from the portal and has been drifted on for about 100 feet to the east and 200 feet to the west. Although it has been stoped somewhat at one point, the stope was not accessible and no ore was seen in the drifts, the vein being simply a zone of slight fracturing.

A vein which strikes about N. 60° E., and which is said to be the Enterprise, has been cut by the tunnel about 935 feet from the portal. Considerable drifting has been done upon it, but the drifts were caved 130 feet east and 100 feet west of the tunnel. In the part accessible for inspection no ore was observed, the vein being a zone of slightly fractured country rock showing local stringers of red jaspery silica one-half to 1 inch wide.

A third fracture zone, striking about N. 70° E., is cut about 1,185 feet from the portal. The drifts were caved a short distance on each side of the tunnel. No mineral was seen, although 1 to 2 inches of gouge was observed at one place.

Lindgren, who examined the tunnel in 1906 when the veins were better exposed, says:[2]

> 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. * * * No accurate data of 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.

Ore shipped from the Mogul tunnel in 1905 is said to have averaged about 1 ounce per ton in gold. Ore from the tunnel workings on the Enterprise vein is said to have ranged from $24 to $40 per ton in gold.

SWATHMORE MINE.

The Swathmore shaft, near the station at Eldora and close to the mouth of the Mogul tunnel, was idle at the time of this survey and could not be entered. The only ore seen on the dump showed either fine-grained pyrite in a quartz gangue or specularite and cherty-

[1] Rickard, T. A., The veins of Boulder and Kalgoorlie: Am. Inst. Min. Eng. Trans., vol. 33, p. 568, 1903.

[2] Lindgren, Waldemar, Some gold and tungsten deposits of Boulder County, Colo.: Econ. Geology, vol. 2, pp. 457-458, 1907.

looking silica presumably derived from the pyrite and quartz through surficial alteration.

Admittance to the Swathmore tunnel, located a short distance above the village of Eldora was denied. Three other veins carrying ore similar to that of the Enterprise are said to have been cut by this tunnel before the Enterprise vein was reached. Ore seen in the bins is an association of cherty silica, fine-grained pyrite, and a greenish mineral that is probably roscoelite. The tellurides are said to be carried in narrow seams (those seen measured one-sixteenth to one-eighth inch) of dark-gray quartz that traverse the greenish aggregate. Upon exposure the ore becomes coated with a blue film of oxides of molybdenum formed from the molybdenite in the ore.

KOH-I-NOOR TUNNEL.

The Koh-I-Noor tunnel extends northward into the north valley wall of Middle Boulder Creek from a point about a mile west of Eldora. From the size of the dump it is inferred that there must be several hundred feet of development, but the workings could not be entered. The dump consists of altered schist and pegmatite; some of the schist shows small stringers of gray cherty quartz, accompanied by a little siderite, which generally occurs in narrow bands, but in places as coatings on small druses. The material is all somewhat iron stained, but no metallic minerals were noted.

SCANDIA VEIN.

The Scandia vein is on the south side of Middle Boulder Creek about three-fourths of a mile east of Hessie and 1¼ miles west of Eldora. It is opened by a tunnel now inaccessible and by several pits. The vein apparently strikes N. 80° E. and is entirely in Idaho Springs formation. The mouth of the tunnel is near the east edge of a large mass of monzonite porphyry, and some of this rock is on the dump, which also carries some crushed highly altered silicified schist containing a small amount of disseminated pyrite. Mineralization along this vein was apparently weak.

JASPER TUNNEL.

The portal of the Jasper tunnel is on the north side of Hicks Gulch at an elevation of about 9,250 feet. The development work consists of a crosscut tunnel about 680 feet in length trending slightly west of north. A 3-foot vertical dike of felsite porphyry is cut 385 feet from the portal. Two other dikes of similar felsite appear to cut a broad dike of hornblende andesite porphyry, which is intersected by the tunnel about 490 feet from the portal. The exact nature of the felsite was not determined.

About 520 feet from the portal a drift to the northwest exposes about 320 feet of what is known as the Anything vein. The average strike of this vein is N. 45° W. and its dip 30°–45° NE. This vein is well defined but varies from a mere knife-edge fracture to 1½ feet in width. In most places it consists of altered wall rock which carries disseminated pyrite and is traversed by stringers of quartz and pyrite. Most of the pyrite is fine-grained. Some small vugs are lined with quartz crystals. The vein shows no evidence of longitudinal postmineral movement nor of the development of secondary minerals. Its walls are in part pegmatite and in part hornblende andesite porphyry. It cuts the porphyry and is distinctly younger.

About 560 feet from the portal an east drift about 160 feet in length leaves the tunnel. After following several barren postmineral fractures it cuts a vein similar to the Anything but with a more westerly trend (about N. 75° W.) and a dip of 45° N. It is uncertain whether this is the Anything vein or another vein of similar character. The average value of the total width of the Anything vein is said to vary from $18 to $27.50, mainly in gold.

A second vein, known as the Rosalind, which has not yet been reached by the tunnel, is developed by a 60-foot shaft and is said to have yielded rich silver ore near the surface.

Mining on this property was begun about 1903 and was in progress at the time of this survey.

SUMMIT PROSPECT.

The Summit prospect is on Mineral Mountain between Eldora and Caribou. A shaft 90 feet deep has been sunk in granite gneiss but could not be entered. The ore seen consisted of small stringers of pyrite in the gneiss.

OTHER PROSPECTS.

In the small valley between Hicks Gulch and Coon Trail Creek there are three prospect tunnels which are now idle and which were not entered. Ore on the dump consisted of pyrite, galena, and white quartz. Vugs are common.

CHAPTER XV.—GILPIN COUNTY.

SOUTH BOULDER CREEK, JENNIE LIND GULCH, AND PHOENIX.

BLATERNICK TUNNEL.

The Blaternick tunnel is on the northwest side of Black Canyon about 1½ miles southeast of Tolland. It could not be entered, but it is said to be 300 feet long and to follow a tight unmineralized slip plane. Two small veins carrying pyrite in a quartz gangue are said to have been cut in this tunnel.

HILL AND GOLD TUNNEL.

The Hill and Gold tunnel is on the southeast side of Black Canyon 1½ miles southeast of Tolland. It is a 600-foot crosscut but was inaccessible on account of caving. It is reported to have cut no veins. All the rock on the dump is schist from the Idaho Springs formation. Some of it shows a little pyrite along joints.

ROOKS COUNTY MINE.

The Rooks County mine is about 1½ miles north-northwest of Apex, in a gulch on the north side of Colorado Mountain. It is developed by a tunnel about 700 feet long, which is somewhat crooked but which as a whole trends southeast.

No large veins have yet been found, but the tunnel is still being extended. The wall rock is pegmatite for the first 450 feet from the portal, but beyond 450 feet is Idaho Springs formation. The small veins intersected belong to the pyritic and the galena-sphalerite types. The principal pyritic vein is reached about 570 feet from the portal and is exposed for 50 feet to the face of the drift. It strikes about N. 65° W. and dips 30° N. It consists of several subparallel pyrite veinlets, the largest 7 inches wide, commonly in a quartz gangue. All these veinlets lie in the plane of foliation of the schist. Vugs in the larger pyrite veinlets are lined with crystals of octahedral pyrite, a form which is rare in this district. Implanted on these pyrite crystals and evidently formed later is a mixture of crystals of light-brown siderite and snowy-white feldspar (probably soda orthoclase). Under the microscope this feldspar shows no twinning. Its index of refraction as determined by the immersion method is about 1.520. It gives strong flame reaction for both soda and potash. Closely associated with and apparently contemporaneous with the siderite and feldspar is a little sphalerite and galena. In some places both these sulphides form crystals which are clearly implanted on pyrite crystals, and in other places the galena forms thin films in fractures in the pyritic ore. The post-pyritic vug minerals were presumably deposited in the more porous portions of the pyritic vein at a slightly later stage in the process of mineralization. Some of the sphalerite crystals in these vugs are in turn coated with minute crystals of chalcopyrite, possibly deposited by descending solutions. Ore from this vein is said to assay about $5 a ton.

A small vein cut about 500 feet from the portal is composed of galena, sphalerite, and chalcopyrite in a calcite gangue. It varies from one-half to 2 inches wide and lies in general parallel to the foliation of the schist, which strikes N. 55° W. and dips 30° NE. The contact between ore and wall rock is of extreme sharpness and the walls are free from disseminated sulphides. Ore from this vein is said to have assayed gold 0.25 ounce, silver 11 ounces, copper 8 per cent, and lead 40 per cent.

Mining to the time of survey had been entirely exploratory.

MELROSE TUNNEL.

The Melrose tunnel, on the east side of Jenny Lind Gulch, three-quarters of a mile south of South Boulder Creek, intersects two veins, the Melrose striking N. 20° E. and dipping 65° W. and the Bonanza striking N. 65° E. and dipping 70° N. The two veins intersect about 30 feet from the mouth of the tunnel and 15 feet below the surface. The drift on the Melrose is 80 feet and that on the Bonanza 125 feet long. These veins, so far as exposed, cut only Idaho Springs formation injected by granite pegmatite. They both vary from a few inches to a foot in width and consist largely of crushed wall rock carrying disseminated pyrite. The Bonanza comprises several lenses of quartz carrying pyrite and a little chalcopyrite; its ore is all oxidized to a depth of 50 feet, and its face in the southeast drift about 100 feet below the surface shows a small amount of limonite.

The ore is said to average about $30 a ton in gold, silver, and copper, in the proportion of 1 to 2 ounces of gold to each ounce of silver. There has been no production from the property.

EARLY BIRD TUNNEL.

The Early Bird tunnel is on the east side of Jenny Creek just north of Boulder Park. The tunnel, a crosscut, is said to be 125 feet long and to intersect two small and unimportant stringers of pyritic ore. The country rock is Idaho Springs schist with abundant lenses of granite pegmatite.

BLACK HILLS VEIN.

The Black Hills vein is on the crest of the ridge between Jenny Creek and the drainage into Peterson Lake, about 1½ miles north of the east end of Boulder Park. It is developed by a shaft which follows the vein to an unknown depth. A crosscut tunnel has been started from Boulder Park, but is not very long, for the dump is small. The shaft is in granite gneiss just east of a contact with Idaho Springs formation. Two kinds of ore, both apparently low grade, are stored in the bins; one is a silicified granite gneiss containing sparsely disseminated galena, sphalerite, and subordinate pyrite; the other is a breccia of dark-gray quartz containing small amounts of sulphides in a matrix of buff-colored cherty silica. All the cavities are not completely filled; and the druses that remain contain small crystals of barite and yellowish quartz coated with a little limonite. The vein apparently strikes N. 60° E.

BUCKEYE MINE.

The Buckeye mine is on the north side of South Boulder Creek about three-quarters of a mile north of Jenny Gulch. The old shaft, now abandoned, is said to be 80 feet deep. The country rock is granite gneiss cut by a coarse-grained monzonite porphyry dike 8 feet wide that strikes N. 75° W. The porphyry contains a little disseminated pyrite, and both sides of the dike are bordered by pyrite in bands 1 to 2 inches wide, which locally expand into lenses as wide as 8 inches. The ore to a depth of 15 feet was oxidized and is said to have been rich, but below 15 feet the sulphides carry only $2 to $3 a ton in gold.

A few shallow pits on a group of claims south of the Buckeye show several small veins, all oxidized, with a general east-west strike.

GOLDEN SUN TUNNEL.

The Golden Sun crosscut tunnel starts on the south side of South Boulder Creek, three-fourths of a mile east of the mouth of Jenny Lind Gulch. In August, 1911, this tunnel was 2,410 feet long, extending under Jumbo Mountain toward Perigo, through Idaho Springs schist, which in this vicinity is not ordinarily much fractured. Several small zones of slight crushing exposed in the tunnel trend in general about parallel to the foliation of the schist and commonly dip with it north or northwest. A few of these fractures are slightly mineralized with pyrite, which is disseminated in the schist for a few inches on either side of the plane of fracture, but most of them are barren. The workings are shown in figure 22.

About 1,200 feet from the portal of the tunnel an 8-foot dike of monzonite porphyry strikes about N. 46° E. and dips 50° N. The two principal veins of the tunnel are short distances north and south of this dike.

The more southerly vein (*A*, fig. 22) strikes N. 85° E. and dips 60–65° N. This vein has faulted the monzonite porphyry dike, which it cuts about 125 feet west of the tunnel, displacing it by about 20 feet. The vein consists of 2 to 10 inches of crushed schist containing a little disseminated pyrite and chalcopyrite. Next the hanging wall there is from 2 to 8 inches of gouge.

The vein north of the dike (*B*, fig. 22) strikes N. 47° E. and dips 80° NW., parallel to the foliation of the schist. In most places this vein consists of 3 to 4 inches of crushed schist with disseminated pyrite and scattered chalcopyrite. A few small lenses of white quartz with the same sulphides are found in the crushed material. This vein intersects the east-west vein 190 feet west of the tunnel. Postmineral movement along vein *B* has offset vein *A* about 10 feet.

At the mouth of the Golden Sun tunnel there is a power house and 50-ton mill equipped with crusher, rolls, Wilfley tables, and Frue vanners.

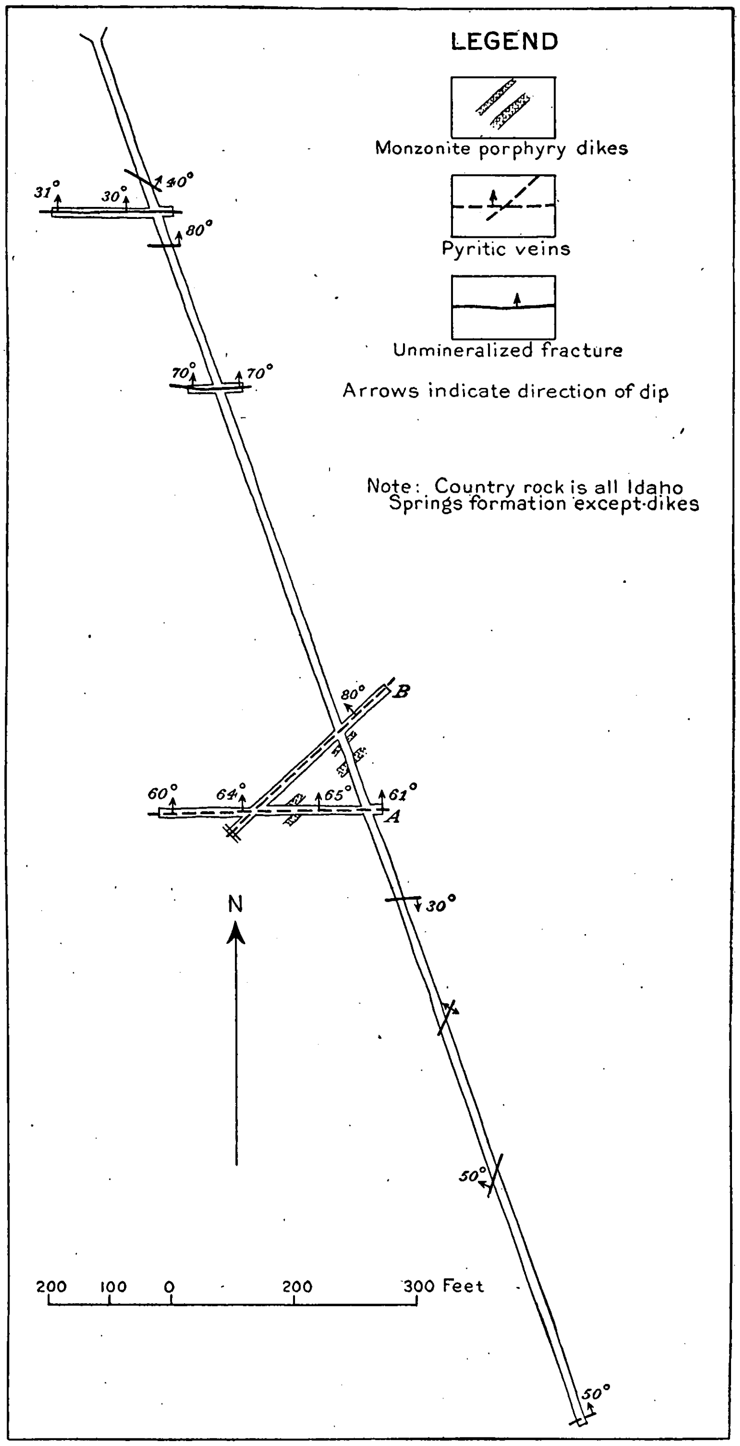


FIGURE 22.—Geologic plan of Golden Sun tunnel. Surveyed by hand compass and pacing.

GRAND UNION TUNNEL.

The Grand Union tunnel is on the south side of South Boulder Creek, 2¼ miles west of Rollinsville, in a region underlain by Idaho Springs formation containing some small lenses of granite-pegmatite. This tunnel is 550 feet long, following a fracture which strikes N. 80° E. and dips 55°–70° N. It is in most places barren, but near the face shows a little pyrite largely altered to soft earthy limonite in an open part of the vein. About 210 feet from the face an opening 4 feet long and 2 inches wide contains crystals of hematite and siderite in druses. Old abandoned workings on this vein are on top of the ridge east of the mouth of the tunnel. The dump at the tunnel shows a little pyrite in a quartz-hematite-siderite gangue. This vein was worked in the early days of the camp, but its production is not known. What little ore is found in the tunnel is said to assay about $18 a ton in gold and silver.

JOHNSON TUNNEL.

The Johnson tunnel, on the south side of South Boulder Creek, 1¾ miles west of Rollinsville, is 270 feet long, running S. 70° W., parallel to the foliation of the Idaho Springs formation, which forms the wall rock. No vein or fracture is to be seen in this tunnel.

FAIRHAVEN VEIN.

The Fairhaven vein, on the ridge between Beaver and South Boulder creeks, about a mile south of Phoenix, is developed by a 40-foot shaft and several pits. The vein strikes about N. 80° W. and dips steeply north, cutting Idaho Springs formation. All of the ore is oxidized, limonite replacing pyrite. The principal ore to be seen at present is very much iron-stained quartz and schist cut by stringers of limonite. It is said that 500 pounds of float from this vein ran 42 ounces gold to the ton.

MELETT VEIN.

The Melett vein is opened by a whim shaft, now water filled, on the crest of the ridge between South Boulder and Beaver creeks, about a mile southwest of Phoenix. The vein apparently strikes about N. 70° E., about parallel to a monzonite porphyry dike. It is about 300 feet west of the dike in Idaho Springs formation. The ore on the dump is much oxidized, but a little pyrite remains in a quartz gangue and disseminated through schist.

LONE STAR VEIN.

The Lone Star vein near Phoenix is opened by a shaft and several pits on the ridge between the north and south forks of Beaver Creek. In this vicinity the Idaho Springs formation is intruded by a large mass of granite pegmatite. The pegmatite has the greatest surface exposure, but it includes many small and a few large lenses of schist.

The shaft is 260 feet deep with levels at 60, 150, and 250 feet. The drifts are practically all east of the shaft, except on the second level where a short drift runs west, with an exploratory crosscut to the south. The ground above the 60-foot level is stoped to the surface for 100 feet east of the shaft, at which point the drift connects with an old shaft. On the 150-foot level a 30-foot stope about 200 feet east of the shaft has been carried to the surface. On the third level a stope beginning near the shaft has been carried to a height of 60 feet for 20 to 30 feet along the vein.

Throughout the drifts and stopes the wall rock is pegmatite. The vein proper ranges from 4 inches to 2 feet in width and averages 12 to 14 inches. It strikes N. 78° E. and stands nearly vertical to a depth of 150 feet, below which it dips 80° N. It is composed of white quartz and massive pyrite and chalcopyrite without other metallic minerals. Almost no banded structure and no evidence of post-mineral shattering was seen. The wall rock on either side of the vein is heavily impregnated with pyrite to a maximum width of 2 feet.

On account of the size of the vein most of the material broken is ore. The massive pyritic material is sent to the smelter and is said to bring from $30 to $100 per ton, mainly in gold with some silver. The less heavily mineralized portions of the vein constitute the concentrating ore, which is reported to assay $8 to $16 per ton. Smelting ore shipped in 1910 averaged gold 1.51 ounces, silver 1.98 ounces, and copper 0.96 per cent.

The claim was located in the late sixties and much of the surface ore was removed during the next few years. Free-milling ore was found to a depth of about 40 feet, but below 50 feet sulphides were encountered and work was abandoned for many years. In 1900 the present shaft house was built and sinking resumed, and the property has been worked at intervals during the last ten years. In 1909–10 it was worked by lessees, who report that they have produced about $4,000 worth of ore.

CHAMPION VEIN.

The Champion vein lies just east of Phoenix and 2½ miles northwest of Rollinsville. It strikes N. 70° W. and follows the northeast side of a mass of white quartz 15 to 20 feet in width. This quartz is probably an offshoot from the pre-Cambrian pegmatite, for it seems to be cut by a 25-foot dike of monzonite porphyry and appears to be barren.

The vein is developed by a shaft said to be 250 feet deep with about 500 feet of drifts. At the time of this survey, in September, 1910, it was water filled.

The ore on the dump consists of pyrite and chalcopyrite in a gangue of quartz and siderite, in many specimens forming the matrix of a breccia of schist fragments. Films of chalcocite and bornite coat the pyritic minerals locally. Near the surface much of the ore has been brecciated and the fractures filled with hematite deposited by oxidizing surface waters.

This property was located in the eighties, but as far as can be learned has made no production. Some surface ore is reported to have been rich, but the sulphide ore is said to be of low grade. The shaft is equipped with a steam hoist, and the company owns a mill situated on Beaver Creek just south of Phoenixville. The mill is equipped with 10 stamps, amalgamating plates, and Gilpin County bumpers.

TUNNELS WEST OF ROLLINSVILLE.

On the south side of Boulder Creek about 1¼ miles west of Rollinsville two crosscut tunnels are driven south through the Idaho Springs formation. As neither of these crosscuts could be entered the position and character of the veins cut are unknown. From the size of the dumps the tunnels are judged to be rather long. They are only 150 feet apart, the western one being 50 feet higher than the eastern. There is very little ore on either dump, though it is evident that some pyritic ore has come from the upper western tunnel.

PERIGO, GILPIN, GAMBLE GULCH, AND MOON GULCH.

PIONEER TUNNEL.

The Pioneer tunnel, on the south side of Moon Gulch, a mile west-southwest of Rollinsville, is a crosscut 1,270 feet long bearing S. 8° E. It is entirely in granite gneiss, which shows little fracturing. It exposes no valuable veins, but in its first 290 feet cuts three small fractures striking about N. 60° E. These fractures are tight slips with a maximum of 4 inches of crushed granite gneiss along them. Two of them show ⅛-inch stringers of pyrite. Two other fractures with about the same strike intersect the central part of the tunnel. One of these is unmineralized and the other shows a ½-inch veinlet of white quartz with a little pyrite.

QUINDARO TUNNEL.

The Quindaro tunnel is on the south side of Moon Gulch about a mile southwest of Rollinsville and just west of the Smuggler tunnel. It is a crosscut running S. 27° E. for 270 feet through the Idaho Springs formation. At 95 feet from the mouth of the tunnel a barren slip plane strikes N. 48° E. and dips 85° SE.; at 210 feet a 1-foot zone of unmineralized brecciated schist strikes N. 15° E., and at 260 feet another brecciated zone strikes N. 78° E. The two zones join 50 feet west of the line of the tunnel. Some iron-stained float lies on the surface above the line of this tunnel, but the development has not yet reached this part of the ground.

GOLD QUEEN VEIN.

The Gold Queen vein is on the north side of Moon Gulch west of the mouth of the south fork. It is developed by a short crosscut tunnel and 100-foot drift and by a shaft now abandoned.

The country rock is schist of the Idaho Springs formation with abundant pegmatite cut by a 6 to 8 foot mafic (basic) dike that strikes N. 20° E. and stands nearly vertical. This dike is presumably very old, for it is intruded by pegmatite and has a rather distinct schistose structure parallel to the general structure in the vicinity. A very narrow dike of quartz monzonite porphyry with an east-west strike cuts both schist and the mafic dike. Movement along the dike since the intrusion of the quartz monzonite dike has offset the latter, the north side now being about 10 feet northeast of the south side. Pyrite, chalcopyrite, and hematite have been deposited in fractures and joints in all the formations, but the chief seat of mineralization seems to have been the much-jointed dike, which has been altered and contains more or less abundantly disseminated pyrite throughout.

SMUGGLER VEIN.

The Smuggler vein is on the south side of a ridge between two forks of Moon Gulch about one-half mile southwest of the head of Traverse Gulch. It is developed by a drift tunnel 797 feet long and by a shaft 150 feet deep. The shaft was under water during the summer of 1911.

The country rock is Idaho Springs formation, containing numerous small tongues of granite gneiss, offshoots from the large mass of that rock on the south side of Moon Gulch. The vein strikes N. 75° E. and dips about 65° N. Its width ranges from a small barren fracture to 8 feet and averages between 2 and 3 feet. The wider parts consist of crushed wall rock carrying more or less abundant disseminated pyrite and lenses of coarse pyrite, most of which are about 2 inches wide but some of which reach 10 inches. Dark cherty silica, siderite, and hematite appear to have been deposited subsequent to the main mineralization.

Mineralization was strong everywhere except for about 100 feet near the face of the drift. The largest body of ore seems to have begun about 300 feet in from the mouth and to have extended for 290 feet. It has been stoped for 209 feet to a height of 80 feet and an average width of 4 feet.

The coarse pyrite is said to carry only about $2 a ton in gold, whereas the general run of mine has a value of $10 a ton. The ore thus far mined has been valuable mainly for its gold. In 1910 the average content of all concentrates sold to the smelter was 0.75 ounce gold to the ton. In 1911 the smelter returns gave an average of 1 ounce gold and 1 ounce silver a ton. A 10-stamp mill is situated at the mine.

The total production is estimated at between $50,000 and $75,000.

BONANZA TUNNEL.

The mouth of the Bonanza tunnel is about 500 feet south of that of the Smuggler tunnel. The tunnel, which is approximately 845 feet in total length, follows a rather winding but generally westerly course. Most of it is crosscut. Four zones of fracturing, some of which have been drifted on for short distances, strike northeast-southwest and dip 40°–50° NW., about parallel to the schistose structure of the Idaho Springs formation. A little disseminated pyrite occurs in the crushed country rock between their walls. At one place calcite was found in a small drusy cavity, but in general the gangue is silicified country rock. The west end of the Bonanza tunnel breaks into the stopes on the Smuggler vein about 45 feet above the Smuggler tunnel level.

DIAMOND BILL GROUP.

The Diamond Bill claims are on the north side of Moon Gulch about 2½ miles southwest of Rollinsville. Two nearly parallel veins that strike N. 50° E. are shown in numerous pits on the surface. The northern vein dips 55° N. and the southern vein a little more steeply. Both are quartz-pyrite veins cutting Idaho Springs formation. A crosscut tunnel at the level of the road has been started to intersect them.

OFFICER TUNNEL.

The Officer tunnel is on the south side of Moon Gulch about a mile from its head. The tunnel, which runs south-southeast through Idaho Springs formation, cuts near its mouth a narrow east-west dike of monzonite porphyry and also exposes a very narrow (1 to 2 inch) nearly barren fracture, in most places filled with gouge. Some rather coarse pyrite is seen on joint planes near the fracture, and at several places the schist for 2 inches on either side of the fracture contains a little disseminated pyrite. Many of the small pegmatite "eyes" in the schist near the fracture are more mineralized than the inclosing schist.

SEA BIRD TUNNEL.

The Sea Bird tunnel, on the north side of Moon Gulch about a mile east of the summit of Jumbo Mountain, runs west-northwest for 385 feet. Between 90 and 180 feet from the portal it cuts the only vein exposed—a lens of ore striking N. 85° W. and dipping 34° N. At its widest place this lens measures 4 feet, but its usual width is less than 1 foot. It consists of silicified schist carrying disseminated pyrite cut by narrow stringers of quartz and pyrite and little scattered chalcopyrite. An incline shaft sunk from the tunnel level in the widest part of the ore lens was full of water at the time of this survey.

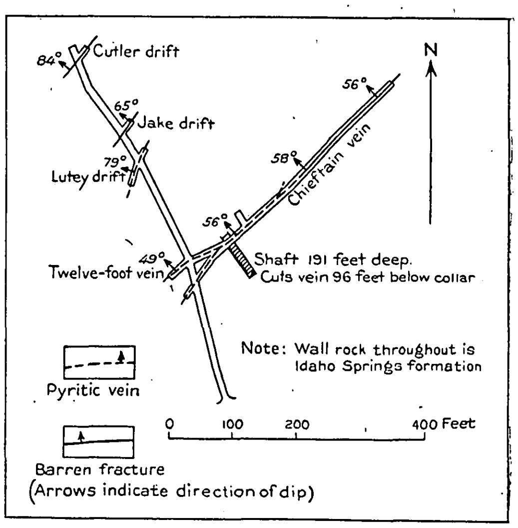


FIGURE 23.—Geologic plan of Mountain Monarch tunnel. Surveyed by hand compass and pacing.

MOUNTAIN MONARCH TUNNEL.

The Mountain Monarch tunnel, on the north side of Gamble Gulch 2 miles south of Rollinsville, is a 600-foot crosscut bearing N. 25° W. It intersects two veins and two barren fractures. (See fig. 23.) The wall rock is schist of the Idaho Springs formation.

The Chieftain vein strikes N. 45° E. and dips about 56° NW. It is a well-marked fracture zone varying from 10 inches to 4 feet wide but is not well mineralized except for about 110 feet near its junction with the Twelve-foot vein. The latter vein, where cut by the tunnel, is a 12-foot zone of schist bounded by well-marked fractures, carrying abundant disseminated pyrite, and cut in all directions by small pyrite stringers. It narrows to about 18 inches as it approaches the Chieftain vein.

Where the two veins come together they form an ore shoot about 3 feet wide of crushed silicified schist heavily impregnated with pyrite which continues 110 feet along the Chieftain vein with fairly constant width and mineralization. In the ore shoot the gangue is crushed silicified wall rock and the principal metallic mineral is pyrite, though in places a small amount of chalcopyrite was noted. The northwest end of the ore body is marked by a well-defined but feebly mineralized fracture making off into the hanging wall at an acute angle. Beyond the main ore body the Chieftain vein consists of about 18 inches of crushed schist between gouge-covered walls and contains a few small lenses of ore.

The Lutey drift is on a fracture striking N. 25° E. and dipping 79° W. The fracture, which contains about 7 inches of crushed schist carrying a little disseminated pyrite, is bounded by gouge-covered walls.

The Jake and Cutler drifts are on unmineralized fractures.

A few hundred tons of ore, said to have assayed $10 to $16 in gold and silver, have been stoped above the tunnel level from the shoot on the Chieftain vein.

A mill at the mouth of the tunnel is equipped with 10 stamps, amalgamation plates, 4 Gilpin County bumping tables, and a Bartlett table.

SWISS TUNNEL.

The Swiss tunnel, on the south side of Moon Gulch about 1¾ miles northwest of Perigo, is a crosscut extending south for 880 feet. The general country rock of the tunnel is Idaho Springs formation with abundant lenses of granite pegmatite, but the last 150 feet is largely in monzonite porphyry. Near the mouth of the tunnel a small dike of monzonite porphyry bears about east and west. No veins and only a few unmineralized slip planes parallel to the schistosity were seen.

PENOBSCOT TUNNEL.

The Penobscot tunnel is on the west side of Gamble Gulch 2½ miles southwest of Rollinsville and about a mile north of Perigo. The tunnel is a drift about 2,100 feet long on the Myrtie Bell vein, with other drifts on the Gold Dirt vein, and a 330-foot crosscut northwest to the Penobscot vein. (See fig. 24.) The country rock throughout is schist of the Idaho Springs formation injected by small lenses of granite pegmatite.

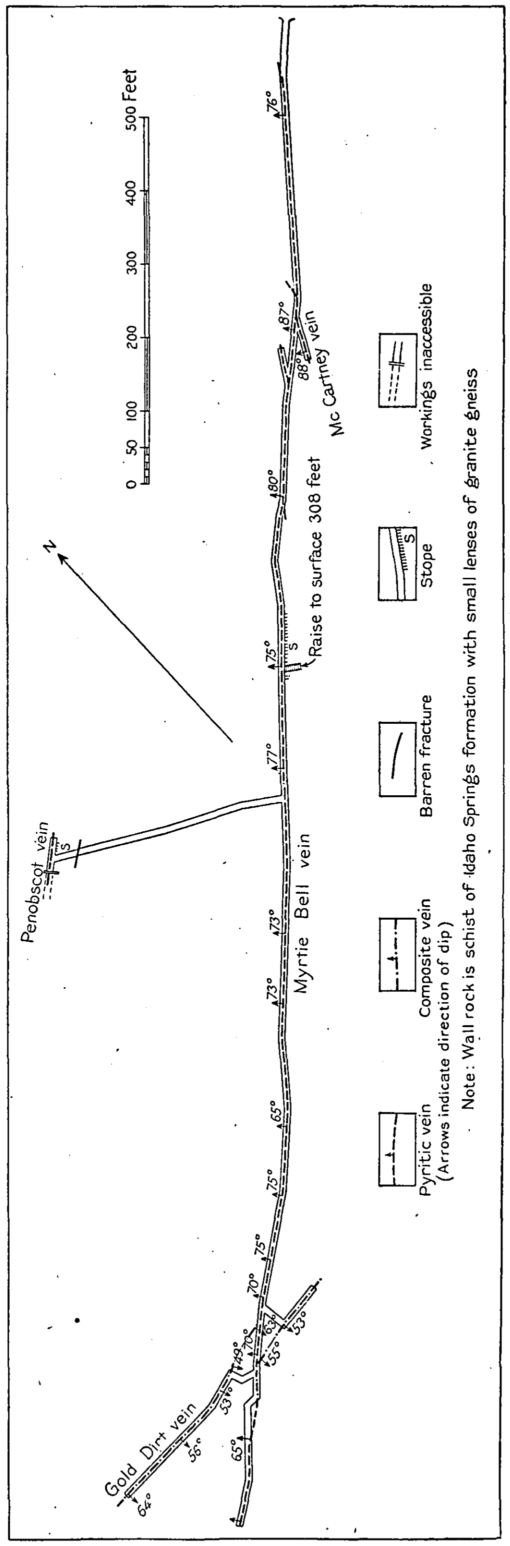


FIGURE 24.—Geologic plan of Penobscot tunnel.

The Myrtie Bell vein strikes N. 47° E. and dips on an average 75° NW. Its width varies from 2 inches to 4 feet, the average being about a foot. Both walls are marked by heavy postmineral gouge which in some places is 4 inches thick. The vein consists of somewhat crushed altered country rock carrying disseminated pyrite and here and there a little chalcopyrite. Just west of where it crosses the Gold Dirt vein the Myrtie Bell vein, here about 18 inches wide, incloses a lens 5 inches wide of solid chalcopyrite. The mineralization is in general not strong, but several small lenses yield concentrating ore. The spurs from this vein shown on the map (fig. 24) are rather small and are mineralized similarly to the Myrtie Bell.

The Gold Dirt vein cut near the end of the main tunnel strikes N. 78° E. and dips 50°–65° SSW. It varies in width from 4 inches to 4 feet, widths of 2 to 4 feet being most common. This vein consists of a number of subparallel fractures between which the country rock is altered and contains abundant disseminated pyrite. This disseminated ore is cut in all directions by stringers of solid pyrite, some of which are one-half inch in width, and by stringers of dark quartz and siderite carrying pyrite, chalcopyrite, and galena. The age relations of this galena-bearing ore are not clear from the exposures seen in this mine. The Gold Dirt vein has been offset for 50 feet by the Myrtie Bell. This movement probably took place after the mineralization of both veins for the postmineral gouge of the Myrtie Bell vein shows horizontal striæ. Postmineral movement along the Gold Dirt fracture has produced a little gouge and some striæ parallel to the dip of the vein.

The Penobscot vein, as exposed at the end of the crosscut from the Myrtie Bell drift, is a zone of fractured rock about 4 feet wide, carrying a little disseminated pyrite. The drift to the west is caved, but is said to be 300 feet long.

The Penobscot tunnel was intended as a drainage and transportation tunnel for the mines on Tip Top Hill west of Perigo, and very little stoping has been done on any of the veins it exposes. In 1911 the owners were drifting west on the Gold Dirt vein and had found some good ore. A 10-stamp amalgamation and concentration mill is situated north of the tunnel mouth in Gamble Gulch.

Some assays of ore from the west Gold Dirt drift are reported to show 0.68 ounce gold, 4.5 ounces silver, and 10.5 per cent copper per ton, though the average ore does not appear to contain so much copper. Some of the chalcopyrite in this drift has altered to soft black chalcocite. Ore from the small stope on the Penobscot vein is said to have carried $30 in gold and silver. The copper ore from the shoot on the Myrtie Bell southwest of the Gold Dirt crossing is said to have had a value of $30 a ton. The ore of the Myrtie Bell northeast of the crossing is generally of low grade.

GOLD DIRT MINE.

The Gold Dirt, one of the first mines discovered in this district, is about a mile northeast of the village of Perigo. It is developed by a drift tunnel starting eastward from Gamble Gulch and by several shafts, the main one of which, 700 feet deep, is sunk beside the road from Perigo to Gilpin. The vein strikes N. 80°–85° E. and dips 80°–85° S.

The ore could be studied only on the shaft dump and in the tunnel, which was entered for 570 feet. That on the dump is composed mainly of coarse pyrite, some of which is copper stained. Near the surface the ore is much altered and secondary hematite is developed, but as exposed in the tunnel about 450 feet from the face it forms a vein of nearly solid coarse pyrite 8 inches thick. Postmineral movement along the vein has crushed and sheared the ore in places. According to Hollister [1] the upper portions of the vein were very rich:

> During the spring [of 1860] the Gold Dirt lode had been struck, and very rich it was. By the end of the year six quartz mills were running from it. One sluice took out in 17 days $2,227.
>
> Hurlbut & Co.'s six-stamp mill started October 1 and up to January 5, 1861, had taken out $11,526.94 and had been idle four weeks of the time. Between June and November two men realized from the lode, over and above all expenses, $35,000. Hollister & Co. struck pyrites on the lode 70 feet from the surface. Before that they had been working 60 hands, and their weekly yield of gold was from $1,500 to $2,000. Upon striking the pyrites, a run of 18 hours gave but $1.40.

The ore below the oxidized-surface portions of the vein is said to average about $13 a ton for concentrating ore and $20 to $60 for smelting ore. A 50-ton cyanide mill is near the mouth of the tunnel.

[1] Hollister, O. J., The mines of Colorado, p. 113, 1867.

COLORADO TUNNEL.

The Colorado tunnel, whose portal is in Gamble Gulch about 100 yards below the portal of the Gold Dirt, extends northeast for about 630 feet through schist of the Idaho Springs formation and pegmatite. From a point 200 feet from the portal to the face it follows a vein. The first 250 feet of this vein is practically barren, but beyond that it is well mineralized and in one place shows 8 inches of coarse pyrite and gray quartz between sharp walls. At 500 feet from the portal the vein is made up of 4 feet of somewhat brecciated schist and pegmatite carrying more or less disseminated pyrite and traversed by a 4-inch sharp-walled pyrite veinlet.

The tunnel forms part of the Gold Dirt group of workings. No shipments have been made from it.

WAR EAGLE MINE.

The War Eagle vein is on the ridge east of Gamble Gulch about a mile northeast of Perigo. It is developed by a shaft said to be 200 feet deep and to have short drifts on three levels. The country rock is granite gneiss.

The vein strikes N. 60° E. through a saddle in the ridge. The ore on the dump is pyrite-impregnated country rock traversed by veins as much as $1\frac{3}{4}$ inches wide of coarse-grained pyrite with a little white quartz. In these sulphide veins individual pyrite crystals attain a maximum size of one-half inch. Some of the ore contains a little specularite and some, it is reported, a very small amount of chalcopyrite. Some ore shows a little postmineral crushing with blackened slickensided faces cutting pyrite stringers.

The ore is said to average about $15 a ton in gold.

PERIGO MINE.

The Perigo is the largest mine in the Perigo region and one of the oldest, having been opened in 1860. The principal development work consists of two tunnels (see figs. 25 and 26) and the stopes connected with them. Several old shafts could not be entered. In general, as may be seen from the maps, the workings develop a complicated set of veins with a general trend somewhat north of east. Toward the southwest the branches unite to form a single fracture zone, which, however, is not so strong nor so heavily mineralized as might be expected from the union of so many branches. All of the veins of this system are similar mineralogically and were plainly formed at the same time. The wall rocks are schist of the Idaho Springs formation, granite gneiss, and pegmatite. (See figs. 25 and 26.) Much of the granite gneiss is unusually coarse grained, approaching pegmatite in texture.

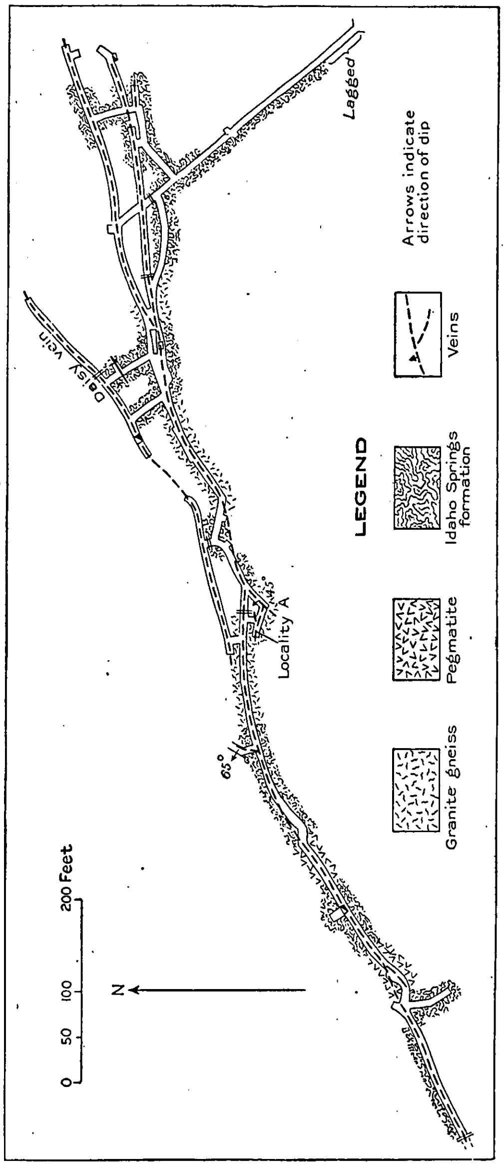


FIGURE 25.—Geologic plan of upper tunnel, Perigo mine.

The veins may be described in general as disseminations of pyrite in the wall rocks along zones of fracturing; with the single exception of the vein at locality A, figure 25, in which fissure filling seems to have been very subordinate. The relations are complex and the degree of mineralization extremely variable.

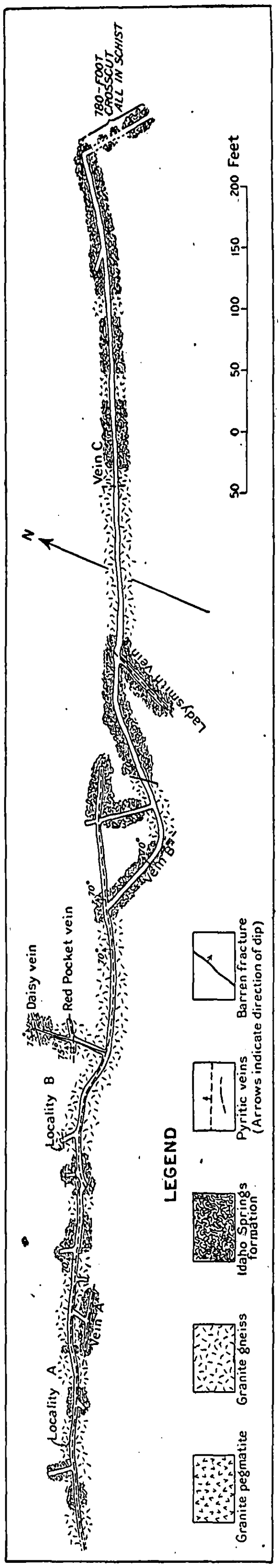


FIGURE 26.—Geologic plan of lower tunnel, Perigo mine.

Although most of the ore of the upper tunnel seen in place was pyritic, some of that on the dump carried a little fine-grained galena. The ore, though commonly a dissemination of pyrite through fractured wall rock, locally occurs in sharp-walled veinlets which may be true fissure fillings. Thus, at locality A, figure 25, the granite gneiss, which carries disseminated pyrite for a width of 2½ feet, is cut by several fairly sharp walled subparallel veinlets of pyrite, some of which are 3 inches in width. The northern vein developed in the upper tunnel is known as the Daisy; other veins have been named the Baker and the Perigo, but as their identification is uncertain these names have been omitted from the map.

In the lower tunnel, at one of the best exposures, the main vein (locality A, fig. 26) consists of schist and pegmatite carrying disseminated pyrite for a maximum width of 6 feet. Some of the pyrite is very fine grained and some of it is coarse, occurring in cubical crystals with maximum widths of three-fourths of an inch.

Vein A, exposed in a branch drift, shows pyrite disseminated through schist bordering a fracture zone. At the east face it is 4 feet wide.

What is probably the Daisy vein (locality B, fig. 26) consists of 3 to 5 feet of fractured gneiss and pegmatite carrying disseminated pyrite.

The Red Pocket vein at the west end of the drift which follows it is a zone of schist and pegmatite 4 feet wide cut by several small pyrite stringers and carrying some disseminated pyrite. A little stoping has been done upon it.

Vein B consists of 2 feet of schist and pegmatite traversed by irregular stringers of coarse pyrite some of which are an inch wide.

The Ladysmith vein, which consists in places of 6 to 8 inches of crushed but unmineralized schist, shows near the main tunnel 2 feet of crushed schist and pegmatite traversed by two 2 to 3 inch veinlets of quartz and pyrite.

Vein C is a strong sharp-walled vein of white quartz which carries irregular masses of pyrite and is traversed by a band of coarse pyrite 1½ inches wide. Pyrite locally forms half the vein but in most places is much subordinate to quartz. Vugs are common; one a foot across is lined with quartz crystals three-fourths of an inch and less in diameter. The vein has not been developed.

The shipping point for ore and concentrates from the Perigo mine is Rollinsville, 3 miles by road from the mine. The lower grades of ore are treated at Perigo in a stamp mill of 100 tons capacity. At present mining on a small scale is in progress in several parts of the mine by lessees, who pay a royalty of 25 per cent on smelting ore and from 10 to 15 per cent on concentrating ore. Short mill runs are made at intervals as sufficient ore accumulates. Fourteen lots of smelting ore aggregating 42½ tons, shipped at different times from 1901 to 1909, showed by sampling-works assays gold 0.44 to 3.16 (average, 1.23) ounces, and silver 1.20 to 4.70 ounces.

FREE GOLD AND MAREAU VEINS.

The Free Gold and Mareau veins, on the hill just west of Perigo village, are developed by shafts 310 and 190 feet deep, respectively. The properties were opened about 1900.

The Free Gold had long been idle at the time of this survey. The vein is at or near the contact between schist of the Idaho Springs formation and monzonite porphyry. The only mineral seen was coarse pyrite in bunches or irregularly disseminated in pegmatite. The average metal content of the ore treated in 1910 was 0.368 ounce of gold and 0.21 ounce of silver.

About 96 tons of ore, obtained recently from the Mareau shaft, were milled in the Daisy mill at Perigo and are said to have averaged about 1 ounce in gold.

The Daisy mill, connected with these properties, is equipped with three batteries of slow-drop 450-pound stamps and three Gilpin County bumpers.

GOLDEN FLINT VEIN.

The Golden Flint vein is about three-fourths of a mile south-southwest of Perigo. It strikes N. 85° W., and appears to dip about 80° N. It is developed by a shaft 400 feet deep, now water filled. The ore is entirely pyrite in a quartz gangue. The mine was an important gold producer in the early days of the district but has been idle for many years.

MOUNTAIN CHIEF MINE.

The Mountain Chief mine is about $1\frac{1}{4}$ miles northeast of Apex, on a north spur of Dakota Hill, within a large stock of monzonite porphyry. The shaft, now long abandoned, is said to be about 300 feet deep. The surface exposures and the remnants of ore on the dump suggest that the deposit represents mineralization along a large number of small subparallel fractures rather than along a wide fissure. In places the porphyry is traversed by an irregular network of pyrite veinlets that range in width from one-fourth inch to paper thinness. Pyrite in disseminated grains and minute lenses is abundant in all of the ore. The only vein mineral observed besides pyrite was hematite, probably formed by oxidation from the pyrite. Some of the oxidized surface ore from this mine is said to have run about 2 to 3 ounces in gold, but the unaltered material was not of profitable grade.

VICTORIA VEIN.

The Victoria vein, on the south side of Lump Gulch, one-fourth mile south and a little east of Gilpin, strikes about N. 22° E. and dips 65° NW. The shaft, now full of water, is said to be 150 feet deep and to have about 290 feet of drifting on the 110-foot level. The vein is largely stoped at the surface for a distance of 250 feet south of the shaft.

The ore is pyrite and chalcopyrite in a quartz gangue. A relatively narrow streak of solid sulphides constituted the higher-grade material, and the country rock impregnated with sulphides for 3 to 11 feet on either side of the vein was considered concentrating ore. It is claimed that the smelting ore averaged about \$54 per ton and the concentrating ore about \$6.

The property, consisting of two claims on the vein and a placer in Lump Gulch, was located in 1879 or 1880 and was worked intermittently until 1906. To that time the gross production is said to have been about \$20,000.

GETTYSBURGH VEIN.

The Gettysburgh vein, formerly called the Illinois, is about one-half mile south of the town of Gilpin. Its trend is slightly north of east and its dip apparently about vertical. It has been developed by several pits and by a shaft, now inaccessible, said to be 225 feet deep.

The ore on the dump shows a pyritic vein in places as much as 6 inches wide though generally much narrower. Gangue minerals are siderite and quartz. Specimens of oxidized ore show limonite and some malachite with remnants of unaltered chalcopyrite. The value of the unaltered ore is said to have been low, but that of the oxidized free-milling ore in surface pockets is said to have been \$50 to \$60 in gold.

The mine was discovered in 1860. The present company has installed three sets of crushing rolls and Crane dry concentrators, which, however, appear to have been but little used.

APEX, AMERICAN CITY, AND KINGSTON.

CHARCOAL CHARLIE VEIN.

The Charcoal Charlie vein, on the north side of Freeman Gulch about half a mile above its junction with North Clear Creek, is opened by a shaft of unknown depth. The vein strikes about N. 55° E. through Idaho Springs formation. Very little ore appears on the dump, but what there is shows a banded vein at least 3 inches wide. Next the walls there is about an inch of siderite carrying pyrite and a little scattered chalcopyrite. The central part of the vein is filled with white quartz free from sulphides.

SCHULTZ WONDER MINE.

The Schultz Wonder mine is on the south side of North Clear Creek just above the junction of Pine Creek, about 2 miles south of Apex.

The principal vein strikes N. 20°–35° E. and dips 75° W. The main development is a tunnel following this vein for about 700 feet through schist of the Idaho Springs formation and subordinate pegmatite. The vein commonly cuts the schist foliation at small angles but in a few places parallels it. A bostonite dike outcrops a short distance west of the vein.

The Schultz Wonder vein is irregular in size and degree of mineralization and exposes no ore shoots of workable size. The largest ore body seen was from 4 to 30 inches wide and persisted for about 125 feet along the adit. It consists of a heterogeneous mixture of chalcopyrite, pyrite, sphalerite, and a little galena in a white to gray quartz gangue. In the narrower portions of the vein there is commonly a band of comb quartz next the walls. Siderite occurs in places, generally in the central portion of the vein. The vein is cut off at the face of the tunnel by a fault striking N. 45° W. and dipping 70° S.

The tunnel cuts a number of lean or barren cross fractures, some of which have been drifted upon.

The claims of this group were located in 1894 and small amounts of ore, said to have averaged about $15 a ton in gold and silver, have been shipped.

PIONEER TUNNEL.

The Pioneer crosscut tunnel, started in the fall of 1910 on the north side of North Clear Creek at the junction of Pine Creek, about 2 miles south of Apex, is designed to run northwest under Arizona and Montana hills. The tunnel is for drainage and transportation and is 8 by 9 feet in the clear. In 1911 a 10-stamp mill was under construction at the mouth of the tunnel. The company owns only a few claims on the southeast slope of Arizona Hill, and no veins have yet been intersected.

GEIGER VEIN.

The Geiger vein is exposed on the west side of Michigan Hill, 1½ miles south of Apex and about opposite the mouth of Pine Creek. It has been opened by shafts, pits, and tunnels from the creek bottom to the top of the hill, a distance of nearly three-fourths of a mile. Owing to caving and flooding, none of the workings are now accessible.

At the outcrop the vein strikes about N. 50° E. and is nearly vertical.

On the top of Michigan Hill the vein, which here cuts granite gneiss, is about 4 to 6 feet wide and consists of white quartz stained yellowish along fractures and traversed by many small veinlets of pyrite. Much disseminated pyrite occurs in the vein material and the adjacent wall rock. Bands of reddish-gray cherty quartz containing a little chalcopyrite and pyrite appear to cut the white quartz. Ore on the large dump of the lower tunnel, just above the road in North Clear Creek opposite the mouth of Pine Creek, shows two distinct periods of mineralization. The first is represented by a vein consisting largely of pyrite in a quartz gangue and by associated pyritic replacement of the schist wall rocks. This vein was fractured and the fractures filled during a second mineralization by an abundant white gangue of quartz carrying chalcopyrite, some pyrite, and scattered sphalerite and galena. Siderite is generally present in the later veinlets as a thin crust next their walls. Vugs lined with quartz crystals are common.

Subsequent to both mineralizations some fracturing of the vein took place, and the fractures were filled with cherty-looking silica, which has also been deposited upon the quartz crystals in some of the vugs.

INGRAM VEIN.

The Ingram vein cuts across the ridge between North Clear Creek and Elk Creek about a mile south of Apex. It was opened in 1896 by a shaft starting on the top of the ridge at an elevation of 10,150 feet. This shaft is said to be 270 feet deep and to be connected with a large amount of drifting. It was last worked in 1909 and could not be entered on account of water. A tunnel from Elk Creek, starting about 50 feet above the valley bottom, was at the time of survey about 120 feet long. The last 70 feet follows an unmineralized fracture zone that strikes N. 55° E. and dips 55° W. Whether this represents the Ingram vein is doubtful.

At the shaft the vein apparently strikes N. 65° E. and dips 70° NW., cutting the foliation of granite gneiss at very acute angles. Some rather obscure outcrops of bostonite porphyry just east of the vein are probably part of a long dike which extends southeast nearly to Nevadaville, a distance of 4 miles.

The ore on the dump is largely chalcopyrite and pyrite in a bluish quartz gangue. Portions of the vein are said to carry galena containing some gold and silver. Much of the massive sulphide ore is crushed and fractured, and the vein material is separated from the wall rock by gouge blackened by an abundance of crushed pyrite. In places a dull black earthy coating, probably chalcocite, appears on the pyrite and chalcopyrite.

The owners estimate the production of the property at about $10,000 from ore running between 14 and 22 per cent copper per ton.

EVERGREEN MINE.

The Evergreen mine in the valley of Pine Creek, about half a mile south of Apex post office, is unique for this district in the nature and mode of occurrence of its ore. The ore is valuable largely for its copper content, and the sulphides occur not in a vein but disseminated through monzonite as an original constituent. The property was worked in the early eighties, but its modern development began with its acquisition by the present company in 1904. The mine is developed by a vertical shaft with levels at 60, 150, and 200 feet. The 60-foot level was inaccessible at the time of the survey. The drift on the 150-foot level extends about 130 feet north-northeast from the shaft. At the 200-foot level the main drifts are connected with the shaft by a crosscut about 100 feet long, from which drifting has been extended for about 270 feet to the north and 220 feet to the south. A tunnel, whose mouth is about 50 feet north of the shaft, runs for about 565 feet a little west of north.

Mining has been largely exploratory; no stoping has been done on the 200-foot level, and only 50 feet of stoping, locally to a height of 15 feet, has been done on the 150-foot level. Almost the only stoping in the tunnel is at a point about 120 feet from the mouth, where a large chamber stope about 40 feet long, 30 feet wide, and from 2 to 12 feet high has been excavated.

The plant, which is operated by steam power, consists of a shaft house and mill. The shaft is equipped with bucket hoist. In the mill, which has a capacity of about 60 tons in 24 hours, the ore, after crushing, goes to a conical settling tank and then to Richards pulsating jigs and Card tables. The concentrate is hauled by team 8 miles to Black Hawk.

The geologic relations at the Evergreen mine and the mineral character and origin of the ore have already been fully described on pages 126–129.

The ore obtained at this mine is said to average about 3 per cent copper and $4 to $5 in gold and silver per ton. Its distribution, however, is sporadic, and with the exception of that in the large chamber stope on the tunnel level no large bodies of it have been found. Only a few carloads have been shipped. and work is still largely exploratory. The ore is unquestionably to be sought in and near the dikes, but as the sulphides are so unevenly distributed in the dike rock no prediction of its probable value or extent can be made.

GOLD STANDARD AND NANCY LEE VEINS.

The Gold Standard and Nancy Lee veins are on the south side of Pine Creek about three-fourths of a mile south of Apex. There are shafts on both veins, said to be over 100 feet deep, and a tunnel now caved has been driven on the Nancy Lee vein. The ore near the surface was free milling as a result of oxidation but passed with depth into pyritic ore with quartz gangue which does not appear to have been payable. A small stamp mill with Gilpin County bumpers is located near the mouth of the tunnel. The gross production is said to have been about $10,000, mainly from oxidized ore.

BULLION TUNNEL.

Several small pyritic veins are cut by a prospect tunnel known as the Bullion (925 feet long) in Whites Gulch about one-fourth mile west of Apex. This tunnel through most of its length runs somewhat west of north and is almost entirely in Idaho Springs formation. It cuts five fracture planes, which strike N. 70° E. to N. 80° W. and dip from 40° N. to vertical. Some of these fractures are barren throughout, but others, though barren locally, carry pyrite in lenticles 2 inches or less across. The pyrite is coarse and is associated with some gangue quartz; none of the seams have been worked. A dike of monzonite porphyry is cut by this tunnel about 420 feet from the mouth and is exposed for 90 feet. It contains much disseminated pyrite in small particles, which are most abundant along and near small fracture planes. Some of these pyritized seams traverse porphyry and schist indiscriminately. A barren fracture similar in trend to the pyritic seams cuts the porphyry, indicating that the pyritic mineralization is probably later than the intrusion of the monzonite porphyry.

A specimen from the tunnel dump shows a coarse pyrite vein cutting sharply across the foliation of schists of the Idaho Springs formation but shows practically no dissemination of pyrite in the schist. Another dump specimen, evidently from a vug in one of the pyritic veins, shows pyrite cubes etched or corroded to steplike or ragged surfaces. Upon portions of these pyrite crystals coatings of siderite, chalcopyrite, and bornite in small crystals were deposited either contemporaneously with or prior to the etching.

ANNIE H. VEIN.

The Annie H. mine, on Elk Creek near Nugget and just southwest of the Mackey mine, was last operated about 1908 and could not be entered. The workings consist of two shafts known as No. 1 and No. 2, 300 and 225 feet deep respectively and 310 feet apart. The most extensive drifting is on the upper or tunnel level, which is 572 feet long and is cut by the No. 2 shaft at a depth of 155 feet. The deeper levels connect only with the No. 2 shaft; one at a depth of 205 feet extends about 60 feet on each side of the shaft, and another at 255 feet extends about 75 feet on each side.

The vein strikes about N. 60° E. Its dip may be inferred from the inclination of the shaft, which, between the surface and the first level, dips 50° N., and between the first and second levels to about 35° N. From the bottom of the shaft a crosscut has been driven northward for about 125 feet.

The ore, which is of the pyritic type, is similar in general to that of the Mackey vein. Available assays of the ore show \$4 to \$50, mainly gold; most of them show \$16 to \$20. Some picked lots assayed as high as 6 per cent copper.

Most of the ore was treated at the mine in a mill equipped with automatic feeders, 10 stamps, 2 Gilpin County bumpers, and 3 Frue vanners.

MACKEY VEIN.

The Mackey mine, about a mile west of Apex near the head of Elk Creek, was idle at the time of this survey, and only a portion of it was accessible. The workings consist of a shaft connecting with two accessible levels at 25 feet and 140 feet and a third, at a greater depth, which was water filled. The vein strikes N. 50°–75° E. and dips 30° to 50° N. The shaft follows the vein.

The 25-foot level is about 200 feet in length and has been considerably stoped. The vein material, however, is highly oxidized and the exposures are not favorable for study. The 140-foot level (see fig. 27) cuts mainly Idaho

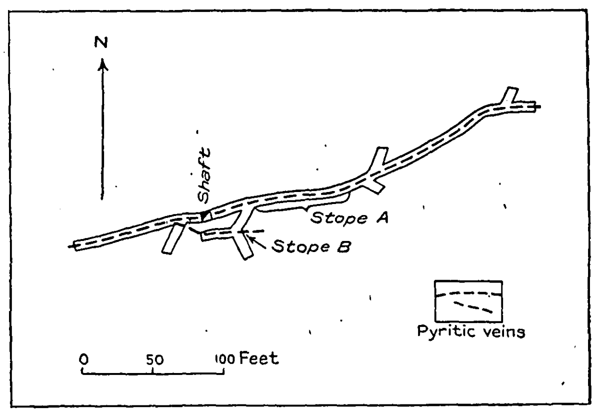


FIGURE 27.—Plan of 140-foot level, Mackey mine, near Apex, Colo.

Springs formation intruded by small amounts of pegmatite. The vein is a well-defined fracture zone, which on the west of the level is practically barren but at most other points is well mineralized. Where widest the heavily mineralized portion is about 2 feet across and appears to be a true fissure filling composed of white quartz and pyrite in nearly equal amounts. Some of the quartz shows comb structure. This is bordered on each side by a foot or so of wall rock carrying some disseminated pyrite. In stope *A* (fig. 27), which connects with the 25-foot level, the vein is commonly about 1½ feet wide. At one place it shows about a foot of nearly solid pyrite, below which, for 2½ feet, scattered stringers of pyrite traverse the schist.

A relatively narrow branch vein, said to be of much higher grade, joins the main vein a short distance west of the shaft. Stope *B*, on this branch vein, extends 15 to 20 feet above the level and shows that it is of very uneven or pockety character and is in places 6 inches wide though commonly narrower. Its richest portions carry chalcopyrite, which is coated along fractures with secondary films that show peacock colors where thin, and where thicker the blue-color characteristic of covellite.

The shaft house is connected by a short tramway with a 10-stamp mill which is also equipped with cyanide tanks. Only experimental runs seem to have been made.

Gold is the principal valuable metal of the ore, but no reliable figures showing the tenor of the ore were accessible. Exceptionally as much as 5 per cent of copper is present. The total production is said to have been about 2,000 tons.

FISH VEIN.

The Fish vein, in the valley of Elk Creek about due west of the summit of Idaho Hill, is opened by a tunnel which is caved 460 feet from the portal. For the first 300 feet the tunnel exposes no important veins, but from the 300-foot point to where it is caved it follows a vein striking N. 60° E. and dipping 50° NW. This vein is typically pyritic, carrying pyrite, some chalcopyrite, and a quartz gangue. Much gouge is present, and the vein is soft and wet. Near the surface some hematite has developed from oxidation of pyrite. The ore appears to be low grade and little has been shipped.

PLATEAU VEIN.

The Plateau vein is on the south side of Colorado Mountain near its crest, about one-fourth mile north of American City. It strikes about east and west and at the surface apparently dips 45° N., but in the lower levels is said to be almost vertical. The main shaft, now full of water, is said to be 640 feet deep, with about 1,000 feet of drifts. The ore on the dump is entirely pyrite and white quartz and is said to carry about $20 per ton in gold and silver. No production figures were obtainable.

HUBERNOCKER VEIN.

The Hubernocker shaft is at the north side of Elk Park near the divide into Black Canyon, about one-half mile northwest of American City. The shaft, now full of water, is said to be about 150 feet deep. The vein strikes northwest and consists of quartz and pyrite; it is said to have been oxidized to a depth of 35 feet.

ANNIE TUNNEL.

The Annie tunnel is in the gulch between Pile Hill and Montana Mountain, about 2 miles west-southwest of Apex. The property was being worked in 1910, the development consisting of a tunnel about 250 feet long, trending N. 60-65° E. for the first 220 feet and thence N. 40° E. to the face. Almost the whole tunnel is in schist of the Idaho Springs formation and pegmatite. At the face is exposed a broad fracture zone, 7 to 8 feet wide, striking about N. 85° E. and dipping 85° N. This fracture zone shows over a foot of gouge and numerous subparallel veinlets of pyrite one-half inch or less in width and of quartz. Some chalcopyrite is present in these veinlets and much pyrite is disseminated in the altered schist between them. Tennantite occurs here and there in small veinlets within the fracture zone. The ore of this vein is said to have an average value of $8 a ton, but picked portions show $26 in copper and $60 in gold. No shipments have been made.

METEOR TUNNEL.

The Meteor tunnel, at the southwest corner of Elk Park, is 225 feet long. It runs S. 67° W. through Idaho Springs formation, following a 2 to 8 inch fracture which dips 35° N. This fracture contains brecciated silicified schist carrying some disseminated pyrite. The vein is partly oxidized throughout its entire exposure, for even at the face the depth attained is only about 75 feet.

GOLD RESERVE VEIN.

The outcrop of the Gold Reserve vein trends east-northeast along the southwest slope of Montana Hill, south of and about parallel to a bostonite porphyry dike. The vein consists of quartz with a little pyrite and chalcopyrite, and its higher-grade ore is said to average about $15 to $20. The shaft is said to be 90 feet deep but is full of water. A crosscut tunnel now 140 feet long, whose mouth if below the junction of Mosquito Gulch and North Clear Creek, has not yet intersected the vein.

MONTANA HILL TUNNEL.

The Montana Hill tunnel is on the north side of North Clear Creek about one-fourth mile above the mouth of Miners Gulch. It is a crosscut, at present about 300 feet long, that bears N. 2° W. It is driven through dense quartz diorite and hornblendite without joints or fractures and exposes no ore.

J. W. PROSPECT.

The J. W. prospect, in Kingston mining camp, consists of a single tunnel 125 feet long from which a branch tunnel 60 feet long has been driven. The main tunnel trends N. 25° E. and the branch tunnel diverges at only a small angle. The main tunnel at one point cuts a breccia of schist fragments in a partly oxidized matrix carrying chalcopyrite, tennantite, sphalerite, quartz, and barite. The 60-foot drift follows a quartz stringer which locally carries some chalcopyrite and tennantite. Work at this property was begun in 1904, but no ore has as yet been shipped.

LONDON VEIN.

The London vein, in the mining camp of Kingston about 3½ miles west-southwest of Apex, strikes N. 80° E. and dips about 70° N. It is developed by a shaft 100 feet deep, from the bottom of which some drifting has been done. The shaft was sunk 12 to 14 years ago, and after lying idle for many years the property was again being worked (by lessees) in 1910. The wall rock is schist of the Idaho Springs formation. The drift on the 100-foot level follows the vein westward from the shaft for about 50 feet, then leaves the main vein and for 50 feet follows a branch, which strikes N. 60° E. and dips 70° NW., to a point where it is cut off by a fractured mass of soft barren schist, into which the drift penetrates for 40 feet.

The ore is pyrite with a little chalcopyrite and is said to average $15 to $20 a ton, principally in gold. Oxidized portions show specular hematite in aggregates of small flakes. Assays as high as $170 have been obtained. The average content per ton of small lots of smelting ore shipped in 1910 was gold 0.97 ounce and silver 3 ounces, and of concentrating ore, gold 0.23 ounce and silver 1 ounce.

MOOSE VEIN.

The Moose mine in Kingston Camp has been long abandoned. It was worked through a shaft now inaccessible. The strike of the vein is about N. 75° W. and the dip near the surface is 70° N. The unaltered ore shows pyrite and subordinate chalcopyrite; the oxidized surface ore carries specular hematite.

ILLINOIS VEIN.

The Illinois vein is in Kingston camp on the northwest slope of Pile Hill. The shaft could not be entered, but from surface appearances the vein appears to strike about N. 50° E. The ore, which is in general similar to that of the Annie H. vein, consists of pyrite and subordinate chalcopyrite.

SILVER CREEK AND STEWART GULCH.

SHERMAN-MACON TUNNEL.

The Sherman-Macon tunnel, on the west side of Silver Creek about three-fourths of a mile north of its junction with Clear Creek, is a crosscut 1,240 feet long trending N. 55° W. through granite gneiss injected by pegmatite. Two systems of fractures cutting the gneiss are shown, one striking about N. 20°–40° E. and the other about 80° E. The northeast-southwest fractures dip steeply west or stand vertical, and the east-west ones dip 40°–70° N. Both systems are mineralized in a few places, but for the most part are nearly barren. The mineralization is pyritic, the pyrite occurring as disconnected lenses and stringers one-fourth to 1 inch wide. Locally the walls are somewhat silicified.

The most prominent and best mineralized fracture is cut about 1,000 feet in from the mouth of the tunnel. It belongs to the east-west system. Drifts have been run both ways on this fracture for about 100 feet from the tunnel, and an 80-foot raise has been excavated at the tunnel. Parallel to the vein and about 10 feet northwest of it a nearly vertical open watercourse is filled with breccia and gouge. No ore had been produced up to the time of this survey.

PETTIBONE MINE.

The Pettibone mine is on the east slope of Oregon Hill about 1½ miles north of the junction of Silver Creek with North Clear Creek.

The workings consist of an upper and a lower tunnel, about 200 feet apart vertically, located a few hundred feet above the level of Silver Creek. The mine has been closed for several years, both tunnels were caved near the portals, and the information in regard to the ores was derived solely from an examination of the dumps. The size of these indicates that the workings were extensive.

The ore on the dumps belongs to two distinct types, presumably coming from different veins. The first type shows pyrite in solid veinlets 2 inches or less in width. A small copper content is indicated by films of chalcopyrite on the pyrite crystals. The second type of ore consists of galena and resinous sphalerite with very small amounts of chalcopyrite, commonly in coarse crystals without any important amount of gangue. In some specimens quartz and barite are present as gangue minerals. Vugs are lined with well-formed crystals of galena, sphalerite, and transparent quartz. The contacts of ore and wall rocks are very sharp, and the walls show almost no disseminated sulphides.

The galena-sphalerite vein has been reopened and brecciated, and the breccia spaces as well as the vugs have been partly or wholly filled with silica and some siderite. Most of these later veinlets have a central portion of crystalline quartz and one-eighth inch borders of cherty silica or siderite. The smaller veinlets also are commonly cherty. Thin layers of white quartz coat the galena, sphalerite, and the original quartz crystals of some of the vugs.

REFORM VEIN.

The Reform vein is on the east side of Silver Creek 1½ miles above its junction with North Clear Creek. The vein strikes N. 11° E. and dips steeply east, cutting granite gneiss. The shaft could not be entered, and no ore was to be seen on the dump, though a little pyrite disseminated through the gneiss was found. The shaft is said to be 160 feet deep with a total of 108 feet of drifting on both the 35 and 130 foot levels. A small seam of smelting ore, largely pyrite, is reported to have run from $20 to $60, but most of the ore averaged from $3 to $8 per ton.

A partly dismantled mill just below the mine was equipped with ten 700-pound slow-drop stamps dropping 16 inches, a Gilpin County bumping table, and a King-Danough concentrator.

GOLDEN ROD MINE.

The Golden Rod mine, on Silver Creek about 1½ miles above its junction with North Clear Creek, is developed by a shaft and tunnel. The tunnel, which was started in 1902, is about 50 feet above the level of Silver Creek and extends for about 825 feet into Oregon Hill. Its average direction is about N. 60° W. For its whole length the tunnel is in Idaho Springs formation highly injected with pegmatite. (See Pl. X, *A*, p. 21.) The tunnel cuts a number of small pyrite veinlets but exposes no important veins in its first 700 feet; beyond this it follows a well-defined vein for 125 feet to the face. This vein strikes N. 85° E. and dips 30° N., about parallel to the foliation of the inclosing Idaho Springs formation. A small amount of stoping has been done on this vein, disclosing 1½ feet of fractured schist traversed by numerous one-eighth inch stringers of pyrite, all lying about parallel to the schist foliation. Specimens from the dump show abundant chalcopyrite locally associated with pyrite. In other specimens chalcopyrite occupies the center and pyrite the walls of the veinlets. The gangue where present is usually quartz. The same vein has been developed by a shaft 240 feet deep from which some drifting has been done. The collar of the shaft is about 200 feet vertically above the tunnel level. The tunnel and shaft workings do not connect and the latter were filled with water. The work on this property has thus far been largely exploratory.

SNOWDEN VEIN.

The Snowden vein cuts across the low divide between Stewart Gulch and Silver Creek. The shaft and tunnels are on the east side of Silver Creek about 2 miles north of its junction with North Clear Creek. The workings are in rather poor condition and the lower tunnel, the only one accessible, could be penetrated for a distance of only about 60 feet. In this tunnel the vein strikes N. 55° E. and is vertical. The walls are granite gneiss, and on the surface the vein cuts this formation throughout. The shaft, which follows the vein, is said to be 140 feet deep. Near the surface it is said a 500-foot drift runs east on the vein.

The ore on the dump is entirely coarse pyrite with some quartz. From the size of the blocks it would seem that the vein is in some places at least 10 inches wide. It is said that its average width is about 6 inches, but that in one place it opened out to form about 4 feet of solid pyrite ore. Postmineral movement has brecciated and ground some of the pyrite.

The ore is said to average about $10 to $12 per ton, some pockets running as high as $40.

OLD KENTUCKY MINE.

The Old Kentucky mine, near the divide between Stewart and Pickle gulches, had been idle for several years at the time of this survey and could not be entered. The claims were located in 1893 and 1894. The vein, which appears to strike about N. 60° E. and to dip northwest, is developed by a shaft about 600 feet deep. The extent of the drifting could not be learned, but the mine has not been a large producer.

STEWART VEIN.

The Stewart vein, about three-quarters of a mile southwest of Wide Awake on the hill north of Stewart Gulch, strikes about N. 30° W. and appears to dip about vertical. The main shaft and a tunnel 200 feet below it lie south of the crest of the hill, but the vein can also be traced along the north side of the hill and has been opened there by three small shafts. All the workings are inaccessible, the mine having been idle for several years.

The remnants of ore on the dump and in the bin indicate that the mineralization was in part, at least, similar to that at the neighboring Caledonia mine. Sampling works assays show the presence of lead and zinc minerals, which were not seen on the dump. The vein in places is a typical fissure filling showing comb quartz next the walls. Small sharp-walled stringers of specular hematite carrying some quartz and pyrite cut the granite gneiss, as at the Caledonia mine.

CALEDONIA VEIN.

The Caledonia vein is opened by several abandoned shafts on the hill west of Missouri Gulch, about 7 miles northwest of Blackhawk and one-half mile southwest of Wide Awake. The vein strikes N. 45°-50° W. and dips 65°-70° NE.

The shaft houses are in ruins and the workings could not be entered, but the size of the dumps indicates that they are extensive. The ore in the bins shows that the vein is a sharp-walled fissure filling in granite gneiss. The minerals seen were pyrite and chalcopyrite in a quartz gangue. Small grains of pyrite are disseminated in the wall rock near the vein. Some specularite was also observed in veinlets or as disseminations in the wall.

It is reported that some rich free-milling ore from stopes near the surface in this vein was milled at a 20-stamp mill in Wide Awake. This mill, called the Douglas, is now leased to the Pine Cone Gold Mining Co., which is working some properties just south of the camp.

PINE CONE TUNNEL.

The Pine Cone tunnel is located on the west side of Missouri Gulch about one-half mile south of Wide Awake. It trends northwest and southeast for about 270 feet, cutting veins 130 and 220 feet from the portal. Short drifts have been run on both veins.

The vein cut 130 feet from the portal is at slight depth and is much oxidized. It strikes N. 20° E. and in general dips about 80° SE. It shows sparse mineralization with pyrite and chalcopyrite, the largest observed streaks being 2 inches wide and having a rather abundant gangue of white quartz and calcite. Drifts are being run on the tunnel level to connect with a shaft 100 feet deep, with a level and short drifts at 94 feet, that has been sunk on this vein.

The vein cut 220 feet from the portal strikes N. 55° E. and dips from vertical to 80° SE. It is a fracture zone 1½ to 2 feet wide, near which there is some dissemination of pyrite.

Small amounts of ore from this property have been milled at a small stamp mill at Wide Awake.

JOHNSON PROSPECT.

A prospect about three-fourths of a mile south of Missouri Lake, on what is said to be a continuation of the Bass lode, was being developed by a tunnel at the time of this survey. A gangue-filled fissure had been exposed, but no sulphides of consequence had yet been found. Assays on surface ore from the claims of this group are said to have shown as high as 250 ounces in silver.

NIGGER AND WINNEBAGO HILLS.

CASTO VEIN.

The Casto vein cuts across Winnebago Hill half a mile north of Central City and is supposed to connect with the Winnebago. The shaft is 420 feet deep along the dip of the vein with levels aggregating 1,000 feet at 178, 214, 283, 334, and 402 feet below the collar. The 283-foot level connects eastward with the Belden tunnel (fig. 28), which has its mouth in Chase Gulch. A drift from the Review shaft connects with the fourth level.

The country rock throughout the mine is granite gneiss. The Casto vein strikes about N. 70° E. and has an average dip of about 80° S. It varies in width from 2 inches to 4 feet, the average being about 2 feet. The main ore shoot of the mine seems to follow in a general way the junction of a northern vein, which is traceable into the Review workings and which has a branch vein coming in at a small angle from the south. The exact junction is not readily determined but seems to lie about 60 feet west of the shaft on the second level, 45 feet west on the fourth level, and in the shaft between the fourth and fifth levels. This ore shoot has been stoped for 100 feet west of the shaft more or less continuously to the fifth level and has also been stoped east of the shaft between the third and fifth levels. At the junction on the fourth level a width of 10 feet of ore has been stoped.

The vein consists of crushed granite gneiss somewhat silicified and containing rather coarse disseminated pyrite. A few specks of galena were seen in the ore but are very scarce. Throughout the ore shoot there are numerous small branching stringers of pyrite, few of which are over 1 inch in width and most of which lie near the footwall.

Some postmineral movement has taken place along the Casto vein, but most of the gouge is very thin. In the shaft between the fourth and fifth levels some striæ on the hanging wall showed that the movement was in part horizontal.

A 10-stamp mill at the shaft treats all of the ore mined. The coarse concentrates from the table carry a very small amount of galena, and it is said that occasionally a little ore that carries chalcopyrite is milled.

SPUR DAISY GROUP.

The Spur Daisy group of claims is on the north side of Nigger Hill near the head of Eureka Gulch. The country rock in this vicinity is granite gneiss cut by several veins, the most pronounced of which trends a few degrees west of north and the others northeast.

Several shafts and pits have been sunk on these veins, but none of the exposures are good and the shafts can not be entered. The veins are all of the galena-sphalerite type.

The total production from this group of 20 claims is said to be about $200,000. The ore is said to average from $25 to $30 a ton in gold and silver.

BELDEN TUNNEL.

The Belden tunnel starts on the south side of Chase Gulch a mile above Blackhawk and about 1,000 feet east of Castle Rock. It appears to have been begun in 1875. The first 690 feet is crosscut, running south-southeast into Winnebago Hill. Beyond this distance the tunnel turns southwest and follows a vein which eventually joins the Casto vein, the Casto shaft being about 1,680 feet from the mouth of the Belden tunnel. (See fig. 28.) Granite gneiss is the only rock seen in the workings.

The Ellery vein, cut 115 feet from the portal, has been developed by a drift on the tunnel level and by a shaft of unknown depth just east of the tunnel. The vein strikes about N. 62° E. and dips 63°–80° (average about 75°) S. Though ranging from a few inches to 4 feet in width, it consists in most places of 8 to 10 inches of crushed bleached granite gneiss carrying here and there a small amount of disseminated pyrite. In the west end of the drift the vein is practically barren. Two hundred and ninety feet in from the tunnel a small, feebly mineralized branch comes into the vein from the north, and just east of this junction a small stope has been excavated on a 4-foot portion of the vein. Here the granite gneiss is brecciated, bleached, and rather heavily impregnated with pyrite. Other stopes, both underhand and overhand, are excavated for 110 feet west of the tunnel; they are from 3 to 4 feet wide and are all timbered, so that the vein can not be seen.

A vein 2 to 4 feet wide, cut 210 feet from the portal, consists of several subparallel quartz stringers three-fourths of an inch or less in width carrying a little pyrite. The granite gneiss is bleached near the veinlets.

At 370 feet from the mouth of the tunnel short drifts run east and west on a relatively barren vein, along which the granite gneiss is

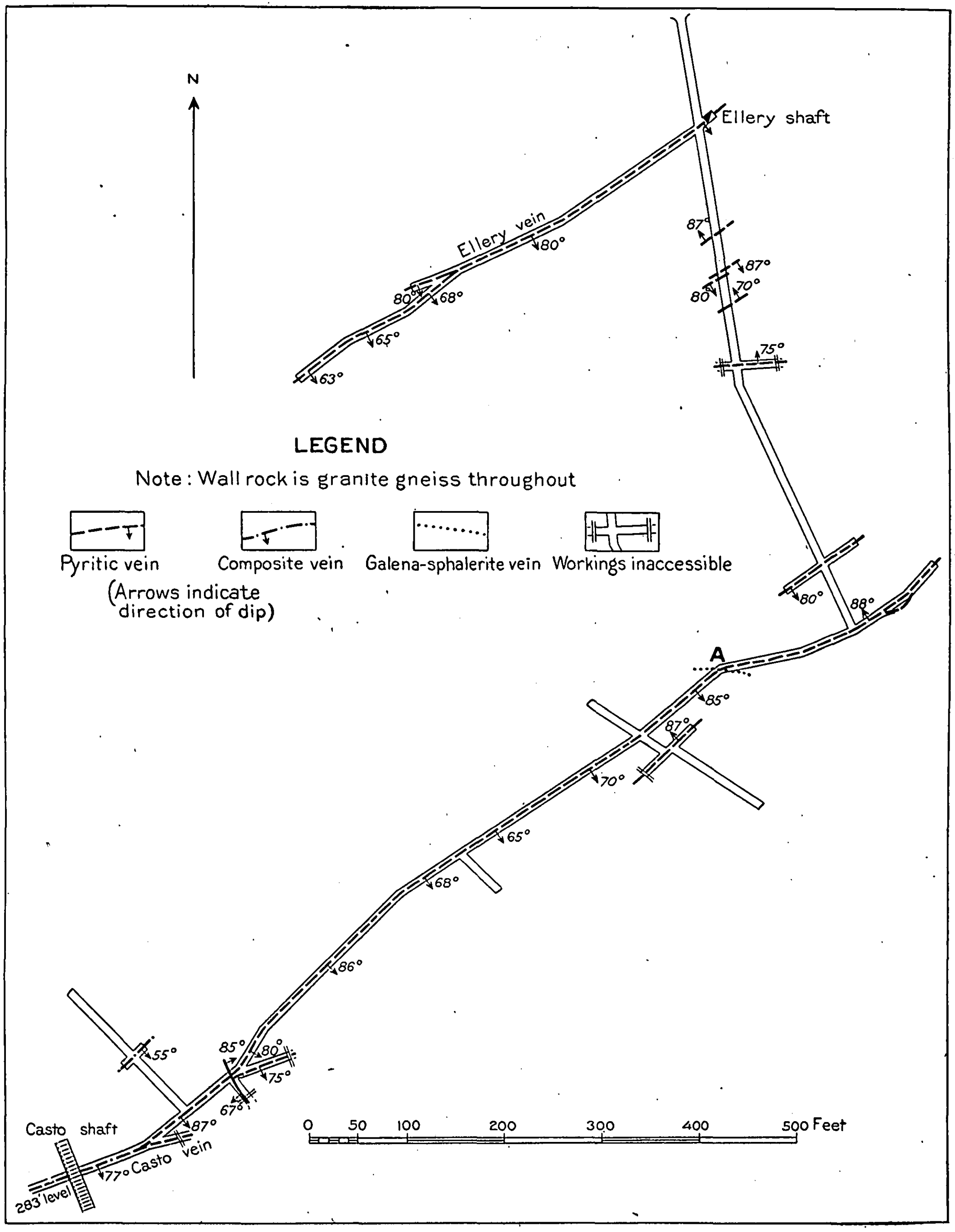


FIGURE 28.—Geologic plan of Belden tunnel. Surveyed by hand compass and pacing.

Between 260 and 300 feet from the mouth the tunnel cuts three narrow seams of rather coarse pyrite, near which the granite gneiss has been bleached for a width of 1 to 2 inches.

bleached and is locally traversed by lens-shaped veinlets of coarsely crystalline pyrite and white quartz, none of which are more than 5 inches wide.

Short drifts 590 feet from the mouth show a vein 6 inches to 1 foot in width, consisting of crushed decomposed granite gneiss carrying a small amount of disseminated pyrite and locally cut by stringers of coarse pyrite and quartz 1½ inches or less in width.

At 690 feet from the mouth the tunnel turns southwest and follows a vein which in most places is from 6 to 10 inches in width and nearly barren, though commonly a small amount of fine pyrite is disseminated through the granite gneiss along it.

Although the dominant mineralization in this mine belongs to the earlier pyritic type, some later galena-sphalerite mineralization was noted.

At a point 140 feet west of the southwest turn in the tunnel (A, fig. 28), a small stringer of galena, sphalerite, and chalcopyrite cuts across the main vein at an acute angle, but its relations are obscured by a raise lately started at this place. Near by a small pyritic veinlet enlarges to a lens of galena and sphalerite with a vuggy center. Another occurrence is noted below.

At 250 feet west of the southwest turn of the tunnel crosscuts run 80 feet north and 140 feet south from the drift. Forty feet from the drift vein the south crosscut cuts a 2-foot vein which strikes about parallel to the drift vein but dips 87° N. This vein has been stoped to some extent, both underhand and overhand, for about 60 feet either way from the crosscut. The ore is crushed granite gneiss carrying some disseminated pyrite and cut by a few small veinlets of pyrite.

At 200 feet east of the Casto shaft a branch vein leaves the drift vein on the south or hanging-wall side. Near the junction there is a 5-foot zone of crushed bleached granite gneiss which carries rather abundant disseminated pyrite and is cut by numerous ⅛-inch to ¼-inch stringers of coarse pyrite. There has been some drifting and stoping on this vein, but the workings are all caved. At the junction of the two veins a barren fracture, which is cut by the drift vein without apparent displacement, crosses the drift.

A crosscut starting 130 feet east of the Casto shaft runs northwest for 170 feet through granite gneiss. Seventy feet from the drift vein it cuts a fracture which is about 4 inches in average width and carries coarse pyrite with some small scattered lenses of galena and sphalerite.

Eighty feet east of the Casto shaft the vein which has been followed by the Belden tunnel joins the Casto vein. Near the shaft the Casto vein, which here consisted of granite gneiss carrying disseminated pyrite and cut by stringers of coarse pyrite, has been stoped for a width of 5 feet. Frozen to the walls are small stringers of galena, sphalerite, pyrite, and chalcopyrite.

MONT D'ORO TUNNEL.

The Mont d'Oro is a drift tunnel running nearly due west on the Delight vein. Its mouth is on the west side of Chase Gulch, about 2 miles northwest of Blackhawk. The tunnel is 590 feet long and has three short branch drifts. The country rock is entirely granite gneiss.

The Delight vein stands nearly vertical and is for the most part a barren fracture zone 2 inches to 2½ feet in width. It is, however, locally mineralized, at one place showing as much as 6 inches of gray quartz bearing scattered crystals of pyrite and bordered by altered gneiss carrying disseminated pyrite cut by small stringers of sphalerite and galena. At another place it consists of 2½ feet of altered gneiss cut by several small subparallel stringers of white and gray quartz carrying pyrite and sphalerite.

The New Century vein joins the Delight about 500 feet from the mouth of the tunnel. It strikes on the average N. 45° E. and dips 55° NW. It consists of 1 to 2 feet of altered country rock containing disseminated pyrite and traversed by small stringers and bunches of galena and sphalerite.

A short branch drift leaving the main drift about 400 feet from the portal exposes two small sphalerite veinlets nearly parallel to the Delight vein. A short crosscut 40 feet long starting about 280 feet from the portal crosses three small parallel veins carrying quartz, pyrite, and sphalerite. They are probably offshoots from the main vein.

Some mill runs of cord lots of ore show a rather consistent saving of 1 ounce gold a cord on the plates. The concentrates vary from 0.4 to 0.64 ounce gold and 2.4 to 19 ounces silver a ton. The ratio of concentration is about 7 to 1. The vein has had as yet no production.

FREEDOM VEIN.

The Freedom vein, discovered in 1865 or 1866, outcrops on the southeast part of Winnebago Hill. It trends about N. 40° E. and is developed by several drift tunnels, one of which is 940 feet long, and by a shaft over 800 feet deep. The workings were not accessible at the time of this survey. The ore seen on the dumps belongs to the galena-sphalerite type.

The following are sampling-works assays of some of the smelting ore shipped from the Freedom mine between 1899 and 1904:

Sampling-works assays of smelting ore from Freedom mine, 1899–1904.

Ore.	Gold.	Silver.	Silica.
Net lbs.	*Ounces.*	*Ounces.*	*Per cent.*
4, 640	1. 60	2. 40	21
7, 300	3. 24	5. 00	22
14, 874	1. 30	2. 70	22
5, 664	1. 30	3. 70	30
20, 390	4. 59	6. 17	29
22, 275	3. 89	6. 23	34
20, 414	1. 40	3. 80	42
12, 444	1. 53	4. 20	40
6, 905	2. 28	5. 70	34
19, 135	1. 36	4. 70	....
22, 687	1. 56	4. 50	....

SILVER HILL.

The silver veins of Silver Hill appear to have been discovered in 1877 or 1878 and are said to have yielded about $150,000 annually for several succeeding years. All of the mines of Silver Hill have been idle for many years and only meager information concerning them is available.

The Cyclops vein was first worked in 1877 or 1878 and has been little worked since 1886. The ore is said to have been rich to a depth of about 300 feet and notably lower grade below that. The rich ore carried wire silver and much so-called "brittle silver" (possibly pearceite) and a very little ruby silver (proustite). The native silver is said to have been confined mainly to the upper 100 feet of the vein. The gold content was negligible.

The following sampling-works assays give an idea of the value of some of the ore mined in 1890 and 1891. The ore obtained in earlier years was presumably somewhat richer.

Sampling-works assays of ore from Cyclops vein, 1890–91.

Ore.	Gold.	Silver.
Net pounds.	*Ounces.*	*Ounces.*
2, 400	....	87. 00
3, 060	....	31. 00
1, 930	....	22. 00
3, 790	0. 05	52. 00
2, 332	....	79. 00
1, 584	....	31. 00
1, 793	....	27. 00
1, 008	....	41. 50
3, 263	....	40. 27
2, 342	....	75. 00
1, 575	....	87. 00
582	....	48. 00
2, 413	. 08	26. 00

Little detailed information concerning the Fannie vein was available, but seven lots of smelting ore shipped between 1888 and 1904 gave the following sampling-works assays:

Sampling-works assays of ore from Fannie vein, 1888–1904.

Year.	Ore.	Gold.	Silver.	Lead.
	Net lbs.	*Ounces.*	*Ounces.*	*Per cent.*
1888.........	1, 950	....	115. 00	6
1889.........	1, 123	0. 12	78. 20	....
1889.........	4, 669	. 25	140. 00	....
1903.........	1, 497	. 10	308. 00	14
1903.........	3, 270	. 07	148. 30	....
1903.........	2, 472	. 10	75. 00	8
1904.........	2, 462	. 14	176. 00	....

That the ores of Silver Hill owed their workability to the process of downward enrichment is attested by the nature of the silver minerals, the high local silver content, and the falling off in the silver value of the ore in depth. The process of silver enrichment is more fully considered on pages 140–149.

MARYLAND MOUNTAIN.

HAYSEED VEIN.

The Hayseed vein is developed by the Hayseed adit tunnel a mile north of Central City on the east side of Chase Gulch. It is close to the Tucker mill and is passed by a spur of the Gilpin tramway.

The adit is 540 feet long and follows the vein throughout. The vein has an average strike of N. 70° E. and dips 55°–57° S. It is strongly defined throughout, but in width and degree of mineralization is extremely variable. At one place the vein changes in a distance of only 10 feet from a well-mineralized zone 2½ feet wide to a tight and nearly barren fracture. At about 275 feet from the tunnel mouth the vein forks, the branches joining again about 50 feet farther on. Near this point also a branch about 4 inches wide diverges into the north wall.

Stoping has extended over about half of the vein as exposed in the tunnel, but only portions particularly rich in sulphides have been worked. The best exposures are in stopes 300 and 400 feet from the tunnel mouth. As exposed in the 400-foot stope, the vein attains in places a width of 1 foot, about 5 inches next the hanging-wall being solid sulphides, galena, chalcopyrite, and some sphalerite. Although the proportions between the sulphides are variable, galena is in general the most abundant and sphalerite is next; chalcopyrite and pyrite are subordinate. Commonly more or less altered wall rock is present in the vein. In some places more or less silicified wall rock is penetrated by a network of sulphide stringers, but in most places the sulphides form a single band, or two or three nearly parallel bands, penetrating the altered wall rock which makes up the remainder of the vein. The greatest observed width in the sulphide bands or veins proper was in the stopes, where 5 inches of solid galena and chalcopyrite with some sphalerite occurs in places.

The various sulphides are intercrystallized in such a way as to indicate that they were deposited during a single period of mineralization. Some crustification is locally apparent and indicates that in a few places most of the sphalerite was deposited before most of the galena and chalcopyrite, and that in certain places the chalcopyrite was later than both sphalerite and galena.

Vugs are rather common, some being several inches across in the plane of the vein. Some contain very beautiful step crystals of galena, and the walls of others carry crystals of transparent quartz associated with galena. Coatings composed of siderite or of an association of siderite and small needle quartz crystals occur on the galena, chalcopyrite, and pyrite of some of the vugs. In places siderite coats the quartz crystals. Dissolving action manifests itself in extensive etching of some of the galena crystals (see Pl. XVII, *A*, p. 136) but not of the chalcopyrite and pyrite. Although a few slightly etched surfaces of the galena have been coated by the siderite and quartz, most of the etched surfaces are free from such coatings, and this suggests that the same waters which deposited the carbonate also dissolved the galena. These effects were presumably the work of ascending solutions from the same general source as, but of different composition from, the earlier ones that deposited the ore.

Work on the property has been in the main exploratory, and stoping has not been extensive. The two claims of this group were located in 1897 and have been worked intermittently since then either by the owners or under lease. The ore is all handcobbed and sorted and is then sent to the smelter. It is said to average 45 to 55 per cent lead, 12 ounces in silver, and 0.75 ounce in gold. Picked ore is said to have given $40 smelting returns. The total production since the opening of the mine was given as $7,000.

ROBERT EMMET MINE.

The Robert Emmet shaft, on the north side of Chase Gulch, was being unwatered at the time of the survey, but the work had not progressed sufficiently to permit an examination. The workings consist of an abandoned shaft 270 feet deep and a main shaft 525 feet deep, which has levels at 100, 200, 335, and 425 feet. The vein strikes about N. 45° E. and dips about 85° SE. The ore on the dump is of the galena-sphalerite type.

The following sampling-works assays of a number of shipments of smelting ore will give some idea of its range in value:

Sampling-works assays of ore from the Robert Emmet mine, 1889–1904.

Year.	Ore.	Gold.	Silver.	Copper.	Lead.	Zinc.	Silica.
	Lbs.	*Oz.*	*Oz.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
1889	2,436	1.80	11.30	......	......	......	......
1889	2,758	2.10	18.50	......	......	......	......
1889	2,040	7.20	38.00	4.50	......	......	......
1889	2,118	2.26	3.00	......	......	......	......
1896	13,820	1.93	7.50	......	......	......	......
1898	3,606	1.42	5.60	......	......	8	53
1898	5,822	5.25	33.60	......	20	12	......
1898	5,102	3.56	24.00	......	12	13	......
1902	7,033	2.36	21.80	......	......	......	45
1902	5,792	1.52	4.50	......	......	......	53
1902	2,187	1.53	13.35	......	......	......	51
1904	1,351	3.17	4.00	......	......	......	58

The gross production of the mine is reported to be about $263,000.

NEVADA HILL AND PROSSER GULCH.

GILPIN EUREKA MINE.

The Eureka vein is on the north side of Prosser Gulch about half a mile west of Eureka Gulch. The shaft, an incline on the vein, is about 700 feet deep with levels at vertical depths of 130, 200, 350, 400, 500, and 600 feet. The first level could not be entered. The country rock throughout the mine is granite gneiss, except for one small lens of schist on the west third level.

Four veins are exposed in this mine. The North vein bears east and the Eureka vein north of east; they converge toward the east and unite near the shaft. About 300 feet west of the shaft a second nearly east-west vein, exposed on two levels, is known as the South vein. On the surface and on the 350-foot level east of the shaft is the Spur vein, which bears northwest.

The Eureka vein as exposed in all of the levels has an average strike of N. 70° E. The dip ranges from 45° to 70° N., being more nearly vertical east of the shaft, where it averages 65°, than west of it. The vein ranges in width from 1 to 6 feet with an average of about 2½ feet. East of the shaft the vein is strongly marked but is not particularly well mineralized, though on the third level it carries small lenses of ore, some of which have been stoped. The principal ore body is west of the shaft and extends along the vein to its junction with the South vein.

The South vein on the third level joins the Eureka vein 200 feet west of the shaft, follows that vein westward for about 50 feet and then resumes its independent course. Normally it strikes N. 85° E. and dips 65°–70° N. It intersects the Eureka about 280 feet west of the shaft on the fourth level and about 300 feet west on the fifth level. The vein is from 12 to 18 inches in width but near the junction widens to 2 feet. Where it joins the Eureka a large body of ore occurs.

The Spur vein is intersected only on the third level about 450 feet east of the shaft. It strikes N. 68° W. and dips 80° SW. Ordinarily it is rather narrow, but near the junction with the Eureka it carries a small ore body whose maximum width is about 2 feet.

The North vein strikes about N. 85° E., joining the Eureka at or near the shaft, and dips very steeply north. It is about 10 inches wide and is not heavily mineralized except for a lens of ore 80 feet long between the second and fifth levels and west of the shaft. At the sixth level the North and Eureka veins are about 12 feet apart near the shaft. The drift has been carried 12 feet wide for a short distance and shows the granite gneiss between the two fractures to be more or less mineralized throughout. There is, however, no particularly good ore on this level.

The mineralization in this mine was particularly strong west of the shaft to a point on the Eureka vein a little beyond the junction with the South vein. In this ore body the lead-zinc sulphides occur in places in solid streaks 8 to 10 inches wide and in sparse dissemination through the intervening parts of the vein.

Two distinct periods of mineralization are shown in the mine. All four of the veins exposed show ore of the pyritic type cut by stringers and lenses of ore consisting of dark-gray quartz, dark sphalerite, galena, and chalcopyrite. Pyrite is by far the most abundant metallic mineral, but is said to carry only small amounts of gold and silver. Of the minerals of the later mineralization sphalerite is by far the most abundant, galena and chalcopyrite commonly forming less than 5 per cent. The principal gangue is quartz and silicified granite gneiss.

Postmineral movement is shown by heavy gouge along the walls throughout the mine and by clay partings in the ore itself. On the fourth level and at the west face of the third level slickensides on the wall pitch 75° E. The Spur vein north of the Eureka has been offset about 2 feet to the west by this movement. On the third level a breccia of fragments of both pyritic and galena-sphalerite ore is partly cemented by bluish-gray cherty silica.

In late years the entire vein has been mined and milled irrespective of the minerals contained. The highest-grade ore was obtained above the second level, but some gold ore has been taken from the junction of the South and Eureka veins on the lower levels. The company has a 10-stamp mill equipped for amalgamation and concentration. This mill produces a lead-zinc concentrate said to have a value of about $90 a ton and an iron-zinc product which carries about $10 in gold and silver.

From 1897 to 1908 14 lots of smelting ore aggregating 30 tons averaged 1.91 ounces gold and 12.37 ounces silver per ton. Most of this ore carried about 16 per cent lead and from 8 to 12 per cent zinc. One shipment of smelting ore mined in 1910 carried 1.58 ounces gold, 10.6 ounces silver and 49.2 per cent lead. In 1910 the average metal content of the concentrating ore was 0.4 ounce gold, 0.47 ounce silver, and 0.47 per cent lead.

The total production is estimated at about $467,000, of which $400,000 is reported to have come from a zone 400 feet long and within 90 feet of the surface.

GOLD COLLAR MINE.

The Gold Collar mine on the Hydrant vein is on the north side of Prosser Gulch just above its junction with Eureka Gulch. The shaft is said to be 712 feet deep but has been idle for some years and could be descended only to the 332-foot level. Lessees had just begun, in September, 1911, to reopen the 332, 257, and 200 foot levels. On the 200-foot level the face of the east drift is 670 feet from the shaft and the west drift is caved 50 feet from the shaft. On the 257-foot level the east drift is caved 50 feet from the shaft but the west drift can be traversed to its face, a distance of 200 feet. The 332-foot level has been run east 80 feet and west 300 feet from the shaft and was open throughout. The wall rock of all of these levels is granite gneiss except for a lens of schist at the end of the 332-foot level east.

The vein strikes N. 76° E. and dips steeply south, the lowest dip noted being 65° S., near the shaft at the third level. Commonly the dip is 75° to 85° S. with an average of about 80°. In the granite gneiss the vein ranges in width from a few inches to 2 feet, but where it passes from granite gneiss into schist on the third level it dies out in a series of small branching fractures parallel to the schistose structure. The principal ore body as far as could be ascertained lay on both sides of the shaft and extended from the surface to some point between the 257 and 332 foot levels, the latter showing only a small amount or ore. In the 200-foot level the shoot extends for an unknown distance west of the shaft and 250 feet east of it. East of the main shoot on this level there are a few small lenses of workable ore. In the 257-foot level the shoot extends the entire length of the drifts now open, but the ore has been entirely removed. At the back of the stope at the west end of the drift the ore is playing out.

The vein filling is somewhat altered granite gneiss, usually barren of mineral but cut in a few places by stringers containing dark sphalerite, chalcopyrite, pyrite, and a little galena, with quartz and some siderite. The sphalerite is by far the most abundant sulphide. These stringers vary from a fraction of an inch to at least 6 inches in width.

Microscopic examination of the wall rock in contact with one of the galena-sphalerite veinlets shows that it has been altered to an irregular aggregate of quartz, carbonate, and chlorite. The quartz forms good-sized grains, and the carbonate and chlorite occur as aggregates of minute plates. Through this rock pyrite is scattered in small grains, and grains of galena and sphalerite occur sparsely. The abundance of chlorite gives the rock a green color.

The smelting ore is said to be only about 2 to 4 per cent of the material mined. This grade of ore, as shipped for 12 to 14 years, has averaged about $70 per ton in gold and silver and is said to contain about 2½ ounces of silver for each ounce of gold. The total production of the mine is said to be about $250,000, all of which has come from the Hydrant vein.

CONCRETE MINE.

The Concrete vein, a westward continuation of the Gunnell, is on the south side of Prosser Gulch. The shaft house is about half a mile west of Eureka Gulch, a short distance south of the Gilpin-Eureka shaft. The shaft is an incline following the vein and is equipped with bucket hoist. It is about 1,285 feet deep, but the lower 150 feet were under water at the time of this survey. As the shaft is near the east line of the Concrete ground the development work lies almost entirely to the west. The Golden Treasure shaft following the Golden Treasure-Slaughter House vein enters the Concrete workings 540 feet west of the Concrete shaft at a depth on the incline of 674 feet. Below this the Golden Treasure shaft follows the Concrete vein, the total depth of the shaft being over 1,300 feet.

Levels have been driven from the Concrete shaft at depths of 530, 608, 681, 761, 900, 937, 1,000, 1,033, 1,127, and 1,208 feet. A level between 681 and 761 feet connects with the Slaughter House workings, and the 1,127-foot level connects with the Gunnell workings. The 761-foot level from the Concrete shaft connects by a winze near its west end with a drift from the Golden Treasure shaft.

The country rock throughout the entire mine is granite gneiss.

The vein strikes from N., 74°–85° E., with an average of about N. 78° E. From the collar to the 530-foot level the shaft dips about 50° S., though in detail the vein flattens and steepens in short distances. On the 530-foot level the vein dips 65° S., on the 750-foot level 64° S. at the shaft, and about 82° S. farther west; and on the 1,033-foot level about 57° N., below which it is nearly vertical.

Above the 1,033-foot level the vein is in few places over 8 feet wide. Its general width is 1 to 3 feet, but in some places it is represented by a single narrow slip plane. Below the 1,033-foot level the vein widens rapidly to a maximum of 25 feet at the 1,127-foot level.

Two main ore bodies have been developed, both of them west of the shaft. The upper has been stoped from about 450 feet down to the 761-foot level. On the 761-foot level it begins about 230 feet west of the shaft and extends to the Golden Treasure shaft, a distance of 300 feet. As exposed on the higher levels the shoot is not so long nor so continuous. Above the 530-foot level the ground has not been prospected, though a 100-foot whim shaft sunk 400 feet west of the Concrete shaft is said to be in good ore. The Slaughter House–Golden Treasure vein is said to join the Concrete vein between the 608 and 761 foot levels. As it is common for a vein to become heavily mineralized near its junction with another vein this union may, in part at least, explain the formation of the ore shoot. The second large ore shoot extends from the 937 to the 1,127 foot level west of the shaft, and is developed by workings from the Golden Treasure shaft. The most productive portions of this shoot appear to lie at or near the junction of the Concrete with the Elizabeth vein. Another ore shoot east of the Concrete shaft on Gunnel ground is stoped at the 608 and 681 foot levels and for 200 feet below the 761-foot level. This shoot probably crosses the Concrete shaft at or near the 761-foot level and joins the large shoot last described.

The Concrete vein consists of somewhat crushed silicified granite gneiss which in the ore shoots has been impregnated with small scattered crystals of sulphides and is cut by a network of veinlets of solid sulphides from knife-blade thinness to several inches in width. They are in general more numerous in the lower half of the vein, though in some places they occur next to the hanging wall. The sulphides in general order of abundance are dark sphalerite, galena, pyrite, and chalcopyrite, but some veinlets consist almost exclusively of galena and sphalerite and others are composed mainly of sphalerite and chalcopyrite. Pyrite is the most abundant sulphide in the wall rock adjacent to the veinlets. Quartz is the common gangue mineral.

Postmineral movement along this vein is shown by tight fractures cutting the ore and in a few places by slickensided surfaces on the walls. The striæ are either parallel to the dip or pitch at 80° E. On the 761-foot level near the west end of the drift an open watercourse follows the vein for about 150 feet. Along this zone somewhat rounded pebbles of ore and wall rock are partly cemented by bluish-gray cherty silica.

In mining the ore bodies it seems to have been the practice to avoid, as much as possible, breaking the ground in which solid sulphide veinlets were small or few in number. The concentrating ore after a concentration of about 18 into 1 yields a product having an average content of 0.64 ounce gold, 5.80 ounces silver, 12.30 per cent lead, 11.20 per cent zinc, and 12.10 per cent silica a ton. About 12 per cent of the ore mined is shipped direct to the smelter. The average assay content for about 307 tons of smelting ore was 1.03 ounces gold, 8 ounces silver, 23.80 per cent lead, and 10.60 per cent zinc. Most of the smelting ore carries so little copper that it is not shown on the assay sheets. In some stopes it was found practicable to separate the smelting ore into two classes, one a typical lead-zinc ore, and the other a zinc-copper-lead ore. Some assays of the zinc-copper-lead ore show about as many ounces of gold as units of copper and a gold value about three times as great as in the lead-zinc ore, though the silver content is about the same in both classes. According to sampling-works assays 32 lots of smelting ore shipped at different times from 1893 to 1909 inclusive showed: Gold, 0.40 to 4.13 ounces; silver, 3.08 to 15.80 ounces; copper, less than 1.5 to 3.70 per cent; and lead, less than 5 to 64 per cent.

The Concrete claim was located in 1879 and its gross production has been about $800,000.

GUNNELL-GRAND ARMY MINE.

The Gunnell-Grand Army mine is on the south side of Prosser Gulch just west of Central City. The vein was discovered in the early sixties, but extensive development was not begun until 1874. At the close of 1875 the Gunnell shaft was 700 feet deep. The property was operated intermittently from 1874 until 1904 when the pump shaft burned and the mine flooded. Not until 1910, when the mine was drained by the Argo tunnel, was work resumed.

The mine has been one of the most productive in the district and the total development work approximates 25,000 feet. The eastern shaft on the main lode is known as the Pump shaft, and the western as the Grand Army shaft. The Slaughter House shaft, farther south, follows a vein which joins the Gunnell workings at depth. The Grand Army shaft, 1,200 feet deep, is the only one now in operation. From it levels have been driven at about 100-foot intervals. A winze from the 1,100-foot level connects with a raise from the Argo tunnel workings. (See fig. 29.) The workings develop the Gunnell North, Gunnell Middle, Gunnell South, Hattie, Wheeler, Elizabeth, and Slaughter House veins. The ore above the 900-foot level is said to be nearly exhausted, and most of the workings above the 700-foot level are inaccessible.

It was manifestly impossible in the present condition of the mine and the brief time available for the work to determine the exact relationships of all the veins. The following account is confined therefore to a description of the general character of the mineralization and to a few of the more salient structural features.

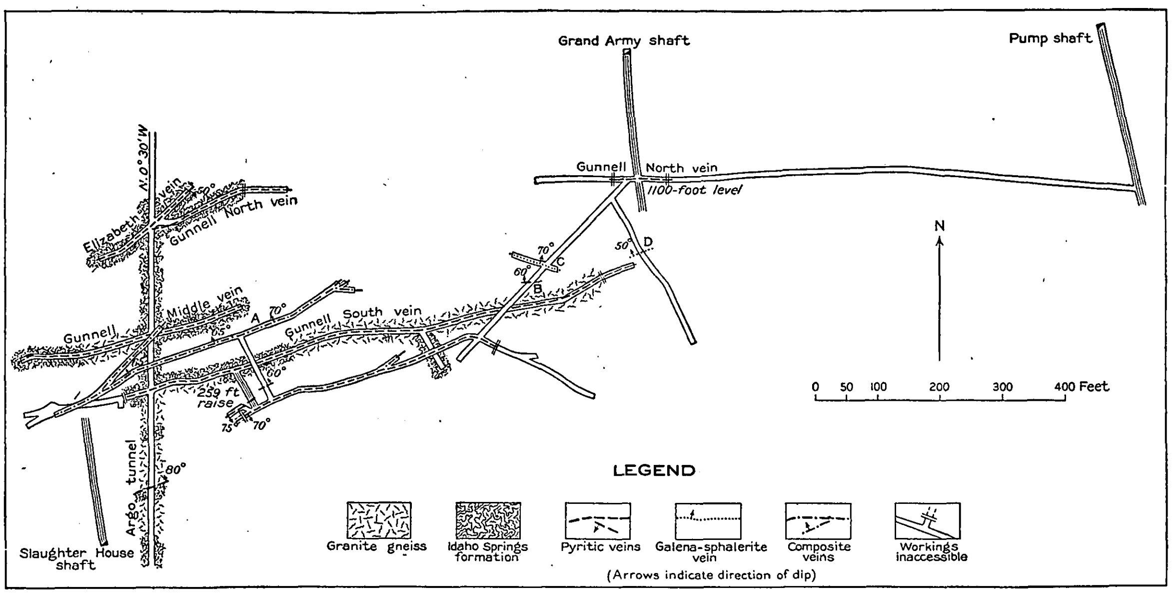


FIGURE 29.—Sketch showing Argo tunnel level and 1,100-foot level of Gunnell-Grand Army mine.

The Gunnell group of veins presents one of the best examples of composite mineralization in this district. The Gunnell-Grand Army system of veins is predominantly pyritic, but some of the smaller veins are of the galena-sphalerite type, and the larger veins have locally been reopened and further mineralized with this type of ore. As the lode is followed westward into the Concrete workings the mineralization becomes almost exclusively of the galena-sphalerite type. On the Argo tunnel level only pyritic ore was observed. The Gunnell-Grand Army-Concrete lode therefore forms an example of a fracture system whose mineralization in some parts is exclusively pyritic, in other parts galena-sphaleritic, and elsewhere composite. Exposures showing clearly the relationships between the two types of mineralization are not numerous. On the 700-foot level, 720 feet east of the Grand Army shaft, an exposure in a stope shows a 10-inch vein of nearly solid fine-grained pyrite. Between this and the wall occurs a lens of sphalerite and some galena sharply demarked from the pyrite. In other parts of the mine galena and sphalerite are common in vugs in the pyritic ore. At one point on the Gunnell Middle vein on the 1,000-foot level the vein is 6 feet wide and consists of a number of pyritic veins 6 inches or less in width, bordered by granite gneiss carrying disseminated pyrite. Cutting across the trend of the pyrite veins are several small stringers of galena, sphalerite, chalcopyrite, and quartz.

The detailed descriptions, though confined mainly to the 1,100-foot and Argo tunnel levels, serve to illustrate the general character of the mineralization in the portions of the mine now being worked.

The Gunnell South vein, as exposed in the Argo laterals, though locally barren, is generally well mineralized; the mineralization is, however, somewhat weaker than on the higher levels. The width varies from 6 inches to 2½ feet. About 150 feet east of the tunnel the vein consists of a 6-inch streak of pyrite and gray quartz next the north or hanging wall, below which for 2 feet small stringers of pyrite traverse the schist. About 700 feet east of the tunnel the vein shows, next the north wall, 8 inches of rather coarse pyrite, bordered by 2 to 4 inches of gouge. The pyrite shows local crushing due to postmineral motion along the vein.

Exposures on the walls of the Argo tunnel show that the rocks for 60 feet south of the Gunnell South vein are more or less mineralized. The walls are granite gneiss with subordinate amounts of Idaho Springs schist and pegmatite. These are traversed by a large number of fracture seams and pyritic veinlets which trend nearly east and west, and dip about 80° N., crossing the foliation of the granite gneiss at large angles. One of the veinlets shows 1 to 1½ inches of coarse pyrite, but most of them are smaller. The granite gneiss bordering the veinlets and seams has been leached, its biotite losing its color, and has been silicified. The average interval between the seams and veinlets is 4 to 5 inches.

Two sublevels have been driven on the Gunnell South vein between the Argo lateral and the 1,100-foot level. These are not shown on figure 29, but start from the raise which connects the Argo lateral and the shaft workings. The sublevel 80 feet above the Argo lateral is 300 feet long. The vein averages about 3 feet in width and shows several veinlets, none more than 3 inches wide, of pyrite and chalcopyrite bordered by wall rock carrying disseminations of these minerals.

Another short sublevel about 70 feet below the 1,100-foot level shows galena, sphalerite, chalcopyrite, and pyrite as the predominant sulphides in sharp contrast to the pyritic character of the vein farther down.

As exposed on the 1,100-foot level the Gunnell South vein is also in the main pyritic, though showing ore of the galena-sphalerite type in a few places.

The Gunnell Middle vein is cut by the Argo tunnel about 90 feet north of the Gunnell South vein. As exposed in the lateral on the Argo tunnel level it is in places a barren fracture zone and elsewhere is not heavily mineralized. The most highly mineralized portion shows 5 pyritic veinlets, the widest 1½ inches across, distributed through a width of 15 inches of granite gneiss. Another exposure shows 7 inches of gray quartz and pyrite. At the extreme west end of the drift (see fig. 29) a tight vein of fine-grained pyrite and chalcopyrite possibly indicates the proximity of a junction with the Elizabeth vein.

As exposed on the 1,100-foot level the middle vein is predominantly pyritic, but carries locally a little galena. It varies from 6 inches to 2 feet in width. At A, figure 29, it includes two veinlets of nearly solid pyrite 3 and 5 inches wide, which a little farther along unite in a single 8-inch vein, bordered by wall rock carrying disseminated pyrite, making the total width of the vein about 2 feet. At the east end of the drift on the 1,100-foot level this vein splits into three branches, none of which are of sufficient size to be worked.

The Elizabeth vein joins the Gunnell North vein in the Argo tunnel. As exposed on the Argo tunnel level, it is not heavily mineralized, showing merely a few stringers of pyrite and quartz which parallel the foliation of the schist. It has not been developed on this level. In general, the Elizabeth vein has not yielded much ore in any portion of the mine, but near its intersection with more productive veins it has probably caused an enlargement of the ore bodies.

The Gunnell North vein as exposed in the Argo lateral is nearly barren, showing only from 2 to 6 inches of bleached schist carrying disseminated pyrite.

At B, figure 29, a crosscut on the 1,100-foot level intersects a quartz-pyrite vein 4 to 5 inches wide. A short distance farther north, at C, figure 29, is another vein 2 to 6 inches wide, consisting of pyrite, galena, and sphalerite in a white quartz gangue. A vein that may be a continuation of that last described is exposed in another crosscut at D, figure 29. It has a maximum width of 4 inches and shows galena, sphalerite, and pyrite in irregular stringers and disseminated through the bordering gneiss.

The value of the smelting ore from different parts of the mine is indicated by the following selected sampling-works assays. The large number of veins developed and the composite character of the mineralization render the value of the ore extremely variable.

Sampling-works assays of ore from the Gunnell–Grand Army mine.

Location.	Ore.	Gold.	Silver.	Copper (wet).
Gunnell:	*Gross tons.*	*Ounces.*	*Ounces.*	*Per cent.*
400-foot level, west spur	8.080	2.40	4.35	....
Do	4.015	2.24	8.80	....
Do	1.375	.69	2.17	....
600-foot level, west spur	5.570	1.09	3.80	....
Do	2.620	.93	2.00	....
Grand Army:				
700-foot level, west spur	1.705	.55	4.80	....
1,000-foot level, North vein	8.170	1.26	13.73	1.40
Do	3.300	2.05	19.17	3.60
Do	3.235	1.68	8.92	.90
Do	4.530	1.08	9.44	.70
1,100-foot level, north	5.485	.74	2.77	....
1,100-foot level, north spur	1.960	1.37	4.15	....
1,100-foot level, North vein	2.585	1.95	5.50	....
Raise from Argo lateral, Gunnell South vein	24.130	.91	2.12	....
Do	28.690	1.23	3.04	Trace.

The copper values in some lots of ore are negligible but in some smelting ore reach 5 per cent.

The sampling of the veins in the lower evels of the mine show interesting results. The Elizabeth vein on the Argo tunnel level gave \$1.14 to \$5.85 per ton for widths of 7 to 24 inches. The Gunnell North vein on the Argo tunnel level averaged \$6.57 for widths of 11 to 20 inches. The Gunnell South vein on the Argo tunnel level showed some barren stretches, but in one block of ground 235 feet long it averaged \$12.20 per ton for an average width of 22 inches; in another block 115 feet long \$8.50 for an average width of 10 inches; and in a third block 120 feet long \$15.20 for an average width of 25½ inches.

In the raise on the Gunnell South vein to the 1,100-foot level much better values were found. The sublevel 75 feet above the Argo lateral averaged \$18.20 for an average width of 22 inches, and in some blocks of ground averaged \$34 to \$36 for widths of 26 to 35 inches.

Computations made for the company from the records of shipments show that from 1874 to 1889 the average value of the smelting ore was \$56.59 and of the concentrating ore \$14.02. As the price of silver for these years ranged from \$0.93 to \$1.28 the value of the returns of course can not be duplicated at the present time.

The total gross production of the mine from 1874 to the close of 1911 was about \$2,760,000.

Three mills are owned by the company—the Fullerton 40-stamp mill on North Clear Creek above Blackhawk, the Mead mill in Blackhawk, now in poor shape, and the Polar Star mill in Blackhawk, now operating. The last named was originally equipped with 40 stamps but 15 have been removed.

Three determinations of the fineness of the bullion obtained by amalgamation show gold 0.805, silver 0.154; gold 0.823, silver 0.163; and gold 0.825, silver 0.162.

WHITING VEIN.

The Whiting vein is on the hill due west of Central City about 500 feet southwest of the Gunnell shaft. It is developed by a shaft that has levels at depths of 200, 300, 400, and 500 feet and follows a vein trending nearly east and west and dipping about 75° S. The mine was idle at the time of this survey. Ore seen on the dump showed only pyrite and chalcopyrite.

HUBERT MINE.

The Hubert mine is on the south slope of Nevada Hill just north of Nevadaville. The workings develop two principal veins (the

North and South) and several branch veins. On the North vein a shaft now used only for ventilation descends to the 370-foot level. The main shaft, through which all ore is hoisted, is about 280 feet west of the North vein shaft; it follows the South vein to the 600-foot level, where it branches, one branch continuing on the South vein to the 1,250-foot level and the other crossing to the North vein and following it to the 975-foot level. (See fig. 30.)

All workings above the 500-foot level and below the 950-foot level were inaccessible at the time of this survey, and most of the ground east of the shaft between these levels is stoped out and could not be entered. Above the 450-foot level the stoping has been practically confined to the North vein; and between the 450 and 900 foot levels most of it has been done on the South vein. Some of the stopes are large and continuous, but the ore shoots seem to possess little regularity.

As a plan showing all of the levels would be extremely complicated figure 31 shows only the vein systems exposed on the 800, 850, and 950 foot levels. Time was not available for ascertaining all of the structural relationships of the complex vein system, and only a few of the salient features are here described.

The North vein was worked mainly in the upper portions of the mine not now accessible; where exposed on the 600-foot level it is in most places a nearly barren fracture zone a few inches to 3 feet in width. The Middle vein was exposed only on the 800-foot level (fig. 31), where it is only feebly mineralized, showing at the east face of the drift a single one-half inch veinlet of white quartz, sphalerite, and chalcopyrite. Exposures of the South vein and its branches are numerous and excellent. One of the best ore bodies is on the 950-foot level (see *A*, fig. 31), where it dips 65° S. and shows the following succession from hanging wall to footwall:

Section of South vein on 950-foot level of Hubert mine.

Hanging wall.	Inches.
White quartz	1
Sphalerite with some chalcopyrite	3
White quartz carrying some sulphides	2
Sphalerite and chalcopyrite	3
Granite gneiss carrying disseminated pyrite and traversed by $\frac{1}{16}$ to $\frac{1}{8}$ inch stringers of sphalerite	18
Footwall.	

Fifteen feet west of the shaft on the 850-foot level the vein consists of 2 feet of altered granite gneiss carrying disseminated pyrite

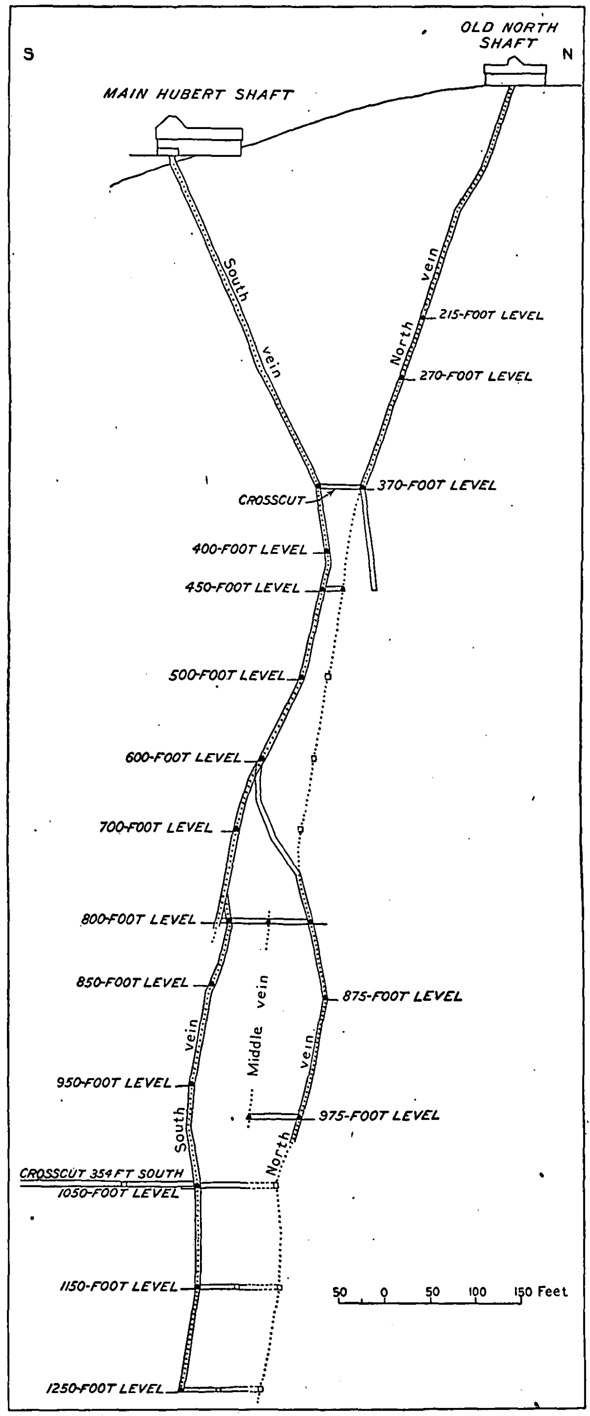


FIGURE 30.—Cross section showing relations of Hubert North and South veins and the shafts which develop them. From map prepared by Percy R. Alsdorf.

and traversed by a network of galena-sphalerite stringers, most of which are less than one-eighth inch in width.

One of the most instructive parts of the mine is the large stope near the west end of the 850-foot level. Near locality *B*, figure 31, the vein begins to split up and eventually forms a network of sulphide stringers traversing the gneiss in all directions; this passes locally into a true filled breccia. (See fig. 6, p. 97.) The fragments have plainly been moved from their original position. The largest are not more than 3 inches in diameter and most of them show sharp angular outlines. Many of the sulphide aggregates between the fragments show roughly triangular cross sections and a central vug lined with quartz, galena, and sphalerite crystals. The large stope at the west end of the 850-foot level is about 35 feet in width. The ore breccia extends upward to the 700-foot level but apparently does not extend downward to the 950-foot level, the vein at *A*, figure 31, in that level branching in a normal manner without notable brecciation. The ore breccia of the Hubert mine is identical in appearance with certain portions of the Patch (see pp. 96–97), and was probably formed by similar processes acting on a much smaller scale. Stress initiated along the South vein fracture and, along several branches leaving it at nearly the same point apparently became more or less distributed through the intervening rock, fracturing it irregularly and in places moving the fragments among themselves. This fractured and porous mass became a favorable locus for ore deposition.

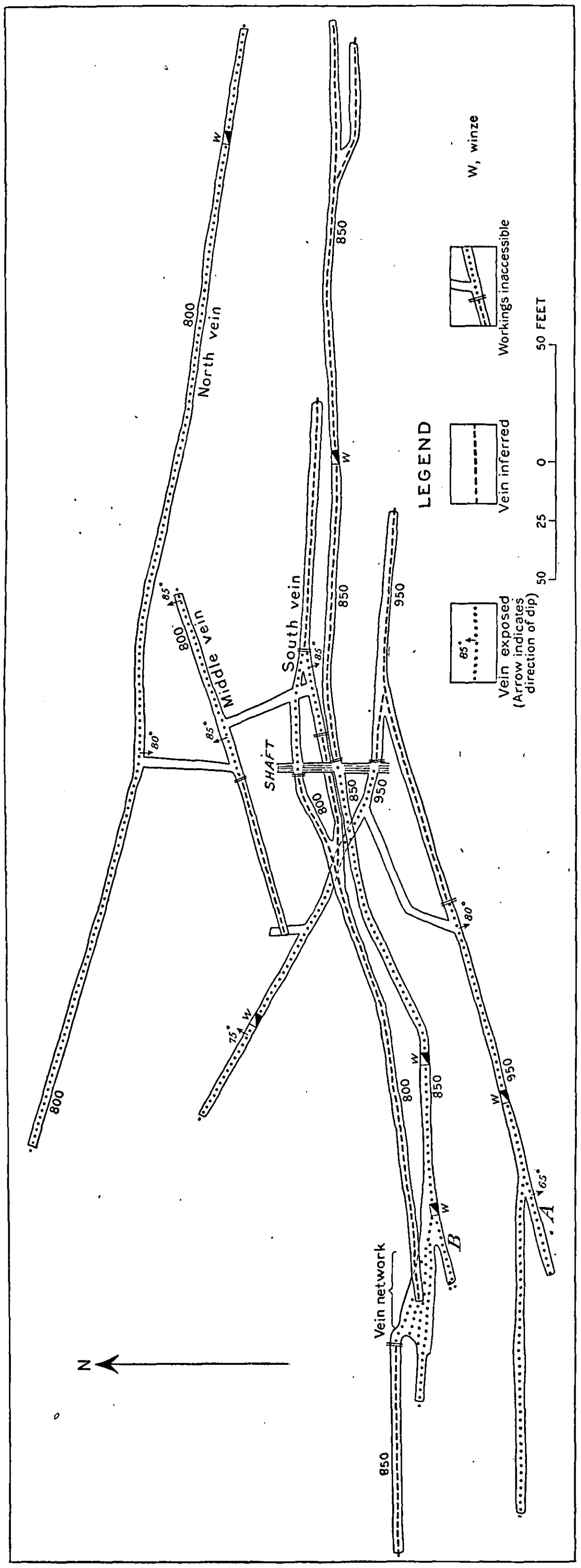


FIGURE 31.—Plan of portion of workings of Hubert mine.

The underground workings and the ore on the dump and in the bins show that the great bulk of the sulphides were deposited in open spaces, either in cracks or between the fragments of a breccia. In places, however, the sulphides are replacements formed by solutions penetrating along hardly perceptible fractures in the granite gneiss. Some irregular areas heavily impregnated with sulphides are not associated with visible fractures.

The ore of this mine is entirely of the galena-sphalerite type, being composed of galena, sphalerite, pyrite, chalcopyrite, and some quartz and siderite.

Sampling-works assays of 41 lots of smelting ore aggregating 131 tons, shipped between 1888 and 1909, show gold, 0.74 to 5.8 (average 2.39) ounces per ton; silver, 2 to 17.6 (average 13.16) ounces per ton; copper, less than 6.5 and generally less than 1.5 per cent; lead, less than 5 to 37 per cent; zinc, less than 32 per cent. Similar assays of smelting ore, aggregating 72 tons, shipped in 1910, show gold, 1.04 to 1.7 (average 1.38) ounces per ton; silver 8 to 15.9 (average 14) ounces per ton; lead, less than 5 to 30 per cent. The average content of concentrating ore shipped in 1910 in bullion and concentrates was gold, 0.21 ounce; silver, 1.8 ounces; lead, 1.3 per cent.

Sampling-works assays of concentrates from Hubert mine.

	Gold.	Silver.	Lead.	Zinc.
	Ounces per ton.	*Ounces per ton.*	*Per cent.*	*Per cent.*
Lead concentrate....	0.58	9.60	16.80	....
Zinc concentrate.....	.39	6.50	....	19.40
	.55	3.57	....	29.80

The mine contains considerable reserves of concentrating ore of the filled-breccia or Patch type. The total gross production of the mine is said to have been about $1,000,000.

PRIZE VEIN.

The Prize vein is on the south slope of Nevada Hill about 600 feet north of the main street of Nevadaville. It is opened by a long-abandoned shaft said to be 870 feet deep. The vein strikes about east and west, with local variations. A lateral from the Newhouse tunnel has been run on what is supposed to be the Prize vein for a few hundred feet, exposing 1 to 4 feet of crushed altered granite gneiss and schist carrying disseminated pyrite and cut by stringers of coarse pyrite 3½ inches and less across.

The ore carries from 0.5 to 2 ounces gold and from 3 to 16 ounces silver a ton. Some assays show as high as 4.5 per cent copper though most of the ore appears to have no copper of value.

The original owners are reported to have taken out between $400,000 and $500,000 worth of ore.

CŒUR D'ALENE MINE.

The Cœur d'Alene mine is in the west part of Central City close to the Catholic school. The mine is developed by a shaft with levels at intervals of 50 or 100 feet. The accessible levels are at vertical depths of about 200, 400, 450, 550, 600, and 700 feet. Most of them are short, the longest being accessible for only about 250 feet.

The workings develop a zone of fracturing that has been locally mineralized, but only a few parts of which can be termed a true vein. The strike ranges from about N. 70° E. in the upper levels to about N. 70° W. in parts of the 600-foot level. The general dip is nearly vertical. In places the wall rock is schist of the Idaho Springs formation with some associated pegmatite and elsewhere is granite gneiss. Throughout the mine the character of the mineralization is strikingly dependent upon the nature of the wall rock. Where the wall rock is granite gneiss, as on the 200-foot level east, the 400-foot level west, and the 700-foot level, most of the mineralization is of the fissure-vein type characteristic of this district, one or more sharp-walled sulphide veinlets 2 inches or less in width being distributed through several feet of granite gneiss carrying disseminated pyrite. The veinlets in places inclose numerous fragments of altered wall rock. Their predominant ore minerals are pyrite and gray quartz in some parts of the mine, and galena, sphalerite, pyrite, and white quartz in other parts, a variation due probably to double mineralization. The ore now being mined is of this type.

Where the wall rock is schist of the Idaho Springs formation, sulphide veinlets are commonly absent and the fractured zone is either barren or carries irregular disseminations of sulphides through a width of 10 to 20 feet. In the past bodies of such disseminated ore were an important resource. One of the largest of the old stopes in this type of ore, on the 200-foot level just west of the shaft, measured about 15 by 20 feet horizontally and extended nearly to the surface. Its average gold content is said to have been about 2 ounces to the ton. In this ore, grains of pyrite, many of them with perfect crystal forms, are disseminated through altered schist now consisting mainly of quartz, sericite, and some siderite, the nonmetallic minerals being stained blue-green by iron sulphate. The ore also carries some sparsely disseminated sphalerite and in places small stringers of galena and sphalerite. Similar ore, but of lower grade, forms a body 10 feet wide on the 600-foot level about 80 feet east of the shaft. Here in places one-half the volume of the ore is pyrite.

NEWFOUNDLAND VEIN.

The Newfoundland vein, on the north side of Nevada Gulch about 1,400 feet west of the railroad station at Central City, is opened by an inclined shaft on the vein, said to be 1,500 feet deep. The shaft could not be entered.

The vein on the surface strikes about N. 70° E. and is reported to have a very variable dip.

All the ore is pyritic. Some picked smelting ore is said to have carried from \$150 to \$200 a ton in gold. Sampling-works assays of seven lots of smelting ore shipped between 1898 and 1906 show gold, 2.01 to 10.04 ounces; silver, 1.50 to 5.25 ounces; and silica, 30 to 56 per cent.

The total production of the vein is estimated to be between \$225,000 and \$275,000, of which \$75,000 was taken out between 1891 and 1911.

CORYDON VEIN.

The Corydon vein is opened by several short tunnels on the west side of Nevada Gulch and by an inclined shaft, said to be 700 feet deep, situated 1,000 feet west of the railway station at Central City. In 1911 some lessees were reopening the shaft, much of which was inaccessible, though the vein could be seen on the 100, 200, 260, and 320 foot levels. The country rock is granite gneiss in all accessible workings.

The Corydon vein strikes N. 56° E., dips 70° SE., and is from 18 inches to 8 feet in width. It consists of crushed silicified granite gneiss, rather heavily impregnated with fine pyrite and cut by veins of solid coarsely crystalline pyrite and chalcopyrite with a little white quartz. In places some of the chalcopyrite crystals are coated with a thin black film of chalcocite. Some of the sulphide veinlets are as much as 10 inches wide, but their average width is only 3 to 4 inches.

Evidence of postmineral movement is found in the crushing of a coarse pyrite stringer at one place and in the occurrence of horizontal striæ on the hanging wall on the 320-foot level.

The ground above the 320-foot level has practically all been stoped, though a few fairly large pillars remain.

Exposures near the shaft on the 260 and 320 foot levels show the junction of the Corydon vein with a branch striking N. 45° W. and standing nearly vertical. This branch vein where exposed has an average width of about 18 inches. The horse between the two veins is all more or less mineralized and near the junction is traversed by several cross veinlets.

Impartially selected sampling-works assays of 16 lots of smelting ore aggregating 51 tons shipped between 1892 and 1897, show 1.08 to 2.62 ounces of gold, 2 to 15 ounces of silver, and 8 per cent or less of copper, the average content being 1.74 ounces gold and 5.63 ounces silver. The ore from the large stope east of the shaft between the second and third levels is said to have averaged 2 to 3 ounces gold per ton, with only a little silver. The total production of the mine is unknown.

CENTRAL, MAMMOTH, GREGORY, BOBTAIL, AND BATES HILLS.

MAINE HAMLET MINE.

The Maine Hamlet mine is just southeast of Central City in the northeast slope of Central Hill. The development consists of a shaft with levels at 178, 210, 310, and 410 feet. A tunnel, now caved, connects with the 178-foot level. The workings (see fig. 32), develop

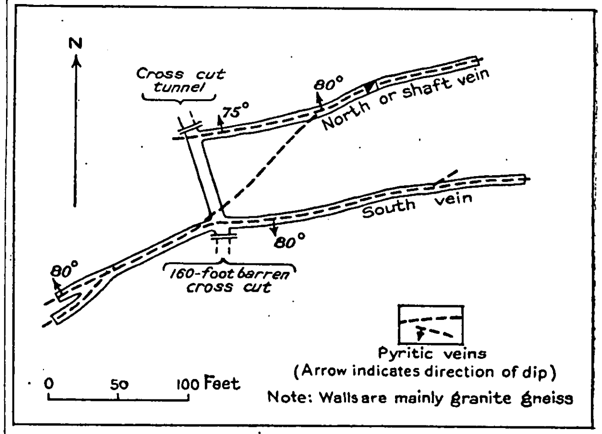
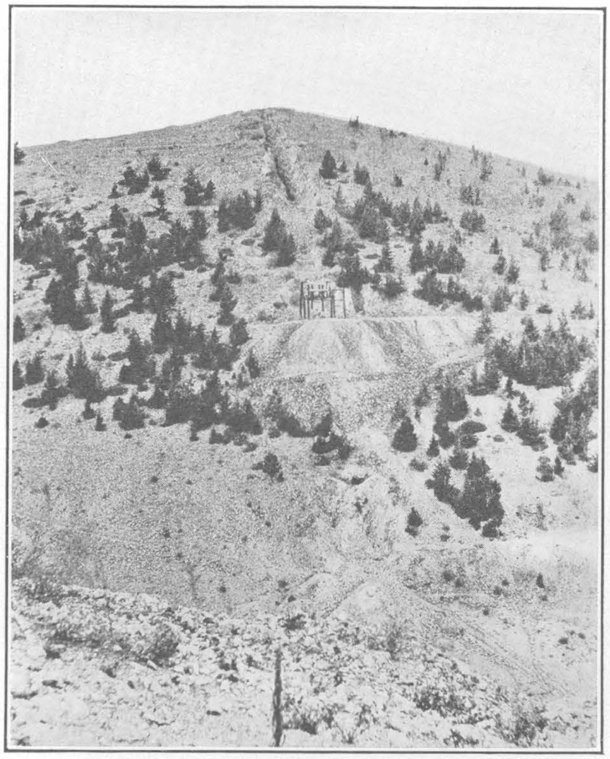
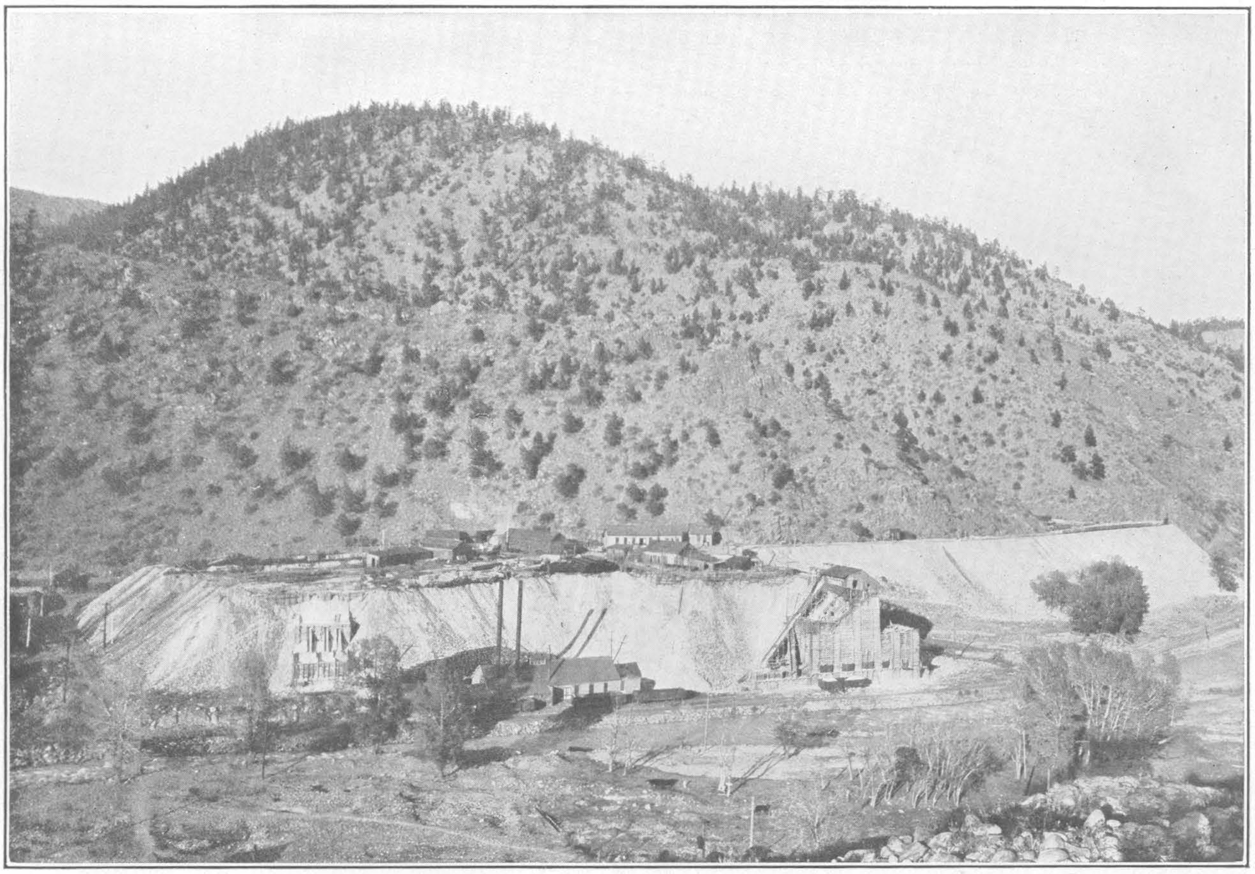


FIGURE 32.—Vein system on 178-foot level of Maine Hamlet mine. Surveyed by hand compass and pacing.

two steeply dipping veins, the shaft being on the northern one. The 178 and 410 foot levels develop both veins and the 210 and 310 foot levels only the North vein. Both veins are of the same age and mineral character and are connected by branch veinlets. The prevailing wall rock is granite gneiss, but lenses of schist of the Idaho Springs formation are locally present. The mineralization is of the true fissure-vein type, consisting characteristically of several sharp-walled sulphide veinlets, in places uniting to form a single larger one. The predominant vein materials are quartz and pyrite, but in a few places galena, sphalerite, and chalcopyrite are present and notably increase the value of the ore. The North vein 10 feet west of the shaft on the 210-foot level is more or less typical of the pyritic portions, showing pyritic veinlets with a maximum width of 3

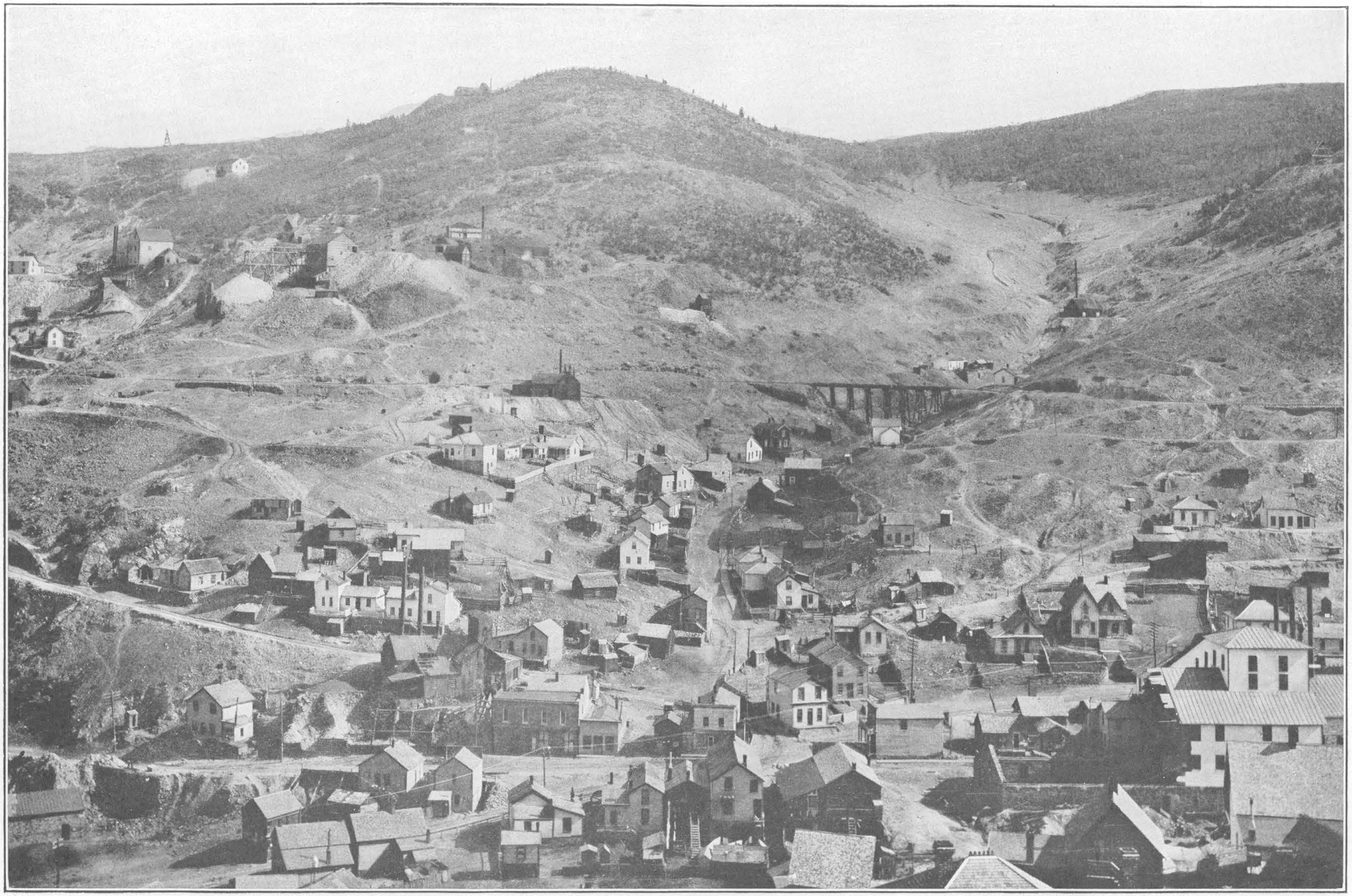


A. MAMMOTH HILL FROM EAST, SHOWING OPEN PITS MARKING OUTCROP OF MAMMOTH VEIN.



B. DUMP AND ORE BINS AT MOUTH OF ARGO TUNNEL BELOW IDAHO SPRINGS, CLEAR CREEK COUNTY.

Photograph by R. B. Morton.



MINES OF GREGORY HILL AND PACKARD GULCH, FROM BATES HILL.

inches forming a network through a thickness of 4 feet of granite gneiss.

The distribution of the pyritic and the galena-sphalerite types of ore is such as to suggest a difference in age. On the 210-foot level, for example, the ore for 40 feet east of the shaft is entirely pyritic and beyond that point is entirely of the galena-sphalerite type. The mutual relations are not definitely shown.

Movement later than the mineralization has in places followed the veins and has produced gouge and crushed ore.

Sufficient data are not at hand from which to estimate the average value of the ore, but the following selected sampling-works returns give some idea of its range:

Sampling-works assays of ore from the Maine Hamlet mine.

Date.	Ore.	Gold.	Silver.	Copper.
	Net lbs.	*Ounces.*	*Ounces.*	*Per cent.*
1888	1,544	11.95	22.00	6.00
1888	2,584	2.30	11.00	4.50
1888	2,822	3.20	6.00	3.00
1896	6,777	.67	5.50	....
1899	20,370	.48	1.50	....

O. K. MINE.

The O. K. mine, on Central Hill just southeast of Central City, is developed by a shaft which, according to the maps available, connects with levels at depths of 200, 400, and 500 feet. The 400-foot level connects with the Bobtail tunnel. The map shows a single vein striking about N. 45° E. and dipping nearly vertical. The ore appears from the available assays to belong largely to the pyritic type, but a little sphalerite was seen on the dump.

Sampling-works assays of 29 lots of smelting ore aggregating 185 tons, shipped at various times from 1893 to 1908, inclusive, show gold, 0.30 to 4.28 (average 1.13) ounces per ton; silver, 3.40 to 10.20 (average 5.59) ounces per ton; copper, 2 to 10.25 per cent. Thirty-five tons of smelting ore shipped in 1910 averaged gold 1.13 ounces and silver 5.37 ounces. The average recovery as bullion and concentrates from concentrating ore shipped in 1910 was gold 0.166 ounce and silver 0.32 ounce per ton treated.

MAMMOTH VEIN.

The Mammoth, sometimes called the Great Mammoth lode, is probably the widest and most conspicuous lode in the vicinity of Central City. (See Pl. XVIII, *A*.) It can be traced continuously from a point near the Cook shaft southwestward until obscured by the alluvium of Spring Gulch. The same general mineralized zone continues west of Spring Gulch, where it is represented by the National and Hecla veins, and finally enters the Patch, from which it emerges as the great California-Hidden Treasure lode. The eastern part of the Mammoth vein was developed in the workings of the Fifty Gold Mines Co. On Mammoth Hill the lode is developed by an almost continuous series of shafts and pits, the principal one being the Great Mammoth shaft on the east side of the hill. A lateral has also been driven under Mammoth ground from the Argo tunnel.

Little statistical data is available in regard to the ore of the Mammoth lode. It is well known that the free-milling surface ore mined in the early days gave good returns. Hollister[1] states that a 4-weeks' run on Mammoth surface ore yielded $5,250. Ore mined in 1875 within 200 feet of the surface is said[2] to have averaged about $10 per ton. The ore from the deeper portions of the lode, on the contrary, is known to be low grade. Careful sampling has been done by several persons interested, but the results do not appear to have encouraged further development under present conditions, and within recent years the lode has not been worked.

Outcrops on top of Mammoth Hill show that the granite gneiss bordering the vein has been much silicified; it has weathered whiter than the normal granite gneiss and is more resistant.

BROOKLYN MINE.

The Brooklyn mine is in the depression between Mammoth and Bobtail hills. The claims of the Brooklyn group cover the outcrop of several veins, but the main shaft and most of the development is in the Washington vein. The shaft, which is about 570 feet deep, follows this vein down to the 370-foot level, below which the shaft is vertical and lies in the footwall country rock. Levels have been driven at vertical depths of 81, 156, 249, 370, and 470 feet. A crosscut north from the 249-foot level at a point 20 feet west of the shaft cuts the Cashier vein 60 feet from the Washington vein

[1] Mines of Colorado, p. 112, 1867.

[2] Raymond, R. W., Statistics of mines and mining in the States and Territories west of the Rocky Mountains, 1875, p. 290, 1877.

and serves as a starting point of short drifts on the Cashier vein.

The average dip of the Washington vein is about 70° S. The average strike is nearly east and west. The workings were closed temporarily at the time of this survey and could not be entered, but an examination of material on the dump indicates that the veins belong to the pyritic type, the ore showing pyrite, chalcopyrite, and tennantite as its metallic minerals. A polished specimen showed minute veinlets of a gray secondary mineral, probably chalcocite developed in the chalcopyrite.

The Brooklyn mill, not now being operated, is on North Fork of Clear Creek, about three-fourths of a mile above Blackhawk. It is equipped with 10 rapid-drop 1,000-pound stamps, Hartz jigs, and Woodbury concentrating tables. The capacity is stated to be 30 to 40 tons daily.

NEXT PRESIDENT MINE.

The Next President mine, on the east side of Packard Gulch at the side of the Colorado & Southern Railway track, is developed by a shaft with levels at 100, 160, 260, 360, and 460 feet. The mine was not in operation and the workings were not examined. The map shows a vein (followed by the shaft to a depth of 350 feet) that has a general northeast to southwest strike, and another vein, intersecting the first, that strikes about N. 70° E. The junction of the two shifts eastward in depth.

The mine is reported to have been worked fairly continuously from 1865 to 1878, spasmodically from 1878 to 1908, and continuously again from 1908 to 1910. Since 1910 it has been idle. There is no reliable record of the production. The Eagle Mill at Blackhawk is owned by the company owning this mine.

The following sampling-works assays are of ore shipments from this mine:

Sampling-works assays of ore from Next President mine, 1901–1910.

Year.	Ore.	Gold.	Silver.	Copper.	Silica.
	Net lbs.	*Oz.*	*Oz.*	*P. ct.*	*P. ct.*
1901	5,556	1.34	4.00	3.20	37
1902	5,220	1.42	2.60		78
1902	4,600	.89	6.90	3.60	
1907	1,182	.78	2.30		
1907	1,636	.48	2.50		
1910	4,413	1.34	4.20	.70	

VASA VEIN.

The Vasa shaft, about 400 feet southwest of the Gregory-Buell mill in Central City, is over 260 feet deep, but only the 260-foot level was accessible. The vein strikes N. 42° E. and dips on an average 80° SE. It varies from 4 to 10 feet in width and so far as seen is in granite gneiss. This vein has been stoped from the surface to the water level (some distance below the 260-foot level) for at least 250 feet northeast of the shaft and for an unknown distance southwest of it. At the northeast end of the 260-foot level, about 200 feet from the shaft, lessees were working in a small block of unstoped ground. At this place the vein, 10 feet between walls, is composed of silicified granite gneiss heavily impregnated with rather coarse pyrite. Numerous small stringers of white quartz and pyrite cut the disseminated ore. On the northwest side of the vein next the wall a 10-inch streak of coarse pyrite and quartz is cut by a one-half to 1 inch stringer of dark-gray quartz carrying black sphalerite, galena, pyrite, and chalcopyrite.

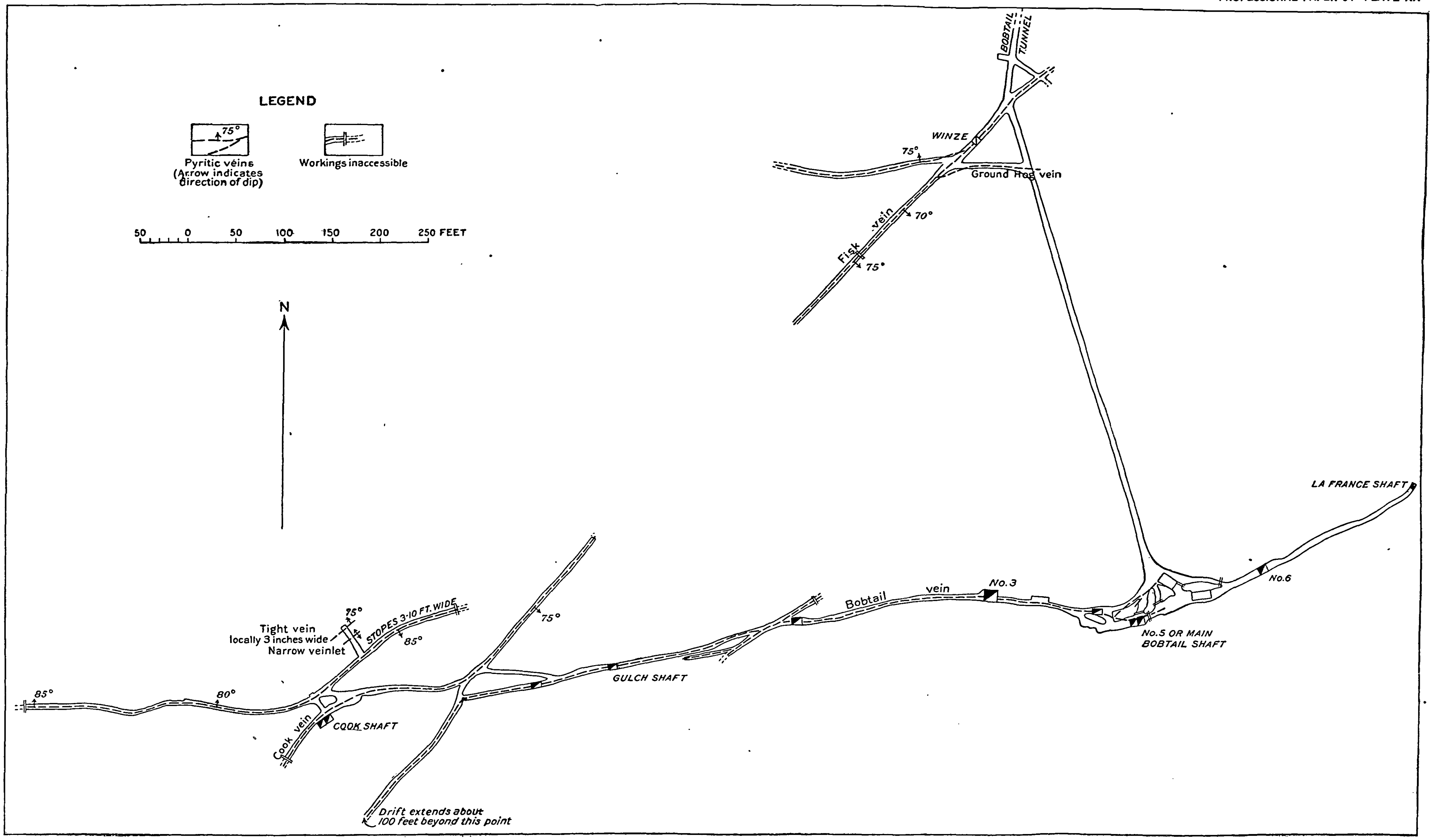
About 75 feet from the face of this drift a branch vein of pyritic ore goes into the southeast wall at a very small angle with the main vein. This branch vein is about 4 feet wide and stands nearly vertical, though near its junction with the Vasa it dips 75° SE. It is well mineralized and has a narrow streak of smelting ore near each wall. Between this junction and the shaft the Vasa vein is 4 to 5 feet wide and has been entirely stoped above and below the level.

The ore is cut by a number of postmineral slip planes, along none of which has there been much movement.

The lessees stated that the 10 feet of material which they are working includes both concentrating and smelting ore and averages about 3 ounces gold a cord (8 tons). (.375 g/T)

O'NEIL VEIN.

The O'Neil lode, which is said to be a westward continuation of the Gregory lode, is opened by a 986-foot shaft on the top of the ridge between Bobtail and Packard gulches. The mine was inaccessible at the time of survey and maps were not available. The workings are said to develop two veins which bifurcate and then rejoin. The 358-foot level connects with the Bobtail tunnel. Ore on the



PLAN OF A PART OF BOBTAIL TUNNEL.

dump consisted mainly of pyrite and chalcopyrite, with in places a very little galena. Free gold inclosed in galena and quartz is reported to have been found at a depth of 866 feet.

The average value of nearly 600 tons of smelting ore mined between 1897 and 1906 is said to have been about $70 per ton. Twenty-one lots of smelting ore, aggregating about 48 tons, sold between 1897 and 1908, averaged 3.10 ounces gold, 7.13 ounces silver, and 5 per cent copper a ton, according to sampling-works assays. The concentrating ore for the same period is said to have averaged about $10 per ton.

The gross output between 1897 and 1906 is said to have been $150,000.

PROPERTY OF FIFTY GOLD MINES CO.

Mining near Blackhawk, on the Gregory, Fisk, Cook, Bobtail, and Mammoth veins and their branches, and on several minor veins, has in recent years been controlled by the Fifty Gold Mines Co. The properties under this management have been among the most productive in the district, but were unfortunately closed down at the time of this survey, and access could be had to only a small part of the workings. The Gregory, in this group, has the distinction of being the first gold lode discovered in Colorado (May 6, 1859). (See Pl. XIX.)

In recent years development has been mainly through the Cook shaft, the Bobtail tunnel, and the Gregory incline. The Cook is a large vertical shaft 1,450 feet deep, equipped with cages. It connects with 14 levels, and from the surface to the eighth level is close to the Cook vein. Below this the Cook vein lies a short distance to the south of the shaft and the Fisk vein to the north. The Bobtail tunnel, begun in 1863, starts in Blackhawk, on the north side of Bates Hill, follows the Gregory vein through the hill, crosses beneath the road from Central City to Blackhawk, and enters the hill south of Gregory Gulch, where it intersects the Fisk and Cook veins. (See Pl. XX.) The Cook shaft is connected with the mill at Blackhawk by a motor railroad running through the Bobtail tunnel. Ore is hoisted to the tunnel level, deposited in ore bins, and automatically loaded onto the motor cars for transportation to the mill 4,200 feet distant. The Gregory incline slopes downward for 1,709 feet at about 25° from the large mill of the company in Blackhawk to a point on the Gregory vein 700 feet below the surface. Crosscuts on the eleventh level connect the Gregory vein with the Cook vein and with the Mammoth vein.

The relations between the veins of the group are complex. In general, as exposed on the surface, the Cook, Fisk, Sleepy Hollow, and After Supper (Banzai) shafts seem to be on one great lode, which preserves a fairly constant trend of about N. 40° E. Near the Cook shaft this main lode is joined from the west by the Mammoth lode and from the east by the Bobtail lode, and the relations are very complicated. (See Pl. XX.) On the hill east of the Cook shaft a large number of minor veins, such as the Warwick and Nemeha, are probably branches from the larger lodes.

The first vein cut in the Bobtail tunnel is the Fisk (Pl. XX), which, where cut by the tunnel, is 2 feet wide and shows numerous irregular veinlets of pyrite traversing silicified granite gneiss. As exposed in the drift extending southwestward from the tunnel it ranges from 2 to 6 feet in width. The vein has been fractured subsequent to mineralization and the fractures filled with cherty silica. A short distance east of the tunnel the Fisk vein is crossed by the east-west Ground Hog vein, which is mineralized in the same manner but less heavily than the Fisk. As exposed, 175 feet west of this junction the Ground Hog is 16 inches wide and includes a ½-inch veinlet of solid pyrite bordered by 2 inches of silicified granite gneiss, the remainder of the vein being gneiss carrying disseminated pyrite.

From the Bobtail tunnel the Cook shaft was descended, and portions of the next three levels were examined. On each level several veins complexly related were exposed near the shaft, but could not be followed far because of caving of the roofs or floors. The veins are all highly pyritic and represent the contemporaneous mineralization of a number of more or less connected fracture zones. Their character may be typified by an exposure 300 feet west of the shaft on the second level below the Bobtail tunnel, where the mineralized zone is about 6 feet wide and consists of granite gneiss carrying disseminated pyrite and traversed by a number of sharp-walled vuggy veins of pyrite 3 inches and less in width.

The northeast part of the Gregory vein, under Bates Hill, is developed by a drift tunnel extending entirely through the hill. The average strike of this part of the vein is about N. 45° E. and its dip is 80°–85° SE. The mineralization is predominantly pyritic but locally has been supplemented by ore of the galena-sphalerite type. The vein varies in width from 2 to 5 feet, and its appearance in the purely pyritic portions is well illustrated 300 feet from the south entrance to the tunnel, where it is 2 feet wide and contains several veinlets which are about half pyrite and half quartz and are sharply bounded by granite gneiss carrying an abundance of disseminated pyrite. In a stope about 670 feet from the south portal, the vein is about 4 feet in width and consists mainly of granite gneiss carrying varying amounts of disseminated pyrite, which in some places constitutes 90 per cent of the vein material. In the more pyritic portions a few vugs are lined with crystals of quartz, pyrite, and chalcopyrite. The pyritic vein material is traversed by a veinlet of galena, sphalerite, and chalcopyrite that appears to be of later origin. This vein usually shows a sharp contact against the pyritic material.

The ores of this group of veins belong almost exclusively to the pyritic type, though in a few places, most of them in the eastern portions of the veins, galena-sphalerite ore also occurs. Pearce [1] recognized the presence of tellurium in certain ores from the Gregory mine, and although it has not been demonstrated that this metal occurs here in combination with gold, the possible existence of tellurides of gold must be recognized and may account for the richness of certain portions of the ore bodies. Raymond mentions the discovery in the Gregory vein in 1874 of a pocket of ore carrying a large amount of free gold, and a specimen from this vein in the collection of the Colorado Bureau of Mines in the State capitol at Denver shows small masses of gold inclosed in light gray quartz.

Sampling-works assays of 100 lots of smelting ore from the Gregory, Fisk, Bobtail, and Cook veins aggregating 410 tons, shipped at different times from 1888 to 1909 inclusive, show gold, 0.52 to 26.4 (average 2.58) ounces; silver, 1.50 to 21 (average 5.4) ounces; copper (wet), less than 1.5 to 13.75 per cent; silica, 30 to 70 per cent.

[1] Pearce, Richard, The association of gold with other metals in the West: Am. Inst. Min. Eng. Trans., vol. 18, p. 449, 1890.

According to a private report by William A. Farish, the books of the Cook and Fisk mines show an average yield of $7.03 per ton from 177,717 tons of ore, 2.6 per cent of which was smelting ore and the remainder concentrating ore. The ratio of concentration was about 9 to 1.

Very few data are available for a comparison of the metal contents in the deeper workings with those near the surface. Sampling of the so-called Fisk-Mammoth vein on the fourteenth level of the Cook shaft shows 0.12 to 0.52 ounce gold and 0.4 to 4.28 ounces silver, with an average of about 0.3 ounce gold and 2 ounces silver. These samples, taken over vein widths of 3 to 6 feet, included both solid sulphide veinlets and gneiss carrying disseminated pyrite. Assays of the solid sulphide veinlets showed a maximum of 5 ounces gold and 11 ounces silver.

According to Farish's report, already cited, samples of ore from every 10 feet in the lower levels of the Cook shaft showed the following results, gold being computed at $20.67 and silver at $0.55 per ounce.

Results of ore sampling from lower levels, Cook shaft.

	Length.	Average width.	Value.
Tenth level:	*Feet.*	*Feet.*	
First block	290	3.87	$1.42
Second block	138	4.1	10.23
Twelfth level:			
First block	110	4.13	4.33
Second block	210	4.94	1.53
Third block	130	3.00	6.86
Thirteenth level:			
First block	120	2.4	11.25
Second block	152	3.53	4.30

There is little doubt that the percentage of gold in the ores near the surface was augmented by oxidation, but it is equally certain that high gold contents are occasionally found at depths far below the reach of this process.

The concentrating ores from the Fifty Gold Mines properties were treated at a large and well-equipped 80-stamp mill in Blackhawk.

AFTER SUPPER-SLEEPY HOLLOW VEIN.

The Sleepy Hollow vein crosses North Clear Creek at the mouth of Gregory Gulch and appears to be a northeastward extension of the Fisk lode. The After Supper or Banzai shaft, north of Blackhawk, is down 714 feet. The Sleepy Hollow shaft, about 700 feet south of Blackhawk post office, is over 1,000 feet deep. The American shaft is on the same vein, 500 feet southwest of the Sleepy Hollow.

The outcrop of the vein strikes N. 45° E. The dip, as shown by the vertical plan of the Sleepy Hollow shaft, varies greatly. This shaft dips 80° S. as far as the second level, then about 80° N. to a little below the fourth level, where a vertical vein joins the vein which it has been following, below which it is about vertical to the ninth level. Below the ninth level the vein splits, one part continuing about vertical and the other, which the shaft follows, dipping 70° N. The vein cuts schist, pegmatite, and granite gneiss.

From the ore on different dumps it is apparent that two periods of mineralization have occurred. The original vein consisted of crushed silicified wall rock with abundant disseminated pyrite cut by veinlets of rather coarse pyrite. This vein was reopened, and white to gray quartz with galena, dark sphalerite, and chalcopyrite was deposited in the fractures. The younger veins cut the older ore in all directions but few of them are very wide. Ore from the Sleepy Hollow mine is said to have carried tellurides of gold locally, and the high gold content of certain shipments may be due to their presence. The high silver content of certain shipments, as high as 492 ounces, is probably a result of downward enrichment in this metal.

On the stope maps of the Sleepy Hollow mine the vein is shown to have been extensively stoped from the second to the eighth levels for 150 to 300 feet east of the shaft. Above the first level the workings are not shown but are supposed to be extensive. The precious-metal content ranges from 0.28 to 34.25 ounces gold and from 2 to 492 ounces silver per ton. In most of the lots of smelting ore the gold content is about 2 ounces and the silver content 10 ounces per ton. Few assay returns record any copper or lead, although a few lots of smelting ore carried as high as 20 per cent lead, and other lots as much as 5.7 per cent copper per ton.

The total production of the Sleepy Hollow mine is stated to be about $800,000 and that of the After Supper about $80,000.

CARR VEIN.

The Carr vein, which crosses Gregory Hill just south of the summit with a general strike of about N. 45° E., is clearly traceable on the surface for about 2,500 feet. It has been developed through two principal shafts, a western one, the Colorado-Carr, on top of Gregory Hill, and an eastern one, the Chicago-Carr, in Bobtail Gulch. The vein is not now worked and the old workings are inaccessible and the only information in regard to the ore was obtained from the sampling-works assays and from examination of the dumps. The latter, however, revealed some interesting relationships.

The principal minerals in the vein rock are pyrite and chalcopyrite, the proportion of chalcopyrite apparently being above the average for most veins in this vicinity. The sulphides occur both as sharp-walled fissure fillings with a quartz gangue and as disseminations in the altered wall rock within the fracture zone. Galena and sphalerite, in association with pyrite, chalcopyrite, and quartz, were observed in a few specimens and in at least some of these were formed after the pyritic mineralization, cutting sharply through the pyritic ore. Later than the pyritic mineralization and possibly also later than the galena-sphalerite mineralization portions of the vein were again opened, more or less brecciated, and wholly or partially filled with gray cherty silica, commonly inclosing angular fragments of pyrite, chalcopyrite, and quartz of the original vein. Some of the cherty silica is pure white. In a few specimens the pyrite and chalcopyrite are cut by small veinlets which show galena and sphalerite next the walls and a center of cherty silica.

Eighty-five lots of smelting ore, aggregating 400 tons, shipped at various times from 1893 to 1910, show, according to sampling-works assays, 0.72 to 9.06 ounces in gold, 2 to 21.2 ounces in silver, and as much as 11.7 per cent of copper. The average was 2.88 ounces in gold and 7.62 ounces in silver. The silica in 21 shipments varied from 33 to 79 per cent but was commonly between 45 and 55 per cent. Concentrating ore shipped from the Chicago-Carr mine during 1910 averaged about 0.18 ounce in gold and 0.3 ounce in silver.

GOLDEN EAGLE VEIN.

The Golden Eagle vein, a short distance east of Bobtail Hill, is developed by several shafts and pits now abandoned. The ore is said to have consisted mainly of coarse pyrite and chalcopyrite of low grade.

UNEXPECTED VEIN.

The Unexpected vein crops out about a mile southeast of Central City and is developed by three shafts now abandoned. Ore on the dumps was mainly coarse pyrite with some white quartz gangue. Small amounts of galena and sphalerite were noted.

CLAY COUNTY VEIN.

The Clay County vein, on the north side of Lake Gulch about three-fourths mile south-southeast of Blackhawk, is developed by a shaft which has not been used for several years. It is also cut at the sixth level by the New National tunnel, which starts below the mouth of Fourmile Gulch on the south side of Clear Creek and also develops the Horseshoe vein. This tunnel was not entered.

On the surface the country rock near the vein is Idaho Springs formation, which contains numerous fairly large lenses of granite pegmatite and is cut by a monzonite porphyry dike.

The vein strikes about N. 21° E. and dips steeply northwest. The ore seen on the dump shows two periods of mineralization: A pyritic vein, consisting of country rock, with fine disseminated pyrite and stringers of coarse pyrite, enargite, tennantite, and quartz, has been brecciated and the fragments have been recemented by ore carrying galena, sphalerite, and chalcopyrite.

Sampling-works assays of 12 lots of smelting ore, aggregating 57.5 tons, shipped between 1891 and 1899, show gold, 0.40 to 1.15 (average 0.65) ounces; silver, 5 to 91 (average 11.28) ounces; and copper (wet), from less than 1.5 to 6 per cent. No lead is quoted.

The gross production of the mine is said to be $600,000 to $700,000, derived almost entirely from ore that came from above the third level of the Clay County shaft.

CHEMUNG-BELMONT MINE.

The Chemung-Belmont mine, about one-half mile south of Blackhawk, develops a lode which forks near the shaft house, but reunites farther west, as well as in the deeper levels of the mine. The north fork is termed the Chemung and the south fork the Belmont. The main shaft is on the south or Belmont vein for the upper 600 feet, but below that follows the united veins to a depth of 820 feet. There are 10 levels; the main development has been on the Chemung vein above the 620-foot level. The mine was last worked in 1907, and the workings were not accessible at the time of survey.

Ore on the shaft dump was in general similar to that of the Clay County vein, showing pyrite and tennantite but also galena, sphalerite, and some chalcopyrite.

Sampling-works assays of 29 lots of smelting ore, aggregating 95 tons, shipped from this mine at various times from 1889 to 1902, show gold, 0.52 to 5.5 (average 1.74) ounces; silver, 7.3 to 28.6 (average 16.03) ounces; copper (wet), less than 1.5 to 7.5 per cent; silica, 23 to 62 per cent in 16 lots.

The shipments of smelting ore in various years showed the following ranges in metal content, according to the records in the books of the company:

Metal contents of smelting ore, Chemung-Belmont mine, 1890–1894.

Date.	Gold.	Silver.	Copper (wet).
	Ounces.	*Ounces.*	*Per cent.*
1890	0.60–3.90	6.47–63.00	6.50 or less.
1891	.90–4.95	7.90–47.60	7.50 or less.
1892–93	.50–4.10	7.00–29.50	7.10 or less.
1893–94	.32–4.50	7.10–64.30	3.10 or less.

The gross production of the mine is estimated to be at least $500,000. The net output from 1887 to 1902, as recorded in the company's books, was $147,366.

ALPS AND QUARTZ HILLS.

KANSAS VEIN.

The Kansas lode on the north slope of Quartz Hill is developed by seven principal shafts which, named in order from east to west, are the Alger-Kansas, English-Kansas, Pease-Kansas, University-Kansas, First National-Kansas, Mammoth-Kansas, and Gold Coin-Kansas. All except the Alger-Kansas were idle at the time of survey, but the Kansas vein was observed where cut by the La Crosse Tunnel.

The Alger-Kansas vein, on the northeast slope of Quartz Hill, about 1,000 feet northeast of the Fourth of July shaft, is opened by two tunnels and by a shaft said to be 390 feet deep. Only the 80-foot west drift of this mine was accessible. The ground east of the shaft is said to be stoped for 100 feet from the surface to the 300-foot level. The ground west of the shaft has been stoped from the 135-foot level to the surface. It is said that on the 300-foot level the Illinois-Kansas vein is exposed in a crosscut 68 feet north of the Alger-Kansas. On the 80-foot level a 25-foot crosscut 135 feet west of the shaft has broken into the south wall of the Illinois-Kansas vein. At the surface the two veins are about 15 feet apart. The Alger-Kansas vein at the shaft strikes N. 60° E. and dips 80° S. On the 80-foot level it varies from 18 inches to 4 feet in width and is entirely in granite gneiss. The vein consists of pyrite-impregnated wall rock, cut by stringers of almost solid pyrite 1 inch and less in width and by a series of veinlets of dark quartz, galena, sphalerite, and chalcopyrite, which are apparently of later origin.

The south wall of the Illinois-Kansas vein was shown in the face of the crosscut at the 80-foot level. It is apparently similar in mineralization to the Alger-Kansas, having a 2-inch streak of galena, sphalerite, and pyrite just below the tight south-wall slip.

The Kansas vein, where cut by the La Crosse tunnel about 180 feet from the portal, is nearly vertical and shows several sharp-walled quartz-pyrite veinlets up to 2 inches wide through a width of 2 feet of granite gneiss.

From all the information available it appears that the ore of the Kansas lode as a whole was predominantly of the pyritic type, although in places the galena-sphalerite type was also present.

The pyritic ore of the Alger-Kansas vein is said to average about $45 a ton in gold and silver. In 1910 the average concentrating ore carried 0.15 ounce gold and 0.16 ounce silver per ton. Six selected sampling-works assays of shipments of smelting ore between 1889 and 1904 showed from 0.32 to 3.5 ounces gold, from 2 to 7.6 ounces silver, and 5.5 per cent or less of copper. The metal content appears extremely variable, owing perhaps to the variable proportions in which the pyritic and galena-sphalerite ore types are associated in the vein.

Sampling works assays of 57 lots of smelting ore aggregating 348 tons, shipped from mines in the central part of the Kansas lode between 1894 and 1905, show gold, 0.35 to 5.56 (average 1.62) ounces; silver, 2.25 to 14.7 (average 6.50) ounces; copper, 5.5 per cent or less; silica, commonly, 25 to 50 per cent. None of these shipments showed lead in commercial amounts but one showed 8.5 per cent of zinc.

BURROUGHS VEIN.

The Burroughs vein outcrops on the north side of Quartz Hill opposite Nevadaville. It is developed by four main shafts, the Conley-Burroughs, Mackey-Burroughs, Ophir-Burroughs, and Phoenix-Burroughs. All of these were idle at the time of survey and could not be entered. The Ophir-Burroughs shaft is said to be 1,200 feet deep. The Phoenix-Burroughs shaft, according to the available maps, connects with 12 levels. The Mackey and Conley shafts are less important.

The appearance of the Burroughs vein in 1870 as exposed in the Ophir workings is described by J. D. Hague[1] as follows:

The walls are usually well defined, smooth, and regular, sometimes carrying a thin gouge of clay, sometimes having the seam of ore resting directly upon it without anything intervening. The vein, however, is not wide as compared with other leading veins, varying from 8 to 10 inches to 3 or 4 feet, seldom exceeding the latter.

The vein matter and the ore, consisting usually of a solid seam of the latter from a few inches to more than 1 foot in thickness and associated with a belt of siliceous and feldspathic material highly charged with pyrites, present the same general features in mode of occurrence and distribution that have been already noted in connection with the other lodes, but the pyritous ore is more exclusively iron rather than copper pyrites; in fact, the small proportion of the latter, at least in the Ophir, is very marked, and the iron pyrites is not only gold bearing but the Ophir ore carries more silver than is generally associated with the ores of the district similar to these in other respects, the average assay of the first-class ores sold at the smelting works showing about 6 ounces of fine gold and 12 ounces of fine silver to the ton. The ground is generally hard, requiring the aid of powder for its removal. Very little of it can be picked down. * * *

The first-class ore, sold at the smelting works, netted the mine, in the month of May, 1868, $93; in July, $98; and in August, $104 per ton, in currency. The yield of the stamp rock, including that treated in the company's mill and in custom mills, was, in May, $24.50; in June, $15; in July, $12; and in August, $19 per ton, in currency.

[1] U. S. Geol. Expl. 40th Par. Rept., vol. 3, pp. 532-536, 1870.

The proportion of first-class or smelting ore to second-class or concentrating ore appears from the accounts to be about 1 to 50.

Thus we have in—

April	8	in	374,	or 1 in 46
May	15	in	445,	or 1 in 30
June	6	in	592,	or 1 in 97
July	4.5	in	598.5,	or 1 in 133
August	12	in	428,	or 1 in 35⅔
For 5 months	45.5	in	2,437.5,	or 1 in 53.6

The ore on the Ophir and Phoenix dumps was composed mainly of quartz and pyrite with, in places, some chalcopyrite and very little tetrahedrite. Coarse pyrite was the only sulphide noted in the La Crosse tunnel workings on this vein. (See p. 237.) Galena and sphalerite, though occasionally noted, appear in general to be rare.

Sampling works assays of 71 shipments of smelting ore, aggregating 251 tons, shipped from 1893 to 1899 from the Conley, Mackey, Ophir, and Phoenix workings on the Burroughs vein, show gold, 0.88 to 12 (average 4.3) ounces; silver, 2.1 to 25.5 (average 9.97) ounces; copper, not more than 4.3 and commonly less than 3 per cent. Ten tons of smelting ore shipped in 1910 averaged gold, 3.31 ounces and silver, 5.9 ounces.

FOURTH OF JULY VEIN.

The Fourth of July shaft is on the northeast slope of Quartz Hill about half a mile southwest of the railroad station at Central City. The shaft is said to be 600 feet deep, but the only accessible levels were 250 and 450 feet below the collar. On the upper level the east drift is caved near the shaft and the west drift about 250 feet from it. On the lower level the drift east was 210 feet and the west drift 190 feet long.

The vein strikes approximately east and west, but in the 450-foot east drift it strikes N. 75° W. for about 180 feet, beyond which it trends N. 80° E. From the surface to a depth of 360 feet the average dip is 87° S.; below 360 feet it is commonly about 85° N., though in many places it stands vertical. It varies from 6 inches to 10 feet in width with an average of about 2½ feet. On the 450-foot level 140 feet east of the shaft a small cross fracture striking N. 70° E. and dipping 73° S. runs into the Fourth of July vein.

Granite gneiss was the only rock seen along the walls of the mine. The vein consists of crushed silicified granite gneiss through which is disseminated fine-grained pyrite with a little scattered chalcopyrite. West of the shaft ore of this kind has been brecciated and recemented by gray quartz carrying an abundance of sphalerite, galena, and chalcopyrite. (See Pl. XIII, *C*, p. 96.) In some places the second mineralization has not completely filled the open spaces, and small vugs remain which are lined with crystals of galena and sphalerite. In places the sulphides are covered with a later coating of dark-gray cherty silica.

Horizontal postmineral movement along the fracture subsequent to the last mineralization is shown by shearing in the ore and by slickensided gouge in the west 450-foot level.

The main ore shoot pitches westward. At the surface the shaft marks about its center, but on the 250-foot level the shoot was reached 80 feet west of the shaft, and on the 450-foot level the west drift appears to be just entering the shoot at its face, 200 feet from the shaft. On the second level the shoot extends for at least 150 feet along the vein.

The pyritic ore is reported to be of low grade. The concentrating ore, containing a little galena and sphalerite, carries about 0.75 ounce of gold to the ton. Three lots of smelting ore shipped in 1896 assayed from 0.4 to 1.16 ounces gold and 2.6 to 14.2 ounces silver.

The total production of the mine is not known, but it is reported that $250,000 worth of ore was taken from the stope connecting with the 250-foot level.

QUARTZ HILL TUNNEL.

The Quartz Hill tunnel, started in the late sixties, has its portal on the south side of Nevada Gulch about 1,000 feet southwest of the railroad station at Central City. The first 1,480 feet (see fig. 33) is a crosscut running south-southwest through granite gneiss containing a few small lenses of schist of the Idaho Springs formation. At 1,480 feet the Hecla vein is cut and the remainder of the workings are drifts on this and on the Barnes vein.

At 155 feet from the mouth the tunnel cuts a very small vein of crushed granite gneiss, which is almost barren except for a ⅛-inch stringer of coarse pyrite near the center. At

310 feet from the mouth an 8 to 18 inch vein has been drifted on west of the shaft for 120 feet to a winze (W, fig. 33) and for an undetermined distance beyond; it varies from 6 to 8 inches in width and consists of 3 to 4 inches of quartz with pyrite and chalcopyrite, the latter mineral being most abundant near the winze. In some places the granite gneiss for 6 to 8 inches on either side of this ore contains a little disseminated fine-grained pyrite; 20 feet north of this vein is an east-west barren fracture. About 400 feet in from the mouth there is a 1-foot zone of bleached granite gneiss along a barren fracture; 30 feet farther in a 3-inch streak of quartz with some pyrite is cut. Between the 450-foot point and the Hecla vein the granite gneiss is barren except for a vein which is cut about 50 feet north of the Hecla. This vein is about one foot wide and is composed of crushed granite gneiss carrying disseminated pyrite and cut by stringers of pyrite and some later veinlets of galena, sphalerite, and chalcopyrite. There are short drifts and small stopes on this vein both east and west of the tunnel.

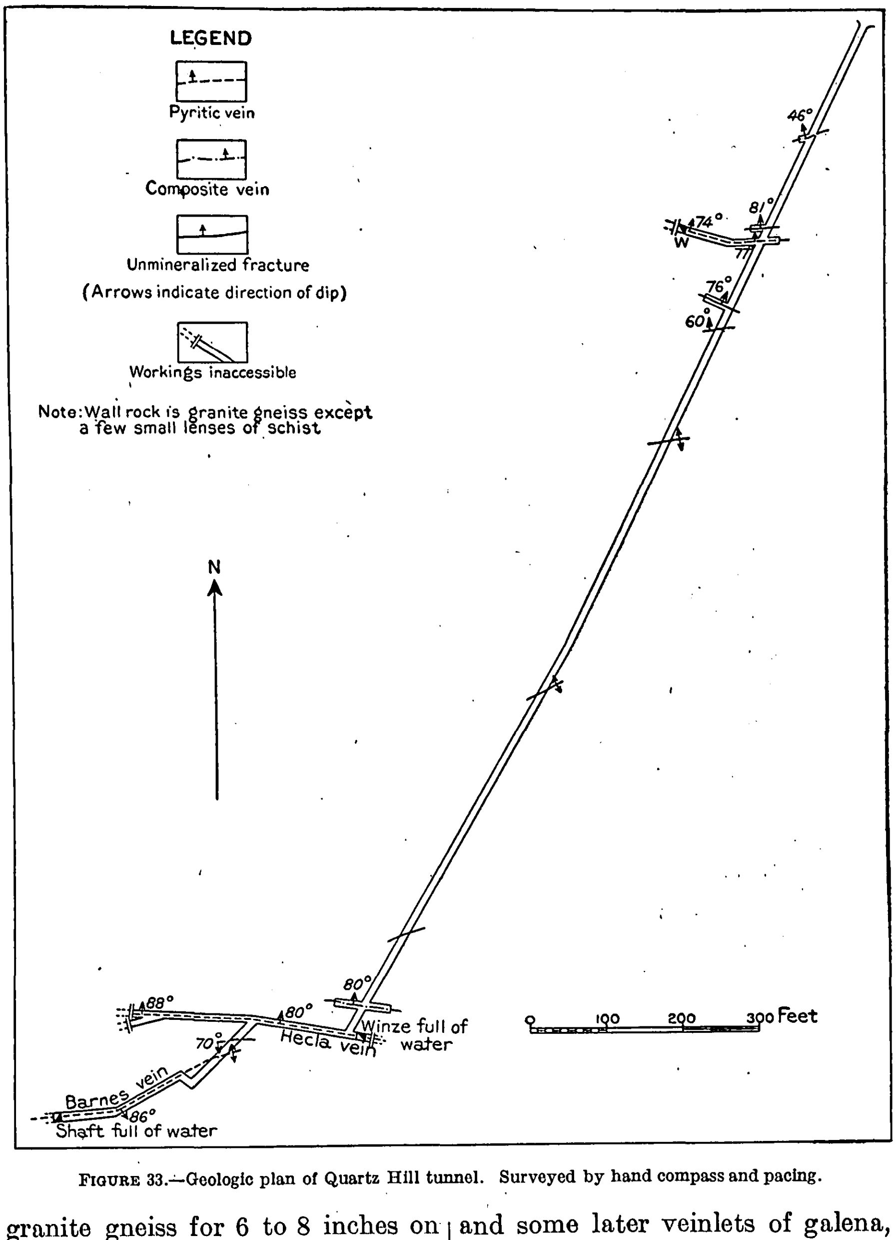


FIGURE 33.—Geologic plan of Quartz Hill tunnel. Surveyed by hand compass and pacing.

The Hecla vein averages about 3½ feet between walls, and that part of it which could be seen consists of pyrite-impregnated granite gneiss cut by narrow subparallel stringers of quartz and pyrite. The ore is said to be largely concentrating ore carrying about 0.2 ounce of gold per ton. The walls of the drift are coated with limonite; stalactites of it are pendant from the roof; and a deposit of it 2 to 6 inches thick covers the floor. The east drift was inaccessible and the west drift could be followed for only 275 feet before the air became bad. A 150-foot crosscut to the south, starting from the Hecla drift 125 feet west of the line of the tunnel intersects the Barnes vein 60 feet from the Hecla drift and follows it west for at least 180 feet, to a shaft full of water, beyond which progress was impossible.

The Barnes vein, where cut in the crosscut, is an 8-inch vertical vein of crushed granite gneiss carrying a little pyrite; toward the shaft it widens to 2 feet of heavily pyrite-impregnated granite gneiss. The crosscut also intersects, 40 feet south of the Hecla vein, a 2-foot zone of crushed pyrite-impregnated granite gneiss.

COLUMBIA TUNNEL.

The Columbia tunnel, on the south side of Nevada Gulch in the southwest part of Central City, extends generally S. 30° W. for about 500 feet to the Columbia vein. On the tunnel level a drift on the vein extends 130 feet west of the tunnel, and a winze provided with a gasoline hoist descends to the 100 and 200 foot levels. The vein strikes on the average about N. 70° to 75° E., and dips about 75° S. The best exposures were on the levels below the tunnel, where mining was in progress at the time of survey.

The 100-foot level extends 35 feet west and 130 feet east of the winze. The 200-foot level extends 50 feet west and 160 feet east of the winze. West of the winze the vein splits into two branches diverging at a small angle. In a stope on the north fork the vein is about 3 feet wide and consists of an irregular network of stringers of nearly solid pyrite traversing altered granite gneiss which carries some disseminated pyrite. Certain parts of these veinlets not sharply bounded from the pyritic portions consist mainly of chalcopyrite and tennantite and in some of the more open portions contain a little sphalerite and some galena. Some of the copper-rich bands are 1 to 3 inches across, and they constitute the richest ore. Microscopic examination shows that the association of chalcopyrite, tennantite, reddish-brown sphalerite, galena, and white quartz present in the richer portions of the ore is later than the pyrite which forms the main mass of the vein. Some specimens of open portions of the pyritic ore show these minerals forming incrustations, in which the tennantite and quartz form well-developed crystals that line the vugs. The Columbia vein, like other pyritic veins, carries minor amounts of chalcopyrite and tennantite belonging to the earlier or pyritic mineralization. One hundred feet east of the shaft on the 200-foot level the vein is 4 feet wide and shows in one place 2½ feet of solid sulphides.

At 370 feet from the portal the Columbia tunnel cuts a vein dipping 60° SE. and follows it for 60 feet to the point where it is cut off by an east-west fault. This vein is a 3 to 8 inch zone of fractured schist that carries disseminated pyrite and is traversed by a few veinlets of nearly solid pyrite not more than 3 inches wide. It has not been developed and is presumably of low grade.

Sampling-works assays of 27 lots of smelting ore aggregating 193 tons, shipped from the Columbia vein in 1910, show gold, 0.68 to 5.52 (average, 2.41) ounces; silver, trace to 13.33 (average, 3.93) ounces; and copper not exceeding 4.8 per cent.

BAXTER MINE.

The Baxter mine is situated in Spring Gulch on the southern outskirts of Central City. It is developed by a shaft, said to be 300 feet deep, which was idle at the time of survey.

Sampling-works assays of 17 lots of smelting ore aggregating 45 tons, shipped in 1910, show gold, 0.29 to 4.78 (average, 2.52) ounces; silver, 2.7 to 10.4 (average, 6.55) ounces; copper, 1.6 to 6 per cent. The mine is credited with a gross production of $120,000.

CLIMAX MINE.

The Climax mine is on Quartz Hill about three-fourths of a mile southwest of Central City. The development work consists of a shaft 532 feet deep connecting with 11 levels. The 263-foot level connects with the La Crosse tunnel. The shaft, which has an average dip of 75° S., follows a vein striking about N. 65° E. The Climax vein becomes dissipated in the Patch a short distance west of the shaft. Mineralization is of the composite type.

HIDDEN TREASURE-CALIFORNIA-GARDNER LODE.

The Hidden Treasure-California-Gardner lode, on the north side of Quartz Hill opposite Nevadaville, is one of the strongest and most persistent in the district. It has been developed to a depth of 2,250 feet by the California shaft, the deepest in the district. All the workings except the Gardner lateral from the Argo tunnel and a portion of the Gardner vein reached through the San Juan mine were unfortunately inaccessible at the time of this survey. The stope map (fig. 34) shows their very extensive character.

The vein as exposed on the surface parallels for most of its length a dike of bostonite porphyry. (See Pl. III.) This relationship is apparent throughout most of the workings

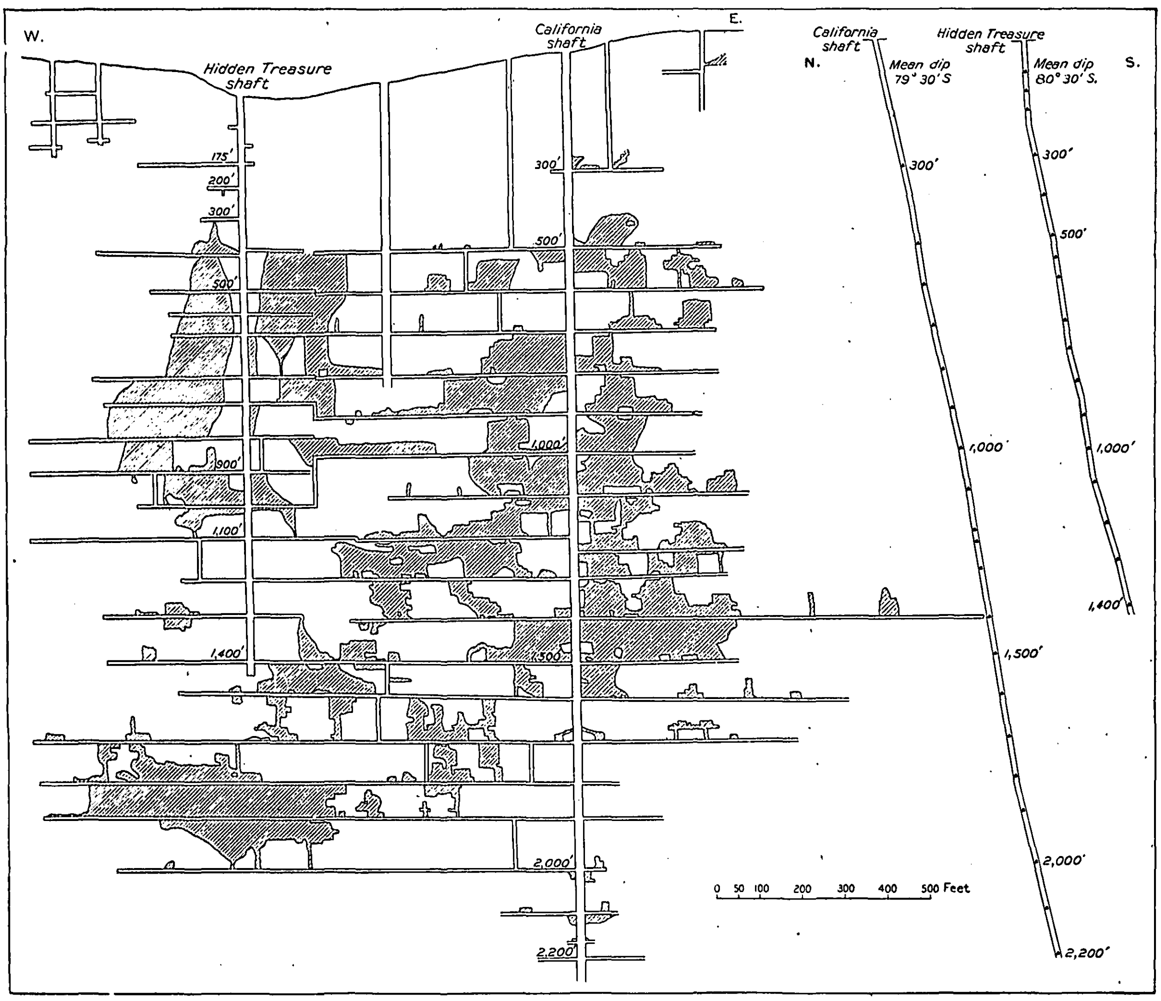


FIGURE 34.—Stope map and north-south sections through shafts, California-Hidden Treasure lode.

and persists even as far down as the Gardner lateral on the Argo tunnel level. The vein appears to furnish an excellent example of composite mineralization, for, according to Mr. Geo. E. Collins, the mineralization was mainly of the galena-sphalerite type in the Hidden Treasure workings and almost exclusively of the pyritic type in the California workings. Fragments on several of the dumps clearly show that both types of ore are later than the bostonite porphyry dike.

As regards the distribution of precious metals in the different ore minerals the following test by Rickard is of interest:[1]

Metallic content of ore from Hidden Treasure-California-Gardner lode.

	Gold.	Silver.
	Oz. per ton.	*Oz. per ton.*
Iron pyrites	0.65	4.85
Copper pyrites	.85	53.50
Gray copper	.90	38.65
Blende	.16	6.45
White quartz	3.32	7.35
Bluish quartz	3.56	5.84
Flinty quartz	.18	1.90
Feldspathic gangue	.90	2.35

The Gardner workings can be reached through one of the large stopes on the La Crosse tunnel level of the San Juan mine. As the workings are in bad shape the Gardner vein could only be explored for a short distance, but the exposures are particularly instructive in showing the transition from the true fissure type of mineralization to the breccia-filled type exemplified in the Patch. (See pp. 96–97.)

The Gardner lateral connecting with the Argo tunnel extends 250 feet east and an equal distance west of the tunnel. The vein varies in dip from 75° S. to 80° N. It follows the south side of a dike of bostonite porphyry. The other wall is schist. The mineralization in these laterals is entirely pyritic. At 130 feet west of the tunnel the vein consists of 14 inches of pyritized and silicified porphyry, somewhat crushed by postmineral movement. At 120 feet east of the tunnel it consists of 6 inches of crushed, pyritized schist. Sampling along these laterals shows in most places a gold content between 0.05 and 0.50 ounce and a silver content between 0.50 and 3.50 ounces. Ore with noticeable amounts of chalcopyrite or of "gray copper" (presumably tennantite) showed gold not exceeding 3.24 ounces and silver not exceeding 9 ounces per ton.

SAN JUAN MINE, LA CROSSE TUNNEL, AND THE PATCH.

The San Juan mine, about a mile southwest of Central City on the crest of Quartz Hill, is unique for the district in that most of the ore occurs not in fissure veins but in an irregular stockwork, the ore minerals being deposited in spaces between the fragments of a breccia or in an irregular network of fractures. The area characterized by mineralization of this sort is known locally as the Patch and its origin has been the subject of much interest and speculation among those familiar with the district. Though opened in the fall of 1888 the main period of activity of the San Juan mine was from 1890 to 1894. From 1894 to 1900 it was worked by lessees and after a period of idleness was taken over by the present company in 1906. In 1911 a little work by lessees was in progress.

The San Juan mine is developed by a shaft 916 feet deep connecting with 11 levels,

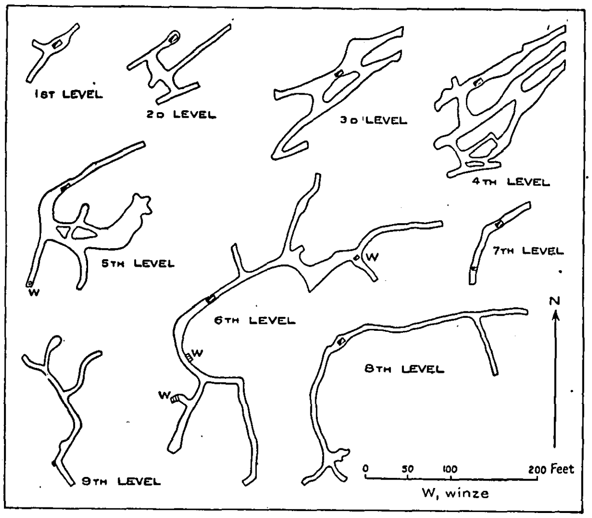


FIGURE 35.—Plans of levels of San Juan mine, Quartz Hill.

whose form, taken from plans furnished by Mr. W. C. Denison, is shown in figure 35. From this the large size and irregularity of many of the stopes is apparent and also (especially in levels 1 to 5) the presence of several northeast-southwest zones of maximum mineralization which have been followed by the development work. The San Juan workings could be entered only through the La Crosse tunnel. The chamber stopes connecting with the tunnel are of immense size and form one of the most interesting features of the district. The principal geologic features of the San Juan mine as shown in the La Crosse tunnel workings may be understood from the following brief descriptions and from the plan shown in figure 36.

[1] Rickard, T. A., The stamp milling of gold ores, p. 26, 1898.

About 585 feet from the portal of the La Crosse tunnel and 60 feet south of the Missouri vein are two pyrite veinlets one-half inch in width separated by 4 feet of brecciated mineralized granite gneiss. The granite gneiss to the south is also brecciated and carries quartz and pyrite in the interspaces between the fragments. This is the beginning of the Patch type of mineralization which (see fig. 36) characterizes all of the remaining accessible parts of the La Crosse workings. The prevailing wall rock of the Patch is granite gneiss, but bostonite porphyry occurs at several places. These rocks have been cut by a most irregular network of fractures, forming blocks that in places show little differential movement but that elsewhere have been moved over each other and more or less rounded, blocks of gneiss becoming mixed with blocks of pegmatite or porphyry. These relations show conclusively that the mineralization was later than the intrusion of the bostonite porphyry.

Not all portions of the breccia are mineralized. The sulphides and quartz gangue occur principally between the fragments of the breccia, in part as true fissure fillings and in part as replacements of the blocks of their crushed matrix. Where the fragments have not been much shifted the replacement reaches a maximum at places where several fractures intersect. Disseminated sulphides may be present even in the centers of the blocks. In one type of ore sphalerite is predominant with a little associated pyrite, galena, and quartz; in the other type the minerals are pyrite, chalcopyrite, and quartz with a little antimoniacal tennantite. Vugs 2 to 3 inches across are common, and in them crystals of clear white quartz occur in abundance. In the northern part of the Patch, as exposed in the La Crosse workings, the mineralization is almost exclusively of the galena-sphalerite type. Some galena-sphalerite ore persists as far as the crosscut leading into the San Juan workings, but in the latter the pyritic type of ore is almost exclusively present.

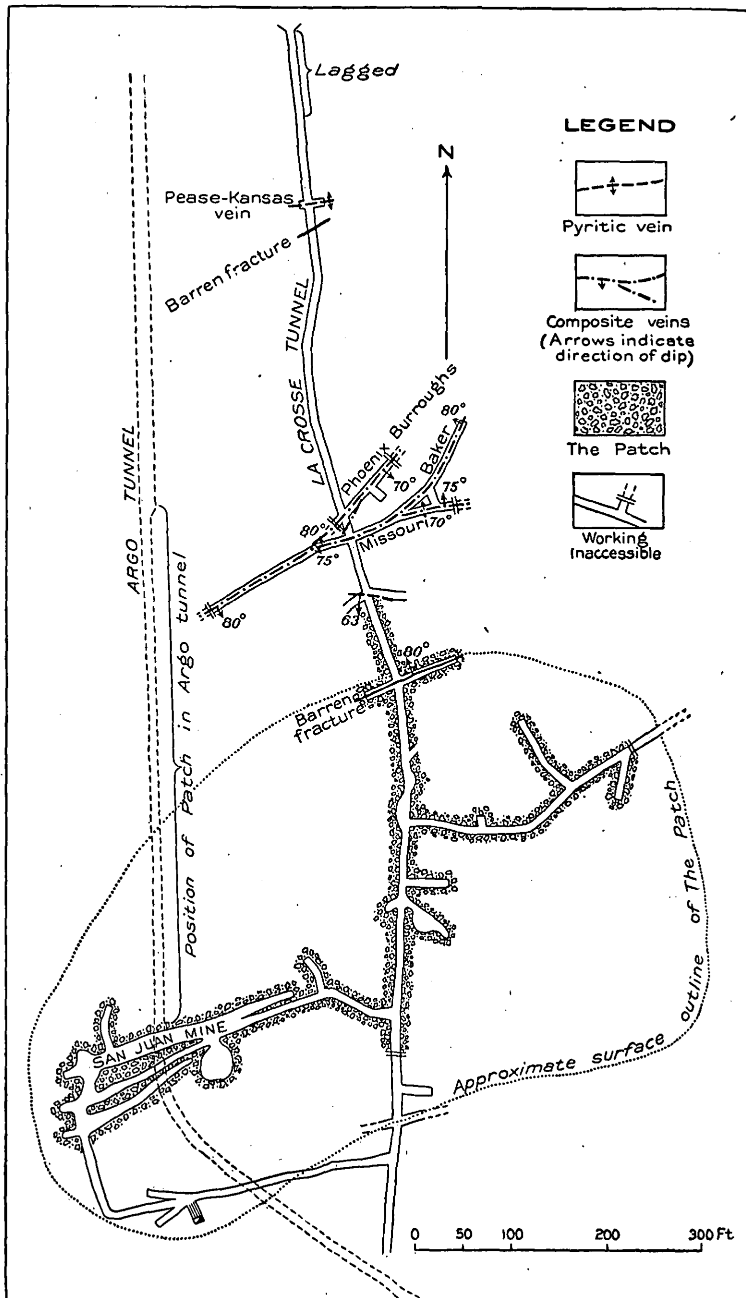


FIGURE 36.—Geologic plan showing veins and the Patch as exposed in the La Crosse tunnel and positions of the Patch on the surface and in the Argo tunnel.

The general conclusions of the authors in regard to the origin of the Patch have been summarized on pages 96–97.

Sampling-works assays of 42 lots of smelting ore aggregating 117 tons, shipped from the San Juan mine between 1888 and 1909, show gold, a trace to 12.2 (average 2.09) ounces; silver, 2.15 to 34 (average 6.81) ounces; copper, from less than 1.5 to 9 per cent. These figures represent, of course, only the richer ore. The gold content of most of the ore in the largest of the San Juan stopes is said to have ranged from 0.44 to 0.78 ounce. The average value may be placed at about $15 per ton. Ore not sufficiently rich to ship directly to the smelter was treated in the Avon mill near the mouth of the La Crosse tunnel. In this mill, which is equipped with 30 stamps, 6 Gilpin County bumpers, and 1 Wilfley table, a concentration of about 10 into 1 was effected. The average value of the concentrates is said to have been about $26 per ton, the larger share of the precious metal content being recovered in the plates.

Most of the ore mined in recent years is of comparatively low grade. Ore shipped in 1910 had the following metal content:

Metal content of ore shipped from the San Juan mine, 1910.

	Gold.	Silver.	Copper.
	Ounces.	*Ounces.*	*Per cent.*
Small lot of smelting ore	1.27	4.54	0.85
Recovered as bullion and concentrates from concentrating ore	.226	.31	....

The gross production of the mine is said to have been about $600,000.

The Patch where traversed by the Argo tunnel has yielded no workable ore, but the unusually complete and fresh section there afforded gives a clear insight into its nature and origin. The Argo tunnel traverses the Patch between 18,867 and 19,412 feet from the portal—a distance of 545 feet. The tunnel lies about 1,600 feet below the collar of the San Juan shaft. The south border of the Patch is a nearly vertical northwest-southeast fault plane about a foot wide, of soft, crushed, bleached schist, carrying bowlder-like masses of pegmatite and gneiss. It cuts sharply across the foliation of the undisturbed schist that forms its south wall. In places along the tunnel the Patch is a breccia of rock fragments not larger than 4 feet in diameter in an arkose-like matrix. The fragments are heterogeneous in size, in lithologic character, and in degree of rounding, most of them being angular and a few perfectly rounded. Fifty feet from the south border of the Patch a bowlder-like mass of schist measuring 3 by 4 feet is bordered by another of schist and pegmatite 1½ feet long by 6 inches wide. The surrounding smaller fragments are mostly granite gneiss with their foliation oriented in different directions. The Patch as exposed in the tunnel is practically barren as compared with the San Juan workings, sulphides being present in only a few small areas.

As shown in Plate XXI, *A* (in pocket), the Patch is traversed on the Argo tunnel level by a number of pyritic veins. The first of these, cut 130 feet north of the south border of the Patch, is a ¼-inch seam of quartz and pyrite that cuts across both "bowlders" and matrix. The second, 50 feet farther north, is similar in size and character. In the northern part of the Patch three veins form the Kansas-Burroughs group. The south member of this group is a 4-foot vein which is sparsely mineralized with quartz and pyrite and in which an active water circulation is depositing limonite. The middle member shows 4 inches of crushed gneiss carrying disseminated pyrite. The northern member shows 4 feet of quartz and fine-grained pyrite. No development work has been done on any of these veins. Two assays of the ore showed gold 0.12 and 0.36 ounce and silver 1.4 and 3.6 ounces. Assays of mineralized portions of the Patch in the Argo tunnel show from a trace to 0.14 ounce in gold and from 0.2 to 0.8 ounce in silver.

The Pease-Kansas vein, the first cut by the La Crosse tunnel, is intersected about 180 feet from the portal. It is nearly vertical and shows several sharp-walled quartz-pyrite veinlets 2 inches or less in width distributed through 2 feet of granite gneiss.

The Phoenix-Burroughs vein is cut about 500 feet from the portal. Near its junction with the Missouri vein it shows 4 inches of sulphides. In a stope about 30 feet above the level of the tunnel and 75 feet east of it one branch of the Phoenix-Burroughs is a tight vein 1 to 4 inches wide composed of coarse pyrite and chalcopyrite, the latter coated along fractures with thin films of secondary bornite and chalcocite.

The Missouri vein is cut about 525 feet from the portal. It joins the Phoenix-Burroughs vein about 70 feet west of the tunnel and the Baker vein about 50 feet east of the tunnel. In a stope 60 feet above the tunnel level in the junction of the Baker and Missouri veins a width of 5 feet of granite gneiss is cut by an irregular network of pyrite veinlets mostly under 1½ inches across. A veinlet of galena, sphalerite, and chalcopyrite one-half to 1 inch wide traverses the center of this zone. In a winze at the east end of the Baker drift the Baker vein is 8 inches wide and shows a pyrite veinlet 2 to 3 inches wide paralleled by several smaller ones. At another place in this winze a small, sharp-walled veinlet of galena, sphalerite, chalcopyrite, and tennantite cuts the pyrite veinlets at a small angle.

The La Crosse level of the San Juan mine connects with the workings on the Gardner vein, but these being in bad shape could only be entered for a short distance. The Gardner vein as exposed just west of the Patch is a sharp-walled fracture filled with pyrite and chalcopyrite. As the Patch is approached the vein sends off branches into the walls, and these branches break up within a short distance into a network of very small veins traversing the wall rock in all directions and dividing it into a multitude of angular blocks which have not, however, suffered much movement with respect to each other. This network of veins passes into the Patch, composed of angular fragments that have been more or less moved upon each other, the interspaces being partly or wholly filled with ore minerals and the fragments themselves partly replaced by sulphides.

NATIONAL MINE.

The National mine is about half a mile south-southwest of Central City, on the west side of Spring Gulch, and appears to be on the westward continuation of the Mammoth vein. The shaft follows the vein, whose dip in general varies from vertical to 80° S. Three levels were studied at depths of 290, 350, and 400 feet, their lengths being 490, 280, and 200 feet respectively. The vein as exposed in these workings ranges from 2 to 8 feet in width and is one of the most heavily mineralized fractures seen in the district. A particularly clean exposure in a stope above the 350-foot level 50 feet west of the shaft showed the following sequence from north to south:

Section of National mine on 350-foot level.

	Inches.
North wall.	
Post mineral slip plane composed of crushed gneiss and pyrite	1–2
Gneiss, brecciated and carrying some fine disseminated pyrite	6–12
Granite gneiss, silicified and carrying abundant disseminated pyrite	12
Nearly solid pyrite, with small amounts of gray quartz, chalcopyrite, and tennantite	36
South wall; gneiss carrying disseminated pyrite.	

Other exposures of the vein show similar features but generally lesser widths. In places there are several bands of nearly solid sulphides instead of one. In many places vugs are numerous, and the copper minerals seem to be more abundant near them than elsewhere. One vug on the 400-foot level, measuring 6 by 4 inches by 2 feet, lies in gneiss carrying disseminated pyrite and is lined with quartz crystals, some of which are one-half inch in diameter.

The highly pyritic ore of this vein is too low grade to be worked at a profit. By the present operators the ore as hoisted is sorted, the purely pyritic portions are discarded, and only the portions carrying chalcopyrite, tennantite, or both, are saved.

IVANHOE VEIN.

The Ivanhoe vein is on the north slope of Alps Hill south of the east end of Kings Flat. It is developed by several shafts, none of which could be entered in 1911. The vein strikes a few degrees north of east and on the surface dips 75° N. It is strongly marked in the granite gneiss, but just west of the Ivanhoe shaft it dies out on entering an area of schist of the Idaho Springs formation.

All ore seen on the dumps is of the galena-sphalerite type, carrying dark sphalerite, galena chalcopyrite, and a little pyrite, associated with dark-gray cherty silica. Some of the ore has been brecciated, angular fragments of sulphides lying embedded in a matrix of altered country rock. (See Pl. XIV, *B*, p. 97.)

Ten lots of smelting ore aggregating 11 tons, shipped between 1898 and 1902, showed, according to sampling-works returns, gold, 0.1 to 0.9 (average 0.59) ounce; silver, 7.62 to 21.4 (average 13.95) ounces; lead, 10.9 to 54.1 per cent; and zinc, 8 to 18 per cent.

KENT COUNTY VEIN.

The Kent County vein, on the north slope of Quartz Hill south of the California vein, was one of the first to be discovered in the district (1859). It is opened by several shafts, none of which were accessible in 1911. The vein trends about east and west and appears to be the westward extension of the Ralls County and East Kent veins. The surface rock is granite gneiss, though it is reported that porphyry is found on the hanging wall of the fifth level and possibly elsewhere. The main shaft is said to be 1,175 feet deep along the dip of the vein and to have 12 levels, the longest of which, the fifth or 500-foot level, extends 1,500 feet west of the shaft. It is reported that the vein is from 2 to 20 feet wide, consisting of altered wall rock carrying disseminated pyrite and traversed by veinlets composed of galena, sphalerite, and chalcopyrite. Several branches, making into both foot and hanging walls, strike about parallel to the Kent County vein but dip more steeply. The main ore shoot is said to have begun on the second level west of the shaft and to have extended nearly to the eighth level.

Data are not at hand for a satisfactory estimate of the value of the ore. The gross production of the mine is variously estimated at $500,000 to $800,000, but the higher figure is possibly more nearly correct.

RALLS COUNTY MINE.

The Ralls County vein is developed by the Ætna and Ralls County shafts on the north side of Quartz Hill near its summit. The Ætna shaft was idle at the time of this survey, but the Ralls County shaft, said to be 700 feet deep, was accessible on three levels, of which the 500-foot level was the lowest. In 1911 some work was being done on the 300-foot level, and the 180-foot level could be entered for a short distance west of the shaft.

The country rock throughout the mine is granite gneiss. The vein in general strikes nearly east and west and dips 62°–75° S. It ranges in width from 1 to 6 feet, with an average of about 3 feet. On the 180-foot level, 200 feet west of the shaft, a small branch vein dipping 60° S. goes into the south or hanging wall. On the 300-foot level the vein splits 230 feet west of the shaft and comes together again 170 feet farther west, the horse between the two portions being about 15 feet wide and somewhat mineralized throughout. On the 500-foot level the drifts are caved 240 feet east and 120 feet west of the shaft.

The vein may be described as a zone of crushed and altered granite gneiss impregnated with pyrite and cut here and there by stringers composed of chalcopyrite and a little gray copper. In some parts of the vein a later mineralization took place, as is particularly well shown west of the shaft in the main ore shoot, where the pyritic vein is cut in several places by veins 8 inches or less in width composed of dark-gray quartz, galena, sphalerite, and chalcopyrite. This ore shoot presumably extends above the third level in the stopes now inaccessible and appears again on the 180-foot level, where the vein is stoped to the shaft. The shoot is not cut in the part of the fifth level now accessible, but it may have been cut west of the shaft at some point beyond the cave in the drift.

Some postmineral movement along the vein subsequent to the galena-sphalerite mineralization is indicated by the blackened gouge observed along both foot and hanging walls at many parts of the mine. The ore itself is sheared in some places, or is cut by small slip planes.

The gneiss carrying disseminated pyrite which forms the concentrating ore is said to carry in the west fifth level about 0.37 ounce gold per ton. Some smelting ore, presumably the chalcopyrite-rich ore from the stope on the south part of the vein in the west third level, carried about 0.75 ounce gold, 13 ounces silver, and 9 per cent copper per ton. In a number of shipments of smelting ore made in 1905 and 1907 the sampling-works assays showed from 0.54 ounce to 2.08 ounces of gold, 9.1 to 16 ounces of silver, and from 2.5 to 10. 3 per cent of copper. No figures are available for a comparison between the value of the purely pyritic ore and that containing galena and sphalerite of the second mineralization.

The total production of the Ralls County mine is estimated by the company to be about $225,000, most of which has come from the westward-pitching ore shoot above the third level.

EGYPTIAN MINE.

The Egyptian mine is about a mile southwest of Central City near the summit of Quartz Hill. It is developed by an inclined shaft 880 feet deep, connecting with levels at 100, 200, 300, 400, 500, 600, and 700 feet. The 500, 600, and 700 foot levels were under water at the time the mine was studied, and the 100 and 400 foot levels could not be entered for other reasons. The wall rock exposed on the 200 and 300 foot levels (see fig. 37) is almost exclusively granite gneiss.

As exposed at the shaft on the 300-foot level the North or Shaft vein is 8 to 14 inches wide and consists of several subparallel veinlets of pyrite, sphalerite, and gray quartz. The widest of these veinlets is 3½ inches. The Shaft vein has not been extensively worked.

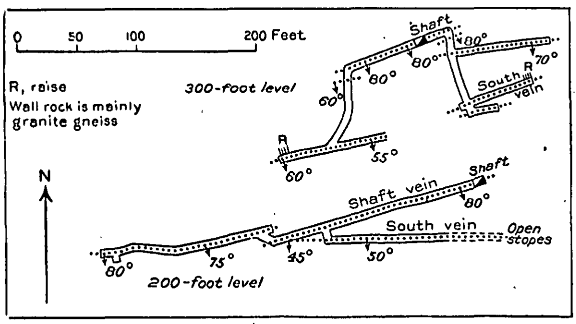


FIGURE 37.—Plan of 200-foot and 300-foot levels of Egyptian mine. Surveyed by hand compass and pacing.

Between it and the South vein occur a number of unimportant branch veins.

The South vein, which has yielded the bulk of the mine's production, is well exposed in a stope nearly 100 feet above the east end of the 300-foot level, where at one point it has a width of about 5 feet, the ore filling a brecciated zone. One vein of solid sulphides is 15 inches wide and incloses in places angular fragments of the wall rock. The primary ore minerals are galena, sphalerite, and chalcopyrite. In the more open portions of the vein some chalcocite, developed from chalcopyrite, by downward sulphide enrichment, occurs as thin films along fractures in the chalcopyrite.

Postmineral movement along the South vein has in places crushed the ore and neighboring wall rock, producing a breccia of angular ore fragments in a groundmass of crushed and recemented granite gneiss.

Sampling-works assays of 18 lots of smelting ore aggregating 63 tons, shipped between 1899 and 1909, inclusive, show gold, 0.28 to 5.77 (average 2.98) ounces; silver, 2.7 to 22.3 (average 12.33) ounces; copper, 9.5 per cent or less. Similar assays for 154 tons of smelting ore shipped during 1910 show gold, 0.64 to 5.48 (average 2.4) ounces; silver, 2 to 23.5 (average 17.35) ounces; copper, 4.65 per cent or less.

ILLINOIS MINE.

The Illinois mine, one of the oldest mines of the region, is about a mile southwest of Central City near the crest of Quartz Hill. The property, formerly known as the North Star, was discovered in May or June, 1859, and its surface-oxidized portions yielded large returns in gold to placer mining. Its appearance in 1870 is described in a report by Hague.[1]

> The vein appears to have a course of N. 60° E., true, though its average course for a longer distance than that observed is said to be more to the eastward, and thus more nearly parallel with the other neighboring lodes farther south, that trend north 85° E. Its dip is 84° S., and so far as sunk upon is very regular. The average width is about 2 feet, frequently expanding or contracting to greater or less dimensions. Its walls are generally smooth and well defined, sometimes polished, grooved, or striated, showing indications of movement. Usually there is a soft "gouge," or seam of clay, between the walls and the filling of the vein. The latter is chiefly quartz; sometimes white, hard, and amorphous, carrying little or no valuable mineral; sometimes showing a sparse distribution of crystallized iron pyrites throughout its mass; but most commonly the vein matter is a mixture of siliceous and feldspathic material, in which occur small seams or scattered particles of pyrites, making a very fair quality of stamp rock, and as in the other veins already described associated usually with a narrower but solid seam of compact pyritous ore. The latter is from 2 or 3 to 10 or 12 inches thick, and furnishes a small proportion of smelting ore. This proportion appears, from all available data, to be between one-twentieth and one-tenth of the whole number of tons produced. The valuable mineral in the vein consists chiefly of iron pyrites with a lesser proportion of copper pyrites and as a characteristic feature some arsenical pyrites; with these are associated some zinc blende and galena. The yield of this ore in silver is shown by the assays of Prof. Hill to be larger than is usual in the pyritous ore veins of the district, the average of 42 tons sold by the mine at the smelting works during the summer of 1868 being about 4 ounces of fine gold and 20 ounces of fine silver to the ton. The yield of stamp rock during a run of 34 weeks in the summer of 1868, when 200 cords, or 1,500 tons, were supposed to have been treated, was 1,538 ounces of crude bullion, or about 1 ounce per ton. The average value of the ounce of this bullion is stated at $15.50, coin.

[1] Hague, J. D., U. S. Geol. Expl. 40th Par. Rept., vol. 3, pp. 524-525, 1870.

At present the shaft is 635 feet deep with levels about every 100 feet. Most of the ore above the 300-foot level has been stoped. For the past 20 years the property has been worked only on a small scale by lessees. It was idle at the time of this survey and could not be entered. The maps indicate that the workings develop two and possibly three veins. Ore seen on the dump showed only pyrite and chalcopyrite. A pyritic vein supposed to be the Illinois is cut by the Argo tunnel 18,088 feet from the portal and has been drifted on for 30 feet east and 50 feet west.

The following are a few sampling-works assays of smelting ore:

Sampling-works assays of smelting ore from the Illinois mine.

Year.	Ore.	Gold.	Silver.	Copper.
	Pounds.	*Ounces.*	*Ounces.*	*Per cent.*
1893	8,390	2.10	6.70	....
1893	2,305	1.58	5.50	2.90
1897	2,827	2.12	8.10	3.90
1903	4,743	1.50	6.50	3.60
1908	2,450	.68	4.80	....

The total gross production is said to be about $350,000.

GAUNTLET MINE.

The Gauntlet mine is about three-fourths of a mile southwest of Central City near the head of Spring Gulch. The development consists of two 500-foot shafts about 300 feet apart, connecting with about 3,000 feet of drifts. None of the workings were accessible at the time of this survey. Ore seen on the dumps was of the pyritic type with some tennantite, but assays show that considerable galena was locally present. The average value is said to be about $10 per ton.

The following are sampling-works assays of a few lots of smelting ore:

Sampling-works assays of smelting ore from the Gauntlet mine.

Year.	Ore.	Gold.	Silver.	Copper.	Lead.
	Net lbs.	*Ounces.*	*Ounces.*	*Per cent.*	*Per cent.*
1889	1,644	1.40	8.80	....	20.50
1894	3,778	1.40	8.00	4.70	....
1895	2,512	1.54	8.40	....	11.00
1895	6,742	3.02	12.80	5.35	48.00
1906	1,414	2.00	2.20	12.00	....
1906	843	1.10	6.50	3.00	....
1906	1,463	2.53	21.70	10.00	....

GERMAN AND BELCHER MINES.

The German and Belcher mines are on the summit of Quartz Hill about 1¼ miles southwest of Central City. The underground workings of the two mines are connected at the first and second levels and being under one ownership are worked as one mine. The German shaft is 600 feet deep, with an average dip of 80° S., and with levels at 130, 250, 400, and 500 feet. Stoping has been confined principally to ground above the 130-foot level. Development work on the uranium ores was in progress at the time of this survey. The writer is indebted to Mr. James Force, consulting engineer in charge at the time of this survey, for information as to the ore values and for personal guidance in the study of the mine.

The vein as exposed in most parts of the mine strikes about N. 75° E. and dips 75°–80° S. That mineralization is not confined to this zone is shown, however, by the occurrence on the 130-foot level, 15 to 20 feet west of the shaft, of a 6-inch band of pyritized and silicified schist that strikes N. 35° E. and dips about 15° NW. This is said by Mr. Force to assay 0.39 per cent of uranium oxide.

The wall rocks of the vein are mainly schists of the Idaho Springs formation and associated pegmatite. Exceptionally, as on the 400-foot level west, there is a small amount of granite gneiss. At the face of the 500-foot level west a 3 to 6 inch dike of bostonite porphyry comes into the drift from the hanging wall and is sharply cut off by the vein, which is clearly later than the dike. A larger bostonite porphyry dike is exposed on the 500-foot level about 97 feet west of the shaft and is also cut off sharply by the vein; it is followed by a crosscut. (See p. 241.)

In general the mineralization in the German mine is of the composite type modified by the deposition of uraninite. In places, as on the 300-foot level west, the vein is a typical fissure filling; but in most parts of the vein metasomatic replacement proceeding outward from small fractures has been equally as important a mineralizing process. Two exposures may be described to show the commoner characteristics of the vein.

In the stope 65 feet east of the shaft on the 130-foot level the vein forks upward like the letter Y, one branch following each wall. The footwall branch is only 2 inches wide; the hanging-wall branch is 10 inches wide and consists of altered wall rock silicified and heavily impregnated with pyrite and to a less degree with sphalerite. Sphalerite, chalcopyrite, and pyrite, with some galena, form narrow veinlets near the hanging wall and irregular lenses or bunches elsewhere in the disseminated ore. Both the disseminated or replacement ore and the sulphide veinlets are traversed by partly open fracture seams a fraction of an inch wide, lined with crusts one-sixteenth to one-fourth inch thick, of which the inner or under part is commonly rosin sphalerite finely banded parallel to the walls and the outer part finely crystalline pyrite commonly showing botryoidal surfaces and in cross section a radiate structure. The free surface of the pyrite is a mass of minute crystals.

No pitchblende was seen by the writer in place on this level, but one sample across the entire vein in the stope 130 feet east of the shaft is said by Mr. Force to have assayed 0.39 per cent uranium oxide, and a second sample across 3.3 feet of vein material assayed 0.5 per cent uranium oxide, 0.02 ounce in gold, and 0.2 ounce in silver.

At the face of the 250-foot level, 124 feet west of the shaft, the vein dips 75° S. between walls of pegmatite. Next the south or hanging wall is a 1 to 1¼ inch band of dark-gray highly siliceous material, probably altered pegmatite, highly impregnated with pyrite, usually in small cubes, and carrying a little sphalerite. Below this is 10 inches of pegmatite less heavily impregnated with pyrite; succeeded by a 1½-inch vein of solid pyrite and sphalerite. Where pyrite impregnates the pegmatite it is usually in well-formed crystals lying in a matrix of quartz and altered feldspar. Where sphalerite is also present in such ore it partly or completely replaces this matrix and was apparently introduced later than the pyrite. On the 300-foot level west the vein is a more typical fissure filling, and galena and sphalerite are the principal sulphides. An assay of a band of ore from the south wall gave, according to Mr. Force, gold, 2.12 ounces; silver, 10.9 ounces; and uranium oxide, 0.015 per cent.

On the 500-foot level 97 feet west of the shaft a crosscut extends N. 35° W. for 102 feet. It follows a fracture zone along the west side of a dike of bostonite porphyry and cuts several small unimportant veinlets and the Bushwacker vein, a small vein which in places shows only pyrite but elsewhere carries also galena and sphalerite. Where cut, at about 26 feet from the main drift, the Bushwacker strikes N. 80° E. and dips 65° N.

Only low-grade uranium ore, in which the pitchblende could not readily be identified, was exposed in the workings at the time of this survey. Such ore consists of schist or pegmatite altered and highly impregnated with pyrite, with lesser amounts of sphalerite, and with still smaller amounts of pitchblende, giving it a content commonly of from 0.25 to 0.5 per cent of uranium oxide. It forms an intimate part of the sulphide vein and would form the concentrating ore of the mine. A specimen of such ore from the 130-foot level west, said to assay about 0.39 per cent uranium oxide, was altered schist of the Idaho Springs formation, highly impregnated with pyrite (in many places in well-formed crystals) and with some sphalerite. The foliated structure was still preserved in places. Microscopic study showed that the rock had suffered practically complete recrystallization, the principal changes being the extensive development of pyrite, the alteration of biotite to chlorite, and the replacement of feldspar by sericite and chlorite.

To judge from the statements of those familiar with the mine and by analogy with neighboring veins bearing uranium, the high-grade pitchblende ore occurs as irregular masses in the low-grade disseminated ore just described. The largest piece known to have been found in the mine came from the 130-foot level west, weighed 240 pounds, and was 88 per cent uranium oxide. According to Rickard[1] "the more solid pitchblende, either in lens form or in a well-defined streak, seldom exceeds 3 to 4 inches in width."

A specimen of the rich pitchblende ore of this mine presented to the Geological Survey by Mr. Hugh C. Brown is particularly instructive. It consists principally of pitchblende, but this mineral is sharply cut by veinlets one-eighth inch or less in width composed of sphalerite, pyrite, and some galena. An enlarged view of some of the smaller veinlets as seen under the reflecting microscope is shown in figure 13 (p. 124). Similar relations in another specimen are shown in Plate XIV, *B*.

[1] Rickard, Forbes, Pitchblende from Quartz Hill, Gilpin County, Colo.: Min. and Sci. Press, vol. 106, p. 854, 1913.

Another specimen of rich ore from the 130-foot level west, presented by Mr. Force, shows under the reflecting microscope pitchblende in botryoidal forms, fractured and traversed by minute later veinlets that are predominantly pyrite, chalcopyrite, and dark-gray quartz, but that contain also some galena and sphalerite. In the more shattered portions fragments of pitchblende lie in a matrix of these sulphides.

A specimen presented by Mr. W. C. Denison of Central City shows portions of a vein at least 2 inches wide consisting of a granular aggregate of pyrite and gray quartz inclosing broken fragments of pitchblende which locally form as much as 25 per cent of the material. Neither the pyrite nor the quartz is shattered, but the pitchblende fragments have clearly been broken from larger botryoidal or globular masses, for some of them show very ragged fractured faces.

A specimen from the German mine in the mineral collection at the State capitol in Denver shows pitchblende and chalcopyrite so intimately intergrown as to leave little doubt of their contemporaneity.

All these relations indicate that after pitchblende (sometimes accompanied by pyrite) was deposited the vein was fractured and later galena, sphalerite, chalcopyrite, and pyrite were introduced.

In regard to the content of the ore in uranium and other metals Rickard [1] says:

Where the vein reaches its maximum width, the proportion of uraninite is inversely small, though for the whole width (apart from the high-grade bunches) the vein carries sufficient pitchblende to constitute a grade of ore for concentration; from 2½ to 4 per cent U_3O_8. Concentration tests now in progress are proving satisfactory and give encouragement for the erection of a reduction plant on the mine premises.

Outside of the general policy of development adopted by the management, a small amount of pitchblende ore is being mined. By crude hand sorting within the shaft house, there is now being produced, in small but increasing quantity, a selected grade of pitchblende carrying 15 to 60 per cent uranium oxide (U_3O_8). An average of approximately 30 per cent U_3O_8 is established and can probably be maintained in quantity of several tons per annum. The bulk of ore suitable for mill treatment accumulates in the proportion of something like 40 tons to 1 ton of "selected pitchblende."

According to Mr. Force various classes of concentrates obtained in milling tests on the lower grades of ore from the mine assayed as follows:

[1] Rickard, Forbes, op. cit., p. 854.

Assays of concentrates of ores from German and Belcher mines.

	Weight.	Gold.	Silver.	Copper.	Uranium oxide.
	Pounds.	*Ounces.*	*Ounces.*	*Per cent.*	*Per cent.*
Slime concentrate..	140	21.75	12.40	0.61	18.79
Jig concentrate......	300	6.49	6.00	1.17	2.34
Slime tailings.......	160	.43	4.30	1.58	2.20

Assay of coarse concentrates from German and Belcher mines.

Gold	ounces..	1.50
Silver	do....	3.71
Copper	per cent..	1.42
Lead	do....	.65
Silica	do....	10.60
Iron	do....	36.69
Sulphur	do....	41.05
Uranium oxide	do....	3.22

Assays of uranium ores from German and Belcher mines.

	Gold.	Silver.	Zinc.	Uranium oxide.
130-foot level:	*Ounces.*	*Ounces.*	*Per ct.*	*Per ct.*
90 feet east of shaft...........	None.	None.	....	1.47
10 feet east of shaft...........	0.12	0.60	....	1.38
500-foot level........	1.20	21.80	12.95	1.10

Sampling-works assays of smelting ore shipped in 1909 are given below. This ore was sold solely for its precious-metal content, the uranium content not being determined.

Sampling-works assays of smelting ores from German and Belcher mines, 1909.

Ore.	Gold.	Silver.	Copper.	Lead.
Net tons.	*Ounces.*	*Ounces.*	*Per cent.*	*Per cent.*
3.122	2.09	7.44	....	....
1.596	2.86	9.60	....	....
1.305	.46	6.90	....	9.70
3.337	.31	4.00	....	....
1.286	3.40	9.00	0.50	....
2.413	5.99	13.64	.95	....
3.580	2.00	12.00	1.80	....
6.205	1.30	2.30	....	....
.907	4.00	21.60	1.90	....
1.443	3.46	11.30	1.50	....
3.270	.76	2.00	....	....

According to a recent report by the Bureau of Mines: [1]

The total production of pitchblende ore from the two mines from the fall of 1911 to January 1, 1913, has been 240

[1] Moore, R. B., and Kithil, K. L., A preliminary report on uranium, radium, and vanadium: Bur. Mines Bull. 70, p. 45, 1913.

pounds of high-grade ore containing more than 70 per cent U_3O_8, 220 pounds of ore containing 20 per cent U_3O_8, 5 tons of ore carrying 2.6 per cent U_3O_8, and 1 ton of ore carrying 2 per cent U_3O_8.

MITCHELL MINE.

The Mitchell mine is in the southeast side of Quartz Hill about a mile southwest of Central City. The vein, which appears to strike nearly east and west, is developed by a shaft said to be 500 feet deep. Ore seen in the bins consisted of pyrite and chalcopyrite in granite gneiss wall rock. Some pitchblende ore is said to have been found in the western part of the vein.

SCANDIA MINE.

The Scandia mine is on the east slope of Quartz Hill a little over a mile southwest of Central City. The development consists of a shaft and a tunnel, neither of which could be entered at the time of survey. The only ore seen on the dump consisted of pyrite in a quartz gangue. The mine has been idle for many years.

BARNES MINE.

The Barnes mine is at the east end of Quartz Hill near the main road from Central City to

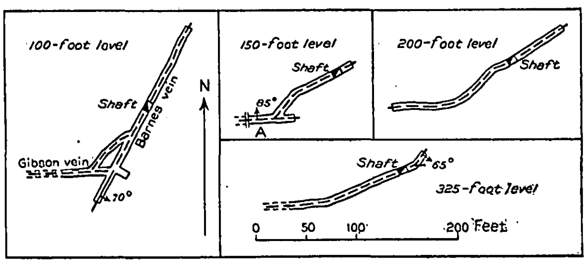


FIGURE 38.—Plan of upper levels of Barnes mine. Surveyed by hand compass and pacing.

Russell Gulch. The development work consists of a shaft with levels at depths of 100, 150, 200, 250, 325, 400, and 500 feet. After a period of idleness the mine was being reopened in 1911, but at the time of this survey the 400 and 500 foot levels, the longest in the mine, were still under water. The wall rock is entirely granite gneiss.

In general the workings down to the 325-foot level may be said to develop an ore shoot formed by the junction of the northeast-trending Barnes vein and an eastward-trending lode. The latter lode, as exposed on the surface, consists of the Gibson and the Stark County veins, nearly parallel in strike but with slightly divergent dip, which unite a short distance below the surface.

The Barnes vein, as exposed on the 100-foot level, is most heavily mineralized near its junction with the Gibson vein and south of this junction is practically barren. The same junction is exposed on the 150-foot level about 75 feet southwest of the shaft. The east-west vein near this junction is 6 inches to 1½ feet in width, is sharp walled, and consists of pyrite and some chalcopyrite; pyrite is also disseminated in the bordering granite gneiss. At A, figure 38, a little farther west, a mass of smelting ore left along the south wall of the vein is 7 inches in width and shows sharp walls. It consists of pyrite and chalcopyrite, the latter in many places covered with a black pulverulent coating, probably chalcocite. Exceptionally some malachite and tennantite are present. Vugs are lined with quartz and very perfect cubes of pyrite. On the 200-foot level the junction between the two veins is not clearly shown. At a point 40 feet east of the shaft on this level the vein is uncommonly wide and consists of 5 feet of granite gneiss cut by a network of sharp-walled veinlets of pyrite and chalcopyrite 2 inches and less in width.

At the time of survey the mine was being placed in shape for further work after a long period of idleness. It was instructive to note that during the shutdown iron rails on the 200-foot level had in places been eaten away and in part replaced by native copper through the action of strong mine waters descending through the vein and collecting in pools on the floor of the drifts. These pools were deep blue-green in color and probably carried copper and iron sulphates in abundance.

In working the upper levels of this mine only the richest ore was saved and much material carrying abundant sulphides was left as stope filling. It is the intention of the present operators to ship much of this filling. Films of pulverulent secondary chalcocite were recognized on fractured chalcopyrite in many of the drifts, and it is evident that chalcocitization has increased somewhat the copper content of the ores.

Sampling-works assays of 14 lots of smelting ore aggregating 108 tons, shipped from this mine between 1893 and 1907, showed gold, 0.27 to 2.68 (average 1.19) ounces; silver, 4 to 17.4 (average 11.81) ounces; copper (wet), 3 to 9.55 per cent; silica, 31 to 52 per cent in 8 lots. The gross production of the mine is not known.

DELMONICO VEIN.

The Delmonico vein crops out near the summit of Alps Hill and is developed by a shaft which is said to be 1,100 feet deep but which was idle and inaccessible at the time of this survey. The ore seen on the dump showed pyrite, sphalerite, galena, and chalcopyrite. A few sampling-works assays of smelting ore follow.

Sampling-works assays of smelting ore from the Delmonico vein.

Year.	Ore.	Gold.	Silver.	Copper.	Zinc.	Silica.
	Net lbs.	*Ounces.*	*Ounces.*	*Per cent.*	*Per cent.*	*Per ct.*
1903..	8,727	4.36	3.10	4.50	....	36
1904..	4,738	4.04	24.40	4.60	....	32
1907..	6,028	5.15	46.55	8.50	11.00	......
1907..	4,236	3.40	48.60	10.00	....	......

ALPS MINE.

The Alps mine, on the summit of Quartz Hill on what appears to be the eastward continuation of the Delmonico vein, was inaccessible at the time of this survey. Although only ore of the galena-sphalerite typewas seen on the dump it is said that the ore of the deeper levels was mainly of pyritic type. The principal development is said to have followed not the Alps vein but a vein with more northerly dip developed by a winze 520 feet deep on the 800-foot level, 360 feet west of the shaft. Some uraninite is reported to have been found in this mine, but no important amounts of that mineral have been shipped.

Sampling-works assays of 43 lots of smelting ore aggregating 148½ tons, shipped from the Alps mine between 1888 and 1909, show gold, 1.92 to 11.45 (average 4.79) ounces; silver, 2.3 to 38.33 (average 23.07) ounces; copper from less than 1.5 to 9.6 per cent. The average value of 77 tons of smelting ore shipped in 1909 was gold 4.53 ounces, and silver 17.28 ounces.

KIRK VEIN.

The Kirk vein is on the south side of Quartz Hill. Access could not be had to the underground workings, but the dumps and surface exposures were examined. The ore on the dump consisted dominantly of pyrite, chalcopyrite, and tetrahedrite, but a few specimens carried a little galena. Uranium minerals have been mined, but none of the ore was seen by the writer. The following account of the occurrence and production of the uranium ores is taken from a recent report of the Bureau of Mines:[1]

> The original workings of the Kirk mine are about 100 feet deep. The majority of these have been filled up. In this manner the larger part of the 500 feet of the lode to the east of the shaft has been worked out to the above depth, but the 1,000 feet to the west has not been opened except by prospect holes. An old shaft and part of the workings are still open. In this shaft and workings a considerable amount of pitchblende was mined in the early days. The miners did not know at the time what the ore was and it was wasted in an attempted treatment for gold. When the pitchblende was found the gold gave out, and therefore the owner left his shaft and started a new one 185 feet to the west, which is now the main shaft. The next owners knew the value of pitchblende and about 1898 took out several tons of good ore. When further development was unsuccessful the mine was bought by the present owner. The mine is more than 400 feet deep. The vein strikes almost due east and west and dips about 80° S. The shaft follows the vein. The main levels are at 97, 140, 200, 300, and 400 feet.
>
> The Kirk lode is 3 to 6 feet wide, and seems to be a fissure vein in gneiss and mica schist. It carries gold, silver, and copper in addition to pitchblende. The best pitchblende was found between the 140-foot level and the 250-foot level on the east side of the shaft. Ore was also found at other places, notably just above the 400-foot level and in this level. The ore shoot seems to pitch from east to west. Except in one place the ore was everywhere against the country rock on the hanging wall. There were practically no stringers, spurs, or other indications that the vein was near except that the country rock carried some uranium. Much of the ore was exceedingly rich, some assaying 60 to 80 per cent U_3O_8. At places this rich ore was a foot thick; one single piece was removed that measured 2 feet 8 inches by 1 foot 4 inches by 1 foot.
>
> Reliable data on the production of pitchblende from the Kirk mine before the present ownership could not be determined. Since the present owner has had the mine, in round numbers about 20 tons of ore with an average content of 35 per cent U_3O_8 and something over 100 tons of ore with a content of 3 to 4 per cent U_3O_8 have been mined. Most of this ore was produced in 1905–6, and practically all of the high-grade ore was sold abroad.
>
> Therefore, at a time when the Austrian mines were apparently the only producers of uranium ore the Kirk mine was sending pitchblende abroad and supplying a large proportion of the radium that was sold on the open market.
>
> During the last few years the Kirk has not been worked regularly; therefore the production of ore has been small.

Several lots of gold-silver smelting ore shipped from the Kirk mine at various times between 1905 and 1910 gave the following sampling-works assays:

[1] Moore, R. B., and Kithil, K. L., A preliminary report on uranium, radium, and vanadium: Bur. Mines Bull. 70, pp. 43–44, 1913.

Sampling-works assays of smelting ores from Kirk mine, 1905–1910.

Year.	Ore.	Gold.	Silver.	Copper.	Silica.
	Net lbs.	*Ounces.*	*Ounces.*	*Per ct.*	*Per ct.*
1905........	4,520	2.00	3.00	....	46
1905........	5,506	.30	7.70	....	....
1905........	1,970	1.75	16.25	9.00	45
1908........	25,443	1.46	14.45	4.70	33
1908........	9,457	.43	3.09	....	....
1910........	1,724	.86	16.70	.60	....
1910........	4,689	.69	11.29	2.10	....
1910........	1,606	.81	11.19	3.32	....

Concentrating ore shipped in 1910 is said to have averaged gold 0.10 ounce and silver 0.50 ounce.

NORTH MINE.

The North mine is on the east slope of Quartz Hill about a mile southwest of Central City. A shaft now in ruins develops a pyritic vein striking about N. 70° E. and dipping about 85° S. The walls are granite gneiss.

GEM MINE.

The Gem mine, on the south slope of Alps Hill a short distance northwest of Russell Gulch village, appears to be on the eastern continuation of the Gold Dollar vein. It is developed by a shaft which could not be entered, the mine being idle at the time of this survey, but which, according to the maps available, is about 270 feet deep, with short levels at depths of 50, 100, 125, 150, 200, and 250 feet. Ore on the dump was of the galena-sphalerite type. The value of the early output of the mine is not known, but its output since its acquisition by the present company is said to have been about $6,000.

WOOD MINE.

The Wood mine, near the head of Leavenworth Gulch, was idle at the time of this survey and was not entered. The vein, which lies just north of the Calhoun vein and strikes somewhat north of east, is said to range from 6 inches to 2 feet in width. The principal sulphides are pyrite and chalcopyrite with local stringers carrying galena and sphalerite. Two shafts, 90 feet apart on the vein, are connected by levels at depths of 50, 135, 160, and 200 feet.

The mine is noted principally for its pitchblende, having been worked for this mineral as early as 1872. The pitchblende ore is said to occur in bunches and pockets from a few pounds to 5 tons in weight in the sulphide ore. The relations of the pitchblende to sulphides in the ore from this mine have already been described on pages 123–124 and illustrated in figures 11 and 12 and Plate XV, *A* (p. 124).

No record exists of the total production of this mine, although the output of crude uranium ore is said to have been about 150 tons. The gold content in the ore extracted in driving the 200-foot level east is said to have averaged $10 per ton. Exceptionally the gold content is very high, one assay showing 25 ounces. During the last few years about 1 ton of medium-grade pitchblende ore has been mined, mainly from between the 135-foot and 200-foot levels.

JEFFERSON-CALHOUN VEIN.

The Calhoun vein, on the south slope of Quartz Hill about 1¾ to 2 miles southwest of Central City, is developed by several shafts whose position and depth are shown in figure 39, taken from a map obtained through the courtesy of Mr. Percy R. Alsdorf, engineer in charge. None of the shaft workings could be entered at the time of this survey. The wall rock along the apex of the vein is granite gneiss, with a few lenses of hornblende schist which represent metamorphosed portions of the Idaho Springs formation. Considerable bodies of schist were, however, intersected in some of the workings, as described in the following statement from a report by Mr. Alsdorf:

> I note that the West Calhoun ore body, which was profitable, ended with depth when the vein fracture went into the formation known as the Idaho Springs schist. I also note [that] the Kemp ore body west stopped when this same schist was encountered; that no values were found in the Jefferson vein after it went into this same formation. From what I can gather, the East Calhoun shaft encountered this, and all work did not yield any encouragement for a distance of 340 feet, when the granite gneiss was again encountered, and with it the regularity of the vein fracture and, coincident, ore yielding a profit to the operators.
>
> Other adjacent mines have sunk through this formation and have been quite discouraged while in this schist, owing to almost total lack of pay values, but have found much better conditions below in the granite gneiss. My data approximates it from 250 to 350 feet in thickness, so far as proven.

Mr. Alsdorf's observations in regard to the marked falling off in the mineralization where the vein passes into considerable areas of schist of the Idaho Springs formation is in entire accord with the writer's observations in many mines of this district. (See p. 104.) His opinion that stronger mineralization will be found when the vein has been followed through the schist into the gneiss again appears to be well founded.

Ore on the various dumps along this vein belongs principally to the galena-sphalerite type. One specimen from the West Calhoun dump showed gneiss carrying abundant disseminated pyrite, in places wholly replaced by covellite. Such coatings are evidently the result of downward sulphide enrichment and indicate that the copper content has locally been slightly augmented through this process.

A feature of especial interest is the presence of uranium ore in the West Calhoun 387-foot level west. To quote from a report by Mr. Alsdorf:

> This level is driven on a vein whose course is 40° north of the regular course of the Calhoun vein and whose dip is 15° flatter. * * *

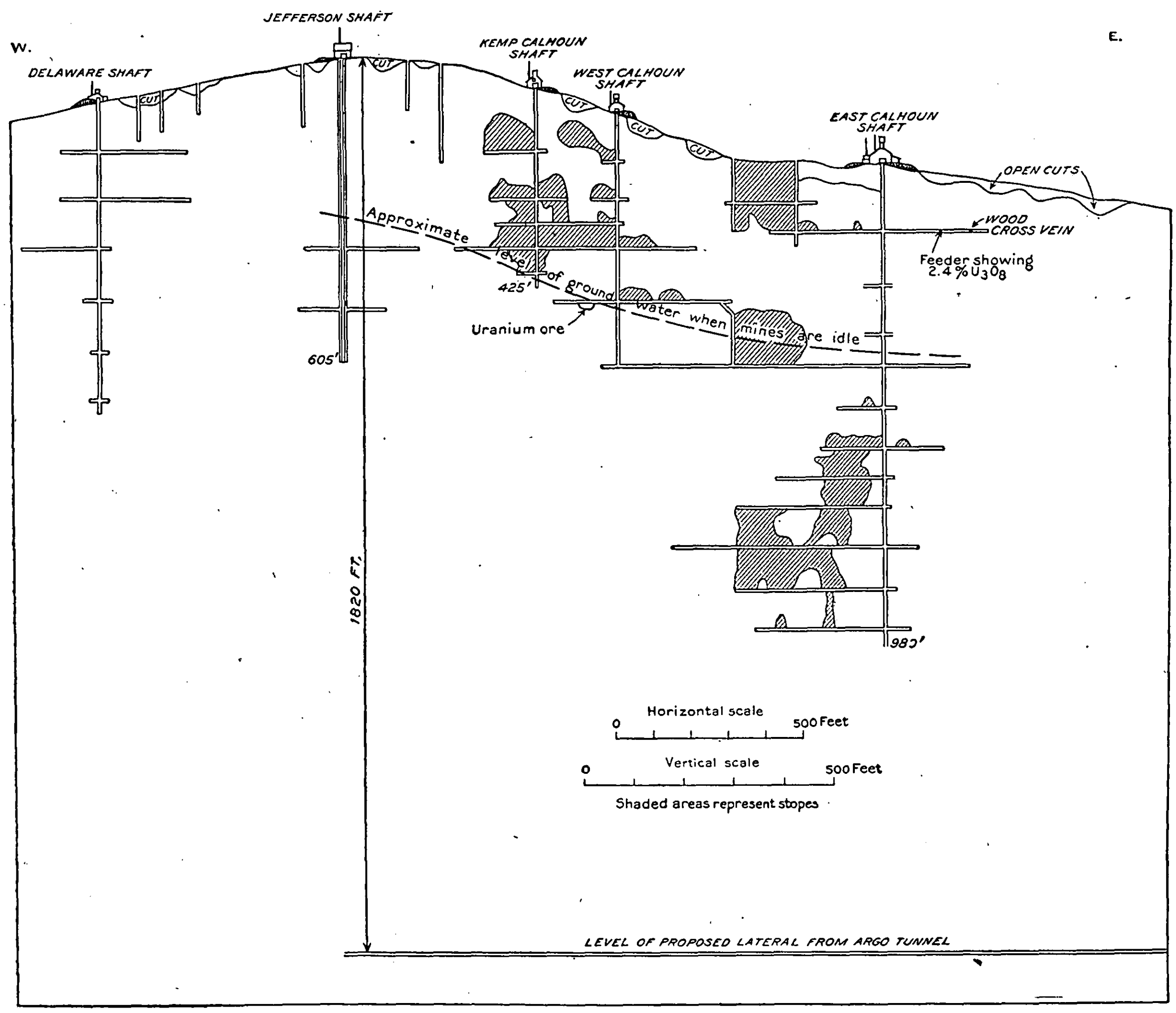


FIGURE 39.—Section showing workings along Jefferson-Calhoun vein. From maps furnished by P. R. Alsdorf.

quartz and pyrite, cut obliquely by a narrow veinlet of dark sphalerite. Another specimen from the same dump shows somewhat porous ore composed of chalcopyrite and sphalerite with subordinate pyrite; the free faces of the chalcopyrite are coated with a black film, probably chalcocite, and the sphalerite is coated with a steel-blue coating resembling

> This vein is followed by the level a distance of 179 feet; the first 35 feet returning negative commercial results, the next 35 feet returned average values of $104 in gold and silver, from 2.4 per cent to 29 per cent uranium oxide, which averaged 6.1 per cent, worth approximately $360 per ton, or a total gross value of $464 per ton, averaging 3.1 inches in width. The next 40 feet gave a gold and silver value of $70 per ton, with small percentages of uranium, while the last 60 feet returned no commercial profit from the ore in sight.

Specimens of the wall rock of the uranium stope forwarded to the Geological Survey are altered Idaho Springs formation carrying disseminated grains of pyrite.

The following assays of the uranium ore were furnished by Mr. Alsdorf:

Assays of uranium ores from Calhoun vein.

Character.	Uranium oxide.	Gold.	Silver.
Vein material:	*Per cent.*	*Ounces.*	*Ounces.*
2 inches wide	28.0	14.20	1.80
4 inches wide	14.4	12.60	1.20
1½ inches wide	10.8	6.40	1.00
Selected piece	46.6		
Mainly sphalerite	3.4	3.40	1.60
Mainly pyrite	1.2	.08	.16

A noteworthy feature is the marked association of high gold content with high uranium content.

A specimen of high-grade pitchblende ore from 45 feet west of the West Calhoun shaft on the 387-foot level, furnished by Mr. Alsdorf, showed similar relations to those described in specimens from the German-Belcher lode, the pitchblende having been brecciated and penetrated by numerous later veinlets composed of pyrite, sphalerite, quartz, and some galena. A specimen from 50 feet west of the shaft on the same level shows altered schist of the Idaho Springs formation traversed across its foliation by a ⅛-inch to $\frac{3}{16}$-inch veinlet of pitchblende. A polished section of this veinlet was studied under the reflecting microscope. It shows that the pitchblende has in places been shattered and that fragments of it lie in a matrix of galena, sphalerite, chalcopyrite, and gray quartz, and that other parts are traversed by veinlets of galena.

During 1912 a small quantity of pitchblende was mined from the West Calhoun workings and sold for about $1,300, mostly for experimental purposes and as specimens. It is said to have averaged about 37.5 per cent uranium oxide.

A lateral started from the Argo tunnel, about 16,506 feet from the portal, on what is supposed to be the Calhoun vein, extends for about 800 feet, of which only the first 350 feet were accessible. If extended it will intersect the Jefferson shaft at a vertical depth of 1,820 feet below the collar. The meager exposures in the lateral are described on page 305.

In periods of idleness the water level in the Calhoun workings stands 300 to 400 feet below the surface. Thus, on December 20, 1912, the water level in the East Calhoun shaft stood, according to Alsdorf, 380 feet below the collar.

Data are not at hand for determining the average value of the ore in the Calhoun vein, but the following selected sampling-works assays give some idea of the metallic content of smelting ore from the Jefferson portion of the vein:

Sampling-works assays of smelting ore from Jefferson vein.

Year.	Ore.	Gold.	Silver.	Copper.	Lead.
	Net lbs.	*Ounces.*	*Ounces.*	*Per ct.*	*Per ct.*
1889	2,911	1.15	22.90		
1889	1,911	1.50	4.20		
1889	2,653	3.10	22.00	3.50	
1894	2,700	2.12	15.00		27.70
1894	1,220	3.00	12.00	2.50	
1908	14,096	.97	6.10		
1908	15,928	2.98	25.25	6.00	
1909	19,464	2.21	23.55	8.10	
1909	14,918	.60	3.80		
1910	4,472	3.72	36.34	15.40	
1910	6,008	3.33	42.85	14.05	
1910	14,174	.63	5.10	.50	
1910	16,922	1.04	6.24	.10	

High copper content (as chalcopyrite) is almost invariably accompanied by high content in both gold and silver.

The average precious metal content of 54 tons of smelting ore shipped in 1910 was gold 1.07 ounces and silver 10.10 ounces.

PROMPT PAY MINE.

The Prompt Pay shaft is about one-fourth mile northwest of the village of Russell Gulch on a short northeast-southwest vein just south of the Jefferson-Calhoun vein. It is developed by a shaft 175 feet deep connecting with four short levels. The mine had been idle since 1905, and the workings could not be entered. Ore on the dump was predominantly pyritic but carried a little sphalerite and galena. Very few data are available in regard to the metal content of the ores. The following are sampling-works assays of a few shipments of smelting ore:

Sampling-works assays of smelting ore from Prompt Pay mine.

Year.	Ore.	Gold.	Silver.	Copper.	Lead.
	Net lbs.	*Ounces.*	*Ounces.*	*Per cent.*	*Per cent.*
1895	1,812	10.80	36.00		18.20
1895	2,069	5.14	16.00	2.50	16.00
1895	2,293	5.79	26.80		18.00
1899	6,797	.32	3.00		

The total production of the mine is said to have been about $30,000.

BEZANT OR QUARTZ MILL MINE.

The Bezant or Quartz Mill mine is on the south side of Leavenworth Gulch, a short distance west of the Russell Gulch and Central City wagon road. The development consists of a shaft 485 feet deep with levels at depths of 75, 165, 250, and 420 feet. The mine was opened in 1864 and was taken over by the present company in 1908. It was closed at the time of this survey, and there were no surface exposures of the vein. Vein material on the dump showed galena, sphalerite, chalcopyrite, and pyrite.

HARSH VEIN.

The Harsh vein shaft is in Leavenworth Gulch about 50 feet west and 100 feet north of the Central City and Russell Gulch road culvert. In the underground workings only granite gneiss is exposed. The shaft is 80 feet deep with drifts 50 feet west and 10 feet east at the bottom.

The vein ranges from 4 to 6 feet in width, strikes N. 61° E., and is nearly vertical. The ore is crushed silicified granite gneiss carrying abundant rather coarse grained disseminated pyrite. Some 4-inch stringers of nearly pure pyrite are seen cutting the disseminated ore. Very rarely small crystals of dark sphalerite and galena are seen.

A crushed zone 1 to 1½ feet wide, formed near the center of the vein by postmineral movement, is filled with angular fragments of ore cemented by a grayish siliceous matrix, which appears to consist of finely ground granite gneiss highly silicified and commonly quite barren although in places containing a very little fine pyrite. Slickensides in the gouge at one place on the south wall of the vein show a horizontal movement along that wall.

The shaft has been opened only recently and little stoping has been done. A shipment of 3 tons of smelting ore in 1910 averaged 0.48 ounce gold and 2.1 ounces silver a ton, which is probably about the average grade of ore. During the same year a small shipment of smelting ore carried 2 per cent copper beside the common gold and silver values.

TOPEKA MINE.

The Topeka mine is about one-fourth of a mile north of the village of Russell Gulch. The development consists of the Topeka inclined shaft connecting with 15 levels and the West Topeka shaft reaching only to the seventh level and used only for ventilation. Levels above the seventh were not accessible for study. Most of the workings are in a single strong vein of the galena-sphalerite type, striking about N. 50° E. and dipping 35°–60° NW. (average about 40°). The vein, which varies from a few inches to 7 feet in width, in places shows only small amounts of disseminated pyrite and elsewhere shows 15 inches of solid sulphides, bordered by several feet of disseminated ore. The wall rock is mostly granite gneiss but in a few places is hornblende schist, a phase of the Idaho Springs formation; the twelfth level is almost entirely in hornblende schist. Some pegmatite is associated with the schist. The mineral character of the vein does not seem to be closely dependent upon the nature of the wall rock. The hornblende schist, unlike the commoner and less rigid phases of the Idaho Springs formation, shows no tendency to dissipate the vein fracturing along a number of minor slips, but carries the fracture as firmly as the granite gneiss does.

At a particularly good exposure of one of the wide portions of the vein 20 feet east of the shaft on the thirteenth level two veins of solid sulphides, 12 inches and 14 inches wide, traverse a zone of altered biotite-hornblende schist 5 feet wide. The veins consist of about 50 to 75 per cent pyrite and 25 to 50 per cent sphalerite, irregularly intercrystallized. The altered schist between and on either side of the solid sulphide veins carries disseminated pyrite and is traversed by small scattered pyrite or pyrite-sphalerite veinlets commonly less than one-fourth inch across. Slip planes occur along the hanging wall and the footwall.

In most places the ore minerals are irregularly mingled but at some points the sphalerite, or sphalerite and calcite, tend to occupy the center of the sulphide veinlets, with pyrite next the walls.

Vugs are small and rather uncommon. The largest observed was 5 inches across, parallel to the vein. Most of them are lined with crystals of quartz, pyrite, and sphalerite; but one on the fourteenth level was lined with calcite. A specimen from the dump showed an aggregate of small pyrite and some sphalerite crystals coated with a layer of sphalerite crystals one-half inch and less in diameter, showing well-developed crystal faces. These in turn were coated with a $\frac{1}{16}$-inch to $\frac{1}{8}$-inch crust of siderite carrying minute intergrown crystals of galena and sphalerite.

In general the relations that have been described, though not implying more than one general period of vein formation, indicate that the character of the solutions changed somewhat during that period, pyrite depositing most abundantly at the beginning and sphalerite and carbonates depositing in proportionately greater abundance later. The presence of resin sphalerite as a late crystallization in a few places is perhaps another indication of a decrease in the iron content of the ore-forming solutions as deposition progressed.

Although the greater part of the mine workings are in the Topeka vein, the richest ore of the mine has come from another vein, known as the Klondike. This vein, which has in places proved fabulously rich in free gold, joins the Topeka on the seventh level about 380 feet west of the shaft. (See fig. 40.) It is also exposed in a drift reached by a crosscut from the eighth level and in extensive stopes between these two levels. It strikes on an average about N. 35° E. and dips 25°–40° NW. As exposed on the seventh level the Klondike vein is only feebly mineralized and nowhere exceeds 4 inches in width. In the stopes between the seventh and eighth levels, however, it was commonly 6 inches to 2 feet wide, and near its junction with the Topeka vein expanded to a width of 10 to 15 feet and carried rich ore. The bonanza ore had all been worked out at the time of this survey, but except for the absence of free gold some of the ore now in place resembles rather closely that extracted from the richer portions of the stope. Some portions of the Klondike vein are entirely similar to the Topeka vein in appearance. The same minerals characterize both veins but commonly in somewhat different proportions, white quartz and calcite being prominent constituents in many portions of the Klondike vein and being less conspicuous in most parts of the Topeka vein. One exposure showed a lens of white quartz 1 foot across, carrying pyrite and sphalerite scattered sparsely and irregularly through it. In one place the vein consists of a number of subparallel bands of white quartz, carrying pyrite, separated by barren fracture seams. The pyrite becomes copper stained on weathering, and is probably cupriferous. The wider portions of the vein are granite gneiss impregnated with pyrite and sphalerite and traversed by those sulphides in somewhat indefinitely bounded veinlets $2\frac{1}{2}$ inches and less across.

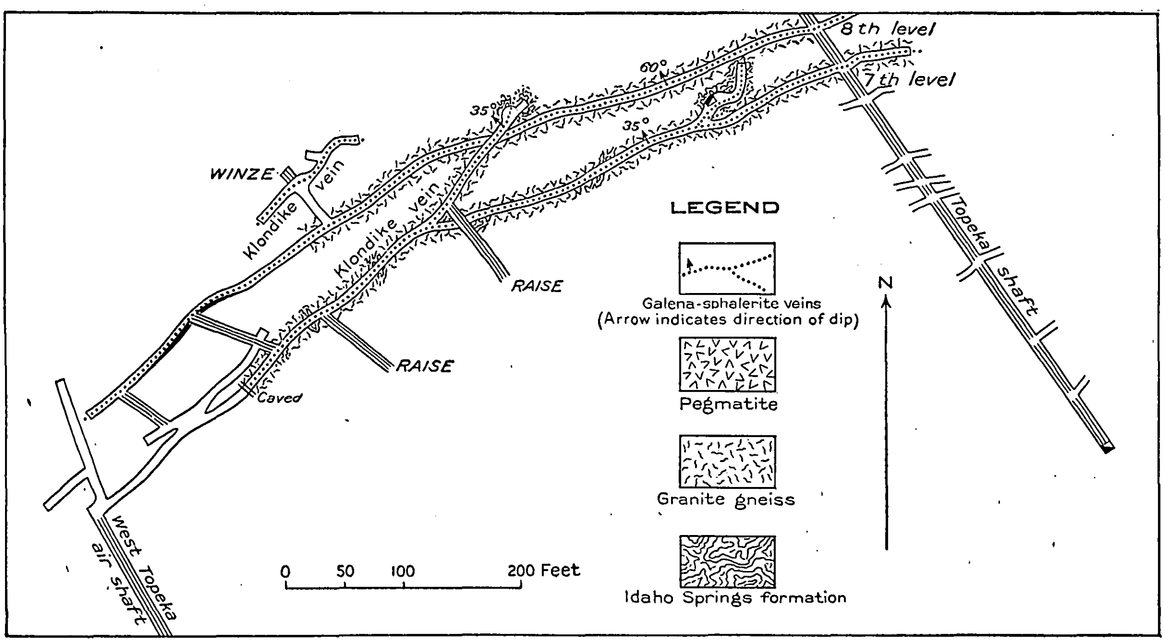


FIGURE 40.—Geologic plan of portions of the seventh and eighth levels of the Topeka mine.

The bonanza ore of the Klondike vein was found mainly between the seventh and eighth levels. A raise above the seventh level and a winze below the eighth both failed to disclose a continuation of the rich ores. The writers' examination, furthermore, yielded no criteria by which the occurrence of other bodies of similar bonanza ore could be predicted. It is reasonably certain, however, that the Klondike vein does not cross the Topeka vein, but is rather a branch from the Topeka mineralized with the same vein minerals and probably during the same mineral-forming period. That it is actually a branch of the Topeka is indicated not only by its position and its general mineralogic similarity to the latter, but also by the presence of uncommon amounts of white quartz in the Topeka vein for some distance west of its junction with the Klondike. A possible explanation for the peculiar richness of the Klondike vein has been suggested on page 110.

The predominant metallic minerals of the Topeka vein are pyrite and sphalerite, with chalcopyrite and galena subordinate. Quartz and altered wall rock and exceptionally calcite are the principal gangues. The vein therefore belongs to the galena-sphalerite type but is characterized by an uncommon preponderance of sphalerite. Most of the sphalerite is dark-colored, but the resin variety was observed at a few places; thus on the seventh level 100 feet west of the shaft a coarse-grained association of resin sphalerite, pyrite, chalcopyrite, and slightly-ferruginous calcite appears to have been the last-formed part of the vein. Small amounts of native bismuth are reported from the fourteenth level.

The sulphides of the Klondike vein, like those of the Topeka, carry important amounts of the precious metals, but the bonanza character of the stopes was due to free gold. This occurred in some places in the white quartz, but elsewhere was intimately associated with sphalerite, chalcopyrite, galena, and pyrite in an irregular manner that showed beyond question that it was a primary constituent that crystallized simultaneously with these sulphides. Microscopic examination of polished pieces of rich gold-bearing quartz courteously donated by Mr. Henry P. Lowe showed that the gold bore no relation to fracture planes in the quartz, but occurred in highly irregular masses which, if their matrix were dissolved, would constitute a veritable sponge of gold. Small amounts of sphalerite and exceptionally a bit of galena are in places intercrystallized with the gold. Like the gold, they are very irregular in form, and they bear the same relation to the quartz that the gold does.

Metasomatic alteration of the granite gneiss bordering the Topeka vein consists in a sericitization of the feldspars and an impregnation of the rock with small grains of pyrite and sphalerite. The sulphides replace feldspar almost exclusively; many of the grains of pyrite show crystal form; the sphalerite grains are commonly smaller and always irregular.

The stope on the Klondike vein, 280 feet long, 44 feet high, and 16 feet in maximum width, yielded about $480,000. A particularly rich piece of ore, which received an award at the Paris Exposition, weighed 88 pounds, and when subsequently melted yielded $5,449. Where this specimen was obtained the vein was 5 to 13 inches in width.

Practically all the present output of the mine is treated at the Penn mill, in Blackhawk, owned by the company owning the mine. This mill is now producing a zinc concentrate which is said to carry about 0.3 to 0.4 ounce in gold, 2 to 4 ounces in silver, and 20 to 30 per cent of zinc.

The total production of the mine is said to have been about $1,850,000.

ROCKFORD MINE.

The Rockford mine is just north of the village of Russell Gulch. The shaft, which is 230 feet deep, and develops a vein of the pyrite type, was idle at the time of this survey. The smelting ore shipped in 1910 carried an average of 1.09 ounces of gold and 4.35 ounces of silver.

UPPER RUSSELL GULCH.

Russell Gulch was the scene of some of the earliest gold discoveries in the district, and was an important placer-mining camp in 1859 and for several years following. Most of the ores belong to the pyritic type and below the oxidized zone are on the whole of comparatively low grade. Some of the veins, however, such as the Old Town, Iron, and Pewabic, are uncommonly strong and persistent, and have yielded large tonnages of ore. A few veins, such as the Belmont and Livingston, are of the galena-sphalerite type.

GOLDEN CLOUD MINE.

The Golden Cloud mine is about one-half mile south of Russell Gulch village, just west of the Idaho Springs road. The shaft dips about 45° N., following the vein. According to the maps it is 670 feet deep on the incline with levels every 100 feet. The ore is entirely of the pyritic type. The two principal stopes are above the 400-foot level and are credited with a production of $25,000 and $14,000 respectively. The mine was first worked in 1860 and the last work was done in 1906.

NASHVILLE MINE.

The Nashville mine is just southeast of the Golden Cloud mine and is owned by the same company. The vein is of the pyritic type and is developed by a shaft 200 feet deep.

LIVINGSTON MINE.

The Livingston mine is developed by a shaft just east of the Idaho Springs road about one-half mile south of Russell Gulch village. The vein, from surface exposures, appears to strike about N. 55° E. and to dip 70° NW. Unlike most of the neighboring veins it is of the galena-sphalerite type.

ROCKY MOUNTAIN TERROR MINE.

The abandoned Rocky Mountain Terror mine, in Russell Gulch just west of the main road to Idaho Springs, is developed by a shaft connecting with six levels. The north-dipping vein strikes slightly north of east.

The ore on the dump was mostly of the pyritic type but is cut in a few specimens by small later veinlets of galena and sphalerite. Slickensides show postmineral movement along the vein.

Sampling-works assays of 8,304 and 5,122 pounds of ore, shipped in 1898, show respectively 1.74 ounces of gold and 8 ounces of silver and 1.9 ounces of gold and 8 ounces of silver.

FEDERAL MINE.

The Federal mine is in Russell Gulch a short distance east of the main road to Idaho Springs. In the older workings above the 300-foot level more than one vein seems to be present, and their relationship to each other is somewhat obscure. The newer workings from the 300-foot level to the lowest or 400-foot level are all on one vein, which strikes nearly east and west and dips 35-65° N. It is exposed in short drifts on the 300 and 400 foot levels and in a winze which extends about 100 feet below the 400-foot level. The wall rock exposed is mainly granite gneiss.

As exposed in these workings the main vein shows from 3 inches to 2 feet of granite gneiss, which carries disseminated sulphides and is traversed in a few places by irregular veinlets, mostly sulphides, whose maximum width is 1½ inches. The great bulk of the vein material, however, is of the disseminated type. The sulphides are pyrite with smaller amounts of chalcopyrite and tennantite. The best ore is that carrying the copper minerals in abundance.

A few sampling-works assays of shipments of smelting ore are given below:

Sampling-works assays of smelting ore from Federal mine.

Year.	Ore.	Gold.	Silver.	Copper.
	Net tons.	*Ounces.*	*Ounces.*	*Per cent.*
1907	1,659	2.88	7.10	....
1907	15,536	.76	4.40	2.40
1907	15,044	.79	6.14	2.65
1910	9,525	.57	3.20	.25
1910	30,437	.80	2.20	.20
1910	7,702	.58	2.71	....

RUSSELL VEIN.

The Russell vein, which crosses the Idaho Springs road just south of Russell Gulch village, is developed by the East and West Russell shafts. None of the workings could be entered. The West shaft is 500 feet deep and connects with five levels. The East shaft is 200 feet deep and at the bottom connects with the Old Town workings. Levels have been driven at 100 and 200 feet depths. The vein, which appears to be nearly vertical, is of the pyritic type.

Smelting ore shipped from the Russell mine in 1910 averaged gold 0.51 ounce, silver 6.23 ounces, and copper 1.41 per cent. Three earlier shipments of smelting ore gave the following sampling-works returns:

Sampling-works assays of smelting ore from Russell vein.

Year.	Ore.	Gold.	Silver.	Copper.
	Net lbs.	*Ounces.*	*Ounces.*	*Per cent.*
1907	1,322	3.22	10.75	7.65
1908	6,182	.56	2.00	....
1909	5,096	.32	3.30	....

OLD TOWN MINE.

The Old Town mine, whose shaft is in the village of Russell Gulch, develops one of the largest and most persistent pyritic lodes of the district. The Old Town or Kimball shaft follows the lode, dipping 35°–50° NW. Some of the earliest development was done through the Wautauga shaft, about 600 feet north of the Old Town shaft, which was sunk on a vein that dips steeply south and joins the Old Town vein at the Wautauga fifth level (Old Town new sixth level). The usual controversy in regard to apex rights began when the juncture was discovered but was settled by a consolidation of interests. The Wautauga shaft is now abandoned. The Old Town shaft is 2,205 feet long on the incline and connects with 21 levels. The lowest or twenty-first level is the Hot Time lateral, 14,306 feet long, which connects with the Argo tunnel and is at present used only for drainage and ventilation, but which, if the mine were operated on a large scale, would presumably be used for electric ore haulage, for which it is already equipped.

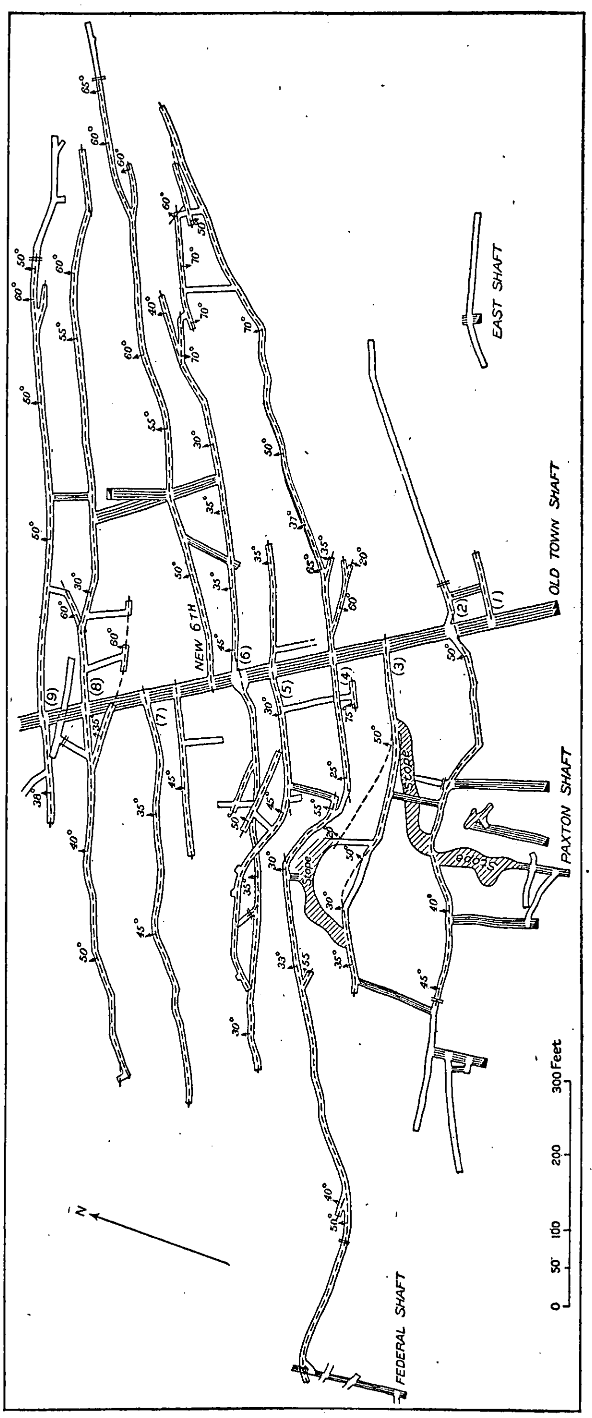


FIGURE 41.—Plan of upper levels of Old Town mine, showing branching vein system.

The wall rock on the first and second levels is schist of the Idaho Springs formation, but below this the shaft workings are almost exclusively in granite gneiss.

The upper levels (see fig. 41) expose a branching vein system whose components show considerable variety in both strike and dip. The eleventh to twentieth levels inclusive are shorter and reveal no forking of the vein.

The mineralization belongs to the pyritic type and in places, as on the fourteenth and fifteenth levels west of the shaft, extends through a width of 6 to 8 feet of granite gneiss. A characteristic exposure on the fourth level about 800 feet west of the shaft shows about 4½ feet of granite gneiss heavily impregnated with pyrite and traversed by numerous pyrite-chalcopyrite veinlets one-fourth inch or less in width and by four or five postmineral slip planes showing gouge and slickensides. On the seventh level about 380 feet west of the shaft similar sulphide veinlets 1½ inches and less in width that traverse the pyrite-impregnated gneiss are almost wholly chalcopyrite.

What appears to be the junction of the Wautauga and Old Town veins is exposed on the new sixth level about 20 feet east of the Wautauga shaft. The Wautauga vein descends with a dip of about 78° S. within 5 or 6 feet of the Old Town vein and then swings into it.

The Hot Time lateral, otherwise the twenty-first level on the Old Town shaft, follows the Old Town vein to about 1,750 feet east of the Old Town shaft and then shifts a short distance north to a nearly parallel vein, said to be the Columbus. This it follows to a point about 2,850 feet east of the Old Town shaft, then shifts south again to the Old Town vein, on which it continues to the Argo tunnel. The prevailing wall rock is granite gneiss, interspersed with a few small patches of schist of the Idaho Springs formation.

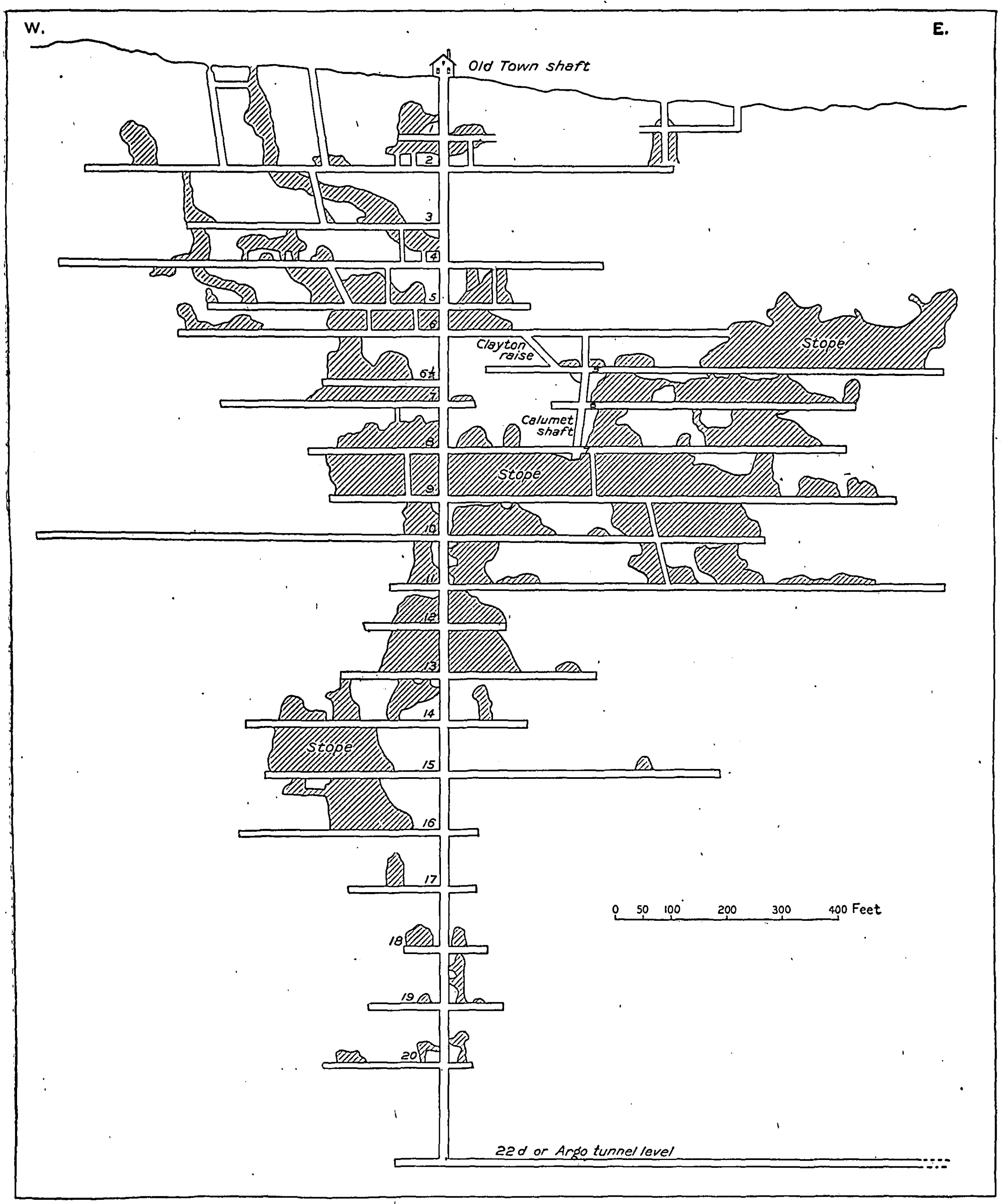


FIGURE 42.—Section in plane of Old Town vein, showing portions that have been stoped.

Mineralization of the Old Town vein on the Hot Time lateral is similar in character to that in the shaft workings but is less pronounced. In an exposure about 70 feet west of the shaft the vein is about 4 feet wide and is not strongly mineralized. The granite gneiss carrying disseminated pyrite is traversed by a network of sulphide stringers, which are commonly not more than one-eighth of an inch wide but which locally swell to 1 inch. The narrower stringers are pyrite with a little chalcopyrite; the wider ones carry also some quartz. In the eastern part of the lateral the veinlets of solid pyrite that traverse the pyrite-impregnated gneiss are sharp walled and are plainly fissure fillings. In one place there is 1 foot of solid pyrite.

The so-called Columbus vein exposed on the Hot Time lateral is also pyritic but is only feebly mineralized. It is a fractured zone from a few inches to 2 feet in width carrying here and there a small stringer of pyrite and a little disseminated pyrite.

All ore is now mined through the shaft and is carried 3 miles to Blackhawk by the Gilpin Tramway. Smelting ore is sold to the sampling works at Blackhawk and concentrating ore shipped via the Colorado & Southern Railway to the Jackson mill at Idaho Springs. It has already been pointed out that the strength of the mineralization decreases in the deeper workings, a fact reflected in decreased value of the ore. An example of the richer portion of the lode is a shoot between the surface and the third level, in which the ore averaged about $59 per ton. A lens between the fifteenth and sixteenth levels averaged $40 per ton, mainly in gold. Chalcopyrite is, as a rule, much richer in gold than pyrite, and the better grades of ore commonly carry about 3 per cent of copper. Sampling of the fourteenth and fifteenth levels by Mr. W. H. Wiley gave an average ore value of $40.58 for one block and $32.01 for another, gold being reckoned at $20 and silver at $0.65 an ounce and copper at $0.18 a pound. The average width sampled was 3.8 feet. In these samples the gold ranged from 0.1 to 6.44 ounces, the silver from 0.3 to 22.1 ounces, and the copper from a trace to 8.8 per cent.

From shaft workings below the fifteenth level 124 samples of ore taken by Mr. Wiley showed gold contents from a trace to 4.22 (average 0.29) ounces and silver from a trace to 5.7 (average 0.78) ounces. The ore of the Old Town vein on the Hot Time lateral is said to average only $0.80 to $1 per ton.

The gross production of the mine is said to have been about $2,700,000.

BECKY SHARP MINE.

The Becky Sharp mine is a short distance southeast of Russell Gulch village, apparently on the westward extension of the Pewabic vein. The development consists of three shafts 120, 135, and 160 feet deep, with connecting drifts. All of the ore is of the pyritic type and of concentrating grade and is sent to the Jackson mill at Idaho Springs, where a concentration of about $3\frac{1}{2}$ into 1 is effected. The value is said to be $8 to $10 per ton.

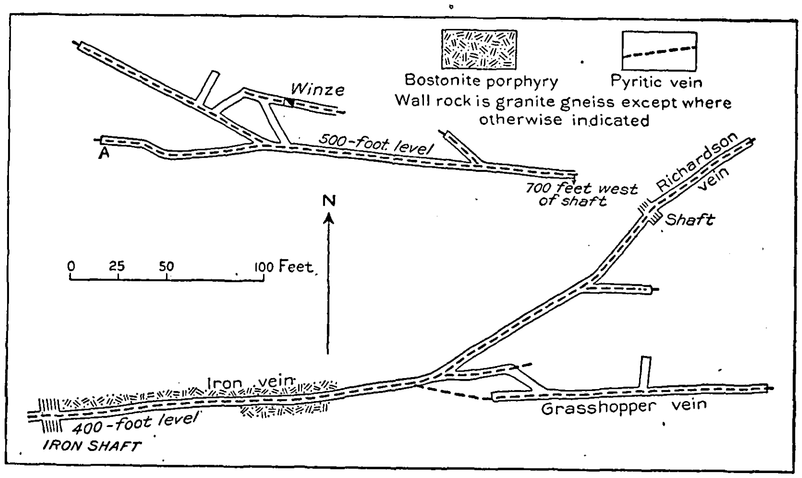


FIGURE 43.—Plans of portions of the 400-foot and 500-foot levels of the Iron mine, showing characteristic branching vein systems.

IRON MINE.

The Iron mine, on the south side of Russell Gulch near the town of that name, is mainly developed through an inclined shaft following the vein, with levels at 120, 250, 300, 400, 500, 600, and 700 feet. The wall rock is granite gneiss except for a small amount of bostonite porphyry. The workings, which are very extensive, are mainly on the Iron vein, whose average strike is nearly east and west and whose dip ranges from vertical to 75° S. On the 300 and 400 foot levels east the junction of the Iron vein with the Richardson and Grasshopper veins is exposed. (See fig. 43.) The 300, 400, and 500 foot levels were examined so far as they were accessible.

The commonest type of mineralization in the Iron vein is a dissemination of pyrite through the altered granite gneiss of a zone of fracturing. This zone may vary in width from a few inches to several feet, the stopes near the shaft on the

400-foot level being 12 feet in width. In a few places this disseminated ore is traversed by a net of minute pyrite stringers and more rarely by several inches of nearly solid pyrite. On the 400-foot level east the vein enters a dike of bostonite porphyry and divides into numerous small stringers, some of which are very vuggy. The mineralization is clearly later than this dike, but in the dike the ore is said to assay only $3 to $4 a ton.

At the time of this survey the mine was being worked by several sets of lessees. Little work was in progress on the Iron vein, the main activity being on branch or subsidiary veins exposed on the 500-foot level more than 800 feet west of the shaft. At the face on this level (A, fig. 43) 1 foot of nearly solid fine-grained pyrite is exposed in a narrow stope; and at a place 320 feet west of the shaft a breccia of gneiss fragments is cemented by pyrite in crystals a quarter of an inch in maximum size. Beautiful green crystals of hydrous iron sulphate are now forming in places on the walls on this level by deposition from surface waters descending along the vein. The waters of this mine are so corrosive that the overalls of miners working in wet places are sometimes eaten to shreds in a day or two, and iron rails, pipes, and nails must be frequently replaced.

The Richardson shaft, about 300 feet northeast of the Iron shaft, was inaccessible. The Richardson vein, however, was studied on the 400-foot level, which connects with the 400-foot level of the Iron mine (fig. 43). The average strike of the Richardson vein is about N. 40° E. and the dip is 65°–80° SE. A shaft with short levels at 160, 200, 300, and 400 feet descends on the vein. East of the shaft the vein was not traced far, but west of the shaft it forms a true junction with the Iron vein. One of the best exposures of the Richardson vein is in a stope 20 feet east of the shaft, where a width of 6 feet of altered granite gneiss is traversed by a network of irregular but sharp-walled sulphide veinlets 5 inches and less in width. These veinlets consist almost wholly of pyrite in crystals whose maximum size is 1½ inches. The vein here is said to sample about $7 per ton, the coarse pyrite being characteristically of low value.

The Grasshopper vein was accessible only on the 400-foot level (fig. 43), where it forms a true junction with the Iron vein about 180 feet east of the Iron shaft. As exposed it strikes nearly east and west and stands about vertical. Its mineralization is feeble. A vein between the Grasshopper and the Richardson (fig. 43) is 1½ feet wide and is similarly but more heavily mineralized.

The Mars vein, which strikes nearly east and west and dips 50°–80° N., is exposed on the 300-foot level of the Iron mine by a crosscut extending south-southeast. It lies about 115 feet south of the Iron vein and has been drifted upon for 85 feet and developed by a stope and winze. The vein shows from 1½ to 3 inches of solid pyrite bordered by granite gneiss carrying disseminated pyrite.

All of the veins described above are similar in mineral character and were formed at the same time. Although pyrite is the principal ore mineral, chalcopyrite and tennantite also occur in more or less pockety distribution and commonly indicate comparative richness. In most places where the ore carries over 2 ounces in gold it also carries copper in commercial amounts (over 1.5 per cent). The coarse pyrite is prevailingly of low grade, but much of the fine pyrite is fairly rich in gold.

The Iron and Pewabic mines being under one management and carrying ore entirely similar in character, the tenor and production of the two may be considered together. Records of shipments show that the smelting ore shipped from February 19, 1910, to December 28, 1910, had an average value of $58.40 per ton. The poorest shipment showed 0.14 ounce in gold and negligible amounts of other metals; the richest showed gold, 10.47 ounces; silver, 15.25 ounces; and copper, 11.65 per cent.

One shipment which approaches the average in value showed gold, 2.62 ounces; silver, 5.75 ounces; and copper, 1.55 per cent. The average value of the concentrating ore is stated to be about $11 per ton, mainly in gold.

The gross production of the Iron and Pewabic mines from 1904 to 1910, inclusive, was $526,000. The production before this period is estimated at $1,500,000 to $2,000,000.

The records of careful samplings fail to show any regular decrease in ore values dependent upon depth, and development has failed to reveal any regularity in the shape or attitude of the richer ore shoots.

PEWABIC VEIN.

The Pewabic vein outcrops about 100 feet north of the Iron vein and nearly parallels it in strike. It dips, however, in the opposite direction; that is, northward. The vein is developed by the Pewabic shaft, over 900 feet deep, and by the East Pewabic shaft, 700 feet deep, each shaft having levels at 100-foot intervals. The amount of drifting done on this vein is much less than that in the Iron mine.

Both shafts having been idle for some time the mine was not entered. The ore is entirely similar in character to that from the Iron vein, except that it is reported to carry uranium in the foot wall on the 200-foot level west. The value of the ore and the production have already been considered in conjunction with the Iron mine.

BANGOR MINE.

The Bangor shaft, which is about 800 feet west-southwest of the Iron shaft, appears to be on the westward continuation of the Iron vein or one of its branches. The shaft is equipped with a whim but could not be entered. The ore seen on the dump was mainly coarse pyrite and some chalcopyrite disseminated in altered schist. A few specimens show vuggy veinlets of galena and sphalerite cutting the pyritic ore sharply and evidently of later formation. Some narrow vugs are lined with crystals of quartz and sphalerite, the latter coated with a thin film of later quartz.

IRON DUKE MINE.

The Iron Duke mine, a short distance southeast of Russell Gulch village, is developed by a shaft 510 feet deep, but was idle at the time of survey. The underground workings are said to total 2,664 feet. The ore is of the pyritic type and appears to be entirely similar to that of the Iron mine.

HALL MINE.

The Hall mine, in the eastern part of Russell Gulch village, is developed by a shaft 260 feet deep, connecting with short levels at depths of 50, 100, and 200 feet. It was idle at the time of survey. The following are sampling-works assays of smelting ore shipped in 1910.

Sampling-works assays of smelting ore from the Hall mine, 1910.

Ore.	Gold.	Silver.	Copper.
Net pounds.	*Ounces.*	*Ounces.*	*Per cent.*
7,223	1.69	11.56	9.20
463	1.16	6.80	....
6,441	1.66	8.60	3.55
3,674	.44	2.90	....
591	1.14	2.60	2.00
462	.76	7.30	4.00

All the ore is of the pyritic type.

LOTUS MINE.

The Lotus mine, in the eastern part of the village of Russell Gulch, was not being worked

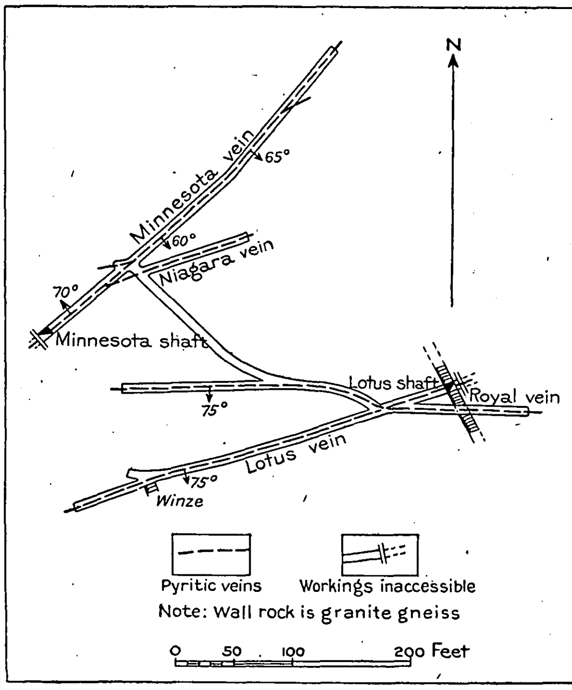


FIGURE 44.—Geologic plan of the 450-foot level on the Lotus vein and connecting workings on other veins. Surveyed by hand compass and pacing.

at the time of survey but was accessible through the first or tunnel level, at the side of the lower road between Russell Gulch and Central City.

The Lotus shaft, 810 feet deep, follows the Lotus vein, which strikes in general about N. 70° E. and dips 65°–75° SE. There are seven levels at intervals of approximately 100 feet. Most of these develop only the Lotus vein, but the 450-foot level (fig. 44) develops also the Royal, Minnesota, and Niagara veins.

The wall rock in the workings is almost exclusively granite gneiss but includes some small lenses of schist. The several veins exposed in the workings all belong to the pyritic type and show dominant pyrite with subordinate chalcopyrite and tennantite.

The Lotus vein as exposed on the tunnel level is in a few places a barren fracture seam; in other places it consists of 2 feet or so of fractured granite gneiss carrying disseminated pyrite; where most heavily mineralized it may show as much as 7 feet of pyrite-impregnated granite gneiss traversed by numerous subparallel veinlets of pyrite and quartz whose maximum width is about 1 inch. In places both the veinlets and the impregnated gneiss contain abundant tennantite associated with the pyrite. On the 210-foot level east the vein in places contains large amounts of coarse pyrite, evidently of low grade. About 250 feet east of the shaft on this level the vein, which is over 3 feet wide, shows 3 to 4 inches of gouge next the hanging wall, then 1½ feet of granite gneiss containing more or less disseminated pyrite, then a 1½-foot vein about one-third quartz and two-thirds pyrite, the latter in very coarse crystals exceptionally 2 inches across.

The Royal vein, as exposed on the 450-foot level about 100 feet east of its junction with the Lotus vein, is about 4 inches wide and is composed of nearly solid pyrite. The granite gneiss walls carry disseminated pyrite in amounts that gradually decrease from the vein outward. Locally some chalcopyrite occurs with the pyrite.

The Niagara vein, as exposed on the 450-foot level, shows in places 3 feet of altered granite gneiss carrying disseminated pyrite and is cut by a number of indefinitely bounded pyrite stringers. In one place a single sharp veinlet of solid pyrite is 1½ inches wide. Near its junction with the Minnesota vein the rock between the two veins is mineralized in a similar manner for a width of 4 feet, some of the solid pyrite veinlets being 5 inches wide.

The exposures in the Lotus mine were the only places at which the Niagara vein could be studied. The Niagara shaft beside the lower road from Russell Gulch to Central City was not accessible.

The Minnesota vein, as exposed on the 450-foot level, consists at one point of 5 feet of granite gneiss carrying varying amounts of disseminated pyrite. At another place a 1½-foot band of gray quartz carries rather fine pyrite. There has been movement along the vein subsequent to mineralization.

The smelting ore from the Lotus vein is said to have an average value of $14 per ton, mainly in gold.

HILLHOUSE-COLUMBUS VEIN.

The Hillhouse-Columbus vein, in the eastern part of Russell Gulch village, is developed by three principal shafts known as the Hillhouse, Columbus, and Ipavia, none of which could be entered at the time of this survey, and by several smaller shafts.

The Hillhouse portion of the vein is developed by two shafts 200 and 600 feet deep with levels every 100 feet. It has been idle since 1908. The average value of the ore is said to have been between $15 and $20 per ton and the gross production about $50,000.

The following are sampling-works assays of smelting ore:

Sampling-works assays of smelting ore from Hillhouse vein.

Year.	Ore.	Gold.	Silver.	Copper.	Silica.
	Net lbs.	*Ounces.*	*Ounces.*	*Per ct.*	*Per ct.*
1903....	5,588	1.25	14.70	....	74
1903....	5,910	.95	9.05	....	76
1903....	16,110	1.08	5.00	....	70
1904....	5,180	1.10	8.00	....	65
1906....	6,944	2.28	19.40	4.25	43
1907....	5,645	5.35	17.80	13.00	26

The Columbus shaft, according to available maps, is a little over 300 feet deep, with short levels at 110, 144, 192, and 300 feet. The following are sampling-works assays of smelting ore shipped in December, 1888:

Sampling-works assays of smelting ores from Columbus vein, 1888.

Ore.	Gold.	Silver.	Copper.
Net pounds.	*Ounces.*	*Ounces.*	*Per cent.*
5,603	1.70	9.10	5.30
3,455	1.90	10.30	9.50
4,535	1.60	10.90	6.00

The Ipavia shaft is 717 feet east of the Columbus shaft and is also on the Columbus vein. At a depth of 280 feet a long level extends eastward for several hundred feet and westward beyond the Columbus shaft. Little ore appears to have been taken from the Ipavia workings. Smelting ore shipped in 1889 gave the following sampling-works assays.

Sampling-works assays of smelting ore from Ipavia shaft (Columbus vein), 1889.

Ore.	Gold.	Silver.	Copper.
Net pounds.	*Ounces.*	*Ounces.*	*Per cent.*
2,058	1.05	5.30	3.00
3,507	.80	2.20	....
436	3.00	13.00	9.50

GETTYSBURGH VEIN.

The Gettysburgh vein lies between Leavenworth and Illinois gulches just west of the Central City-Russell Gulch wagon road. Its shaft was idle at the time of this survey, and no information concerning the workings was obtained. As exposed on the surface the vein strikes about N. 25° E. and dips steeply.

All the ore in the bins at the shaft house was of the pyritic type, consisting mainly of pyrite and chalcopyrite with subordinate amounts of tennantite in a quartz matrix. Vugs are common.

Sampling-works assays of two shipments of 436 and 1,941 pounds show, respectively, gold, 0.55 ounce and silver 3.5 ounces, and gold 2 ounces, silver 7.5 ounces, and copper 3 per cent.

LUTZ VEIN.

The Lutz vein, in the eastern part of Russell Gulch village, is developed by the Lutz, the I. X. L., and several subsidiary shafts. The principal (Lutz) shaft, 530 feet deep, follows the vein and connects with six levels. It dips about 70° N. between the 245 and 325 foot levels, but elsewhere is nearly vertical. The vein strikes nearly east and west.

The mine was idle and none of the workings could be entered. The ore on the dump was all of the pyritic variety, locally brecciated and recemented by gray quartz.

SLIDE VEIN.

The Slide vein on the Wellington No. 2 claim outcrops a short distance southeast of the village of Russell Gulch. It is developed by a shaft that was being sunk below the 200-foot level at the time of this survey, at which time the 100-foot level extended 40 feet east and 50 feet west and the 200-foot level 10 feet east and 20 feet west of the shaft. The vein is of the pyritic type; it strikes about N. 75° E. and dips from 75° N. to 75° S. Its width ranges from 3 to 8 inches. The richer ore carries chalcopyrite and tennantite in addition to pyrite and may reach $60 per ton in value. In the richest ore the copper may run as high as 14 per cent. In places the coarse pyrite is cut by later veinlets of white quartz.

MISSOURI MINE.

The Missouri mine is about half a mile due east of Russell Gulch village. There are two shafts on the property, the Missouri shaft with four levels, now idle, and the East Missouri shaft, through which lessees were doing some mining at the time of this survey. These two shafts are on nearly parallel veins about 40 feet apart.

The northernmost vein is developed by the East Missouri shaft, 250 feet deep. As exposed 15 feet east of the shaft on a level 158 feet below the surface it dips 65° N. and consists of 3 feet of granite gneiss traversed by a network of sharp-walled veinlets of coarse pyrite. A postmineral slip plane follows the vein and has crushed the ore in places.

The southern vein is developed by the Missouri shaft and by a crosscut 40 feet long from the 158-foot level on the northern vein. The drift on the south vein on this level is 130 feet long; at its east end it exposes a tight sulphide vein 2 inches to 2 feet wide, mainly pyrite, but carrying also some tennantite and chalcopyrite. The vein strikes N. 75°-80° E. and dips about 55° N. The ore in this drift is said to carry about 1 to 3 ounces in gold and 2 to 3 ounces in silver.

The following are a few sampling-works assays of shipments of smelting ore from the East Missouri mine:

Sampling-works assays of smelting ore from the East Missouri mine.

Year.	Ore.	Gold.	Silver.	Copper.	Silica.
	Net lbs.	*Ounces.*	*Ounces.*	*Per cent.*	*Per cent.*
1903	7,252	3.22	6.80	2.50	32
1904	8,000	2.40	6.23	....	34
1905	6,125	3.33	5.80	....	17
1906	7,282	4.36	8.70	....	23
1907	13,988	1.27	2.35	....	58
1908	8,116	.65	2.90	....	....
1908	5,498	3.61	8.20	....	....
1908	6,989	1.20	3.80	....	....

The smelting ore shipped in 1910 had an average content of 2.91 ounces gold and about 6 ounces silver, according to sampling-works assays.

JUSTICE HILL AND LOWER PART OF RUSSELL GULCH.

GLADSTONE VEIN.

The Gladstone vein outcrops on the ridge between Spring and Russell gulches about one-half mile due south of the railroad station at Central City. It is developed by a shaft, which dips steeply north, following the vein, and is somewhat over 220 feet deep, with levels at 72, 160, and 220 feet. On the 72-foot level the vein is drifted on for about 280 feet and is stoped to the surface for 120 feet west and 50 feet east of the shaft. On the 160-foot level drifts extend 200 feet west and 160 feet east of the shaft, and the vein is stoped to the first level for about 90 feet west and 25 feet east. On the 220-foot level a 60-foot stope 10 to 20 feet high has been started in the short west drift; the unstoped east drift is about 50 feet long. From this level an exploratory crosscut extends 210 feet south of the Gladstone vein.

The Gladstone vein strikes a few degrees north of east and dips 65°–80° N. Granite gneiss is the only country rock exposed. The vein is a tight, sharply bounded, extremely narrow fissure vein, which varies irregularly from a barren fracture to 4 inches in width, with an average of about 2½ inches, and which locally cuts sharply across the foliation of the granite gneiss. In places it consists of a single ore stringer and in other places of several nearly parallel ones. Several branches digress into the walls.

The principal vein mineral in most places is chalcopyrite, though locally pyrite is dominant. Very rarely a little resinous sphalerite is present. As a rule the vein contains no gangue, but in places it shows some quartz. At one place, for example, it consists of white drusy quartz at the center with chalcopyrite on both walls, and a few feet away it is wholly chalcopyrite. At another place light-gray quartz occurs on both walls with chalcopyrite in the center. Pyrite in small disseminated grains is the only sulphide noted in the wall rock; it is especially abundant within 6 inches or so of the vein.

Changes subsequent to the principal mineralization appear to have been slight. No large fracture-planes follow the vein, and no evidence of enrichment was found on the two accessible levels (160 and 220 feet). In a few places the vein material shows a little shattering without much displacement, and in such shattered portions white quartz containing a little antimoniacal tennantite occurs in small irregular lenses which send off minute stringers between the chalcopyrite fragments.

Although the principal ore mineral of the Gladstone vein is chalcopyrite, the value of the ore is mainly in gold and silver, and picked ore is said to have run as high as 11 ounces in gold.

The metal content of 29 tons of smelting ore shipped at different times between 1893 and 1910, as recorded in sampling-works assays, was gold, 0.56 to 8.1 (average 1.49) ounces; silver, 2.4 to 14 (average 5.35) ounces; copper, 10 per cent or less. All the ore mined is of smelting grade.

Three veins exposed in the crosscut on the 220-foot level differ in character from the Gladstone vein. Two of these, lying about 40 and 50 feet south of the Gladstone vein, strike nearly east and west and dip, respectively, vertical and 65° N. They are tight fissure veins consisting almost wholly of coarse pyrite in crystals up to three-fourths inch in diameter, with very little gangue. The third vein strikes about N. 30° E. and dips 65° SE. and intersects the Gladstone vein about 50 feet west of the shaft, the exact contact not being exposed. The drift follows it for about 25 feet. This vein is 2 to 3 inches wide and consists mainly of pyrite with a little gray copper in places. All three veins are low grade and none of them have been worked.

AURORA MINE.

The Aurora mine, in Russell Gulch about a mile south of Central City, is developed by a shaft 578 feet deep with levels at vertical depths of 85, 183, 258, 316, 392, and 501 feet. The workings develop portions of two nearly parallel veins, striking in general nearly east and west, which are known as the North, or Aurora, and the South veins. In general these veins appear to converge from the surface to the 258-foot level, where they are only 10 feet apart, and thence to diverge. Down to the third or 258-foot level the shaft follows the North vein. Below this there are two shafts, an old one, now closed, which followed the North vein, and a new one, which follows the South vein.

The Aurora, or North, vein, in which most of the mining has been done, was discovered by placer miners working in the bottom of Russell Gulch. For about 100 feet below the collar of the shaft it dips steeply south, but below 100 feet it dips about 70° N. Its most continuous exposures are on the 180-foot level, on which it has been followed for about 280 feet east and 300 feet west of the shaft. Here it is a true fissure vein showing one or more small stringers of pyrite and white quartz in a width of several feet of altered wall rock. Some distance east of the shaft the Aurora vein crosses the Baldwin vein, but the intersection failed to yield high-grade ore. The South vein is exposed in a short crosscut from the 183-foot level east and on all lower levels. Where exposed in the 183-foot level the walls are mainly pegmatite. The vein dips 60° N. and where widest shows a network of pyritic veinlets (maximum width, 4 inches) through a width of 4 feet of pegmatite.

The ores of the Aurora mine belong to the pyritic gold-silver type. In both the North and South veins the richer ores carry in addition to pyrite much chalcopyrite and tetrahedrite, the latter being in some places the last of the primary minerals to crystallize. Free gold, in places forming small nuggets, was abundant in the oxidized ore above the second level and was found in small amounts in the unoxidized ore to the greatest depths to which the veins have been worked. Local oxidation was noted at several places in the 183-foot level. In a specimen obtained from the 392-foot level the gold is irregularly associated with pyrite, tetrahedrite, and quartz and is probably a primary crystallization; at one point on this level free gold was deposited in a narrow watercourse which entered the vein from the north wall. It forms small wires and grains upon the quartz crystals and is plainly later than the quartz and probably later than the pyrite associated with the quartz. It is uncertain whether this gold was deposited by solutions descending from the surface or by solutions ascending in the later stages of the sulphide mineralization.

The oxidized ores above the second level appear to have been notably richer in gold than the unoxidized ores below; smelter returns in the early eighties showed as high as 20 ounces in gold. In the Aurora vein the rich ore in general extended to a vertical depth of about 150 feet; between 150 and 325 feet the ore was of comparatively low grade; but below 325 feet stringers coming in from the footwall carried, locally, ore of good grade, in some places assaying \$100 to \$200 per ton. Many parts of the South vein are low grade; for instance, in places on the 183-foot level, where it attains the unusual width of 4 feet, it assays only 0.3 ounce in gold and less than 2 ounces in silver. On the 258-foot level an underhand stope on the South vein shortly west of the shaft yielded rich ore, one 5½-ton lot netting \$112 per ton. Ore for some distance along the bottom of the 316-foot level had, according to Mr. Percy Alsdorf, an average metal content of gold 1.2 ounces, silver 4 ounces, and copper 4 per cent. At the time of this survey ore of good grade was being obtained from the 392-foot level, assays of \$95 to \$125 per ton being common. At a point about 50 feet east of the shaft on that level the vein consisted of 3 inches of sulphides, assaying gold 3.1 ounces, silver 2 ounces, and copper 1 per cent.

Twenty-three lots of smelting ore, aggregating 114 tons, shipped from the Aurora mine at various times from 1889 to 1910, showed gold 0.87 to 4.48 (average 2.24) ounces, silver 1.3 to 17.15 (average 6.3) ounces, copper 13.65 per cent or less.

ARGO VEIN.

The Argo vein, on the south side of lower Russell Gulch, nearly due south of Gregory Hill, is developed by a shaft 340 feet deep with short drifts on the 150, 200, 265, and 340 foot levels. The country rock is schist of the Idaho Springs formation, heavily injected by granite pegmatite.

At the Argo shaft the vein strikes N. 87° E. and dips 55°–70° N. It varies from a single tight unmineralized fracture to a well-mineralized fracture zone 2 feet in width. The mineralized portions commonly consist of schist carrying disseminated pyrite traversed by veinlets and irregular lenses, 6 inches or less in width, of nearly solid sulphides. On the 200-foot level west the vein splits and shows nearly parallel hanging-wall and footwall branches 2½ to 6 feet apart.

The ore belongs to the pyritic type and is very similar to that of the Aurora mine, except that in places it carries some enargite. Pyrite, coarse in places, is the principal vein mineral, but is locally associated with chalcopyrite, enargite, and antimoniacal tennantite, apparently all contemporaneous. Postmineral slipping along the vein has developed slickensides.

Little of the ore containing only coarse pyrite carries over 0.12 ounce in gold and most of it carries less. The richest is that carrying tennantite, chalcopyrite, and enargite.

Shipments between 1889 and 1908 of 12 lots of smelting ore, aggregating over 30 tons, showed according to sampling-works assays, gold 0.5 to 5 (average 2.39) ounces, silver 2.5 to 12.13 (average 7.31) ounces, and copper 2.1 to 16 per cent. The average value of the smelting ore shipped during 1910 according to sampling-works assays was gold 1.18 ounces, silver 5 ounces, copper 6.1 per cent.

the shaft and is caved 40 feet east of the shaft; the wall rock for this 40 feet is schist. The 700-foot level has not been driven west. The 800-foot level extends west of the shaft for about 120 feet, all in granite gneiss. It has no good exposures of the vein and was not mapped. The 900-foot level is driven about 110 feet east of the shaft, the walls being wholly granite gneiss. It was not mapped. The 1,000-foot level was not accessible during this survey, but ore from it in the ore bins was examined.

The Pittsburg vein strikes in general about N. 65° to 70° E. and dips 45°–65° N. Unlike most of the veins of this district, it shows only slight postmineral movement. The vein is

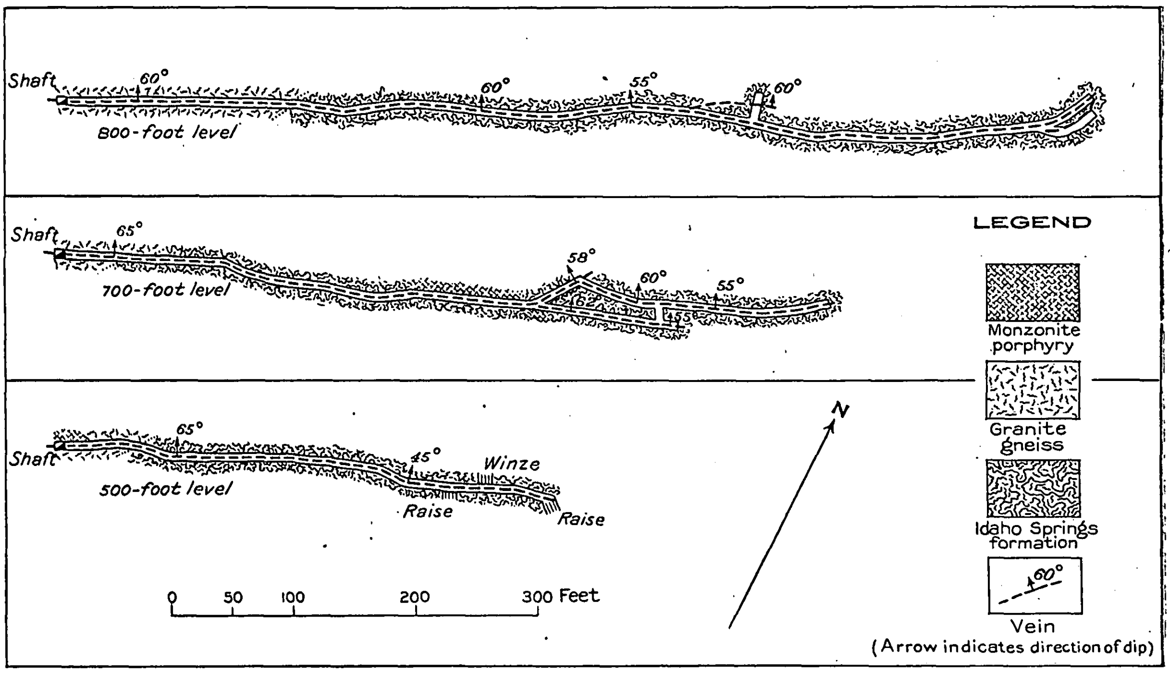


FIGURE 45.—Geologic plans of 500-foot, 700-foot, and 800-foot levels of Pittsburg mine. Surveyed by hand compass and pacing.

PITTSBURG MINE.

The Pittsburg mine is on the north side of Russell Gulch about a mile southeast of Central City. The shaft dips steeply north, following the vein. Only the lower levels, at depths of 500, 600, 700, 800, 900, and 1,000 feet were accessible for study. The relations in some of the levels east of the shaft are shown in figure 45. The 500-foot level west was inaccessible, a pumping station being located there. A sublevel about 200 feet long has been driven 50 feet above the 500-foot level and is reached by an inclined raise from the east end of that level. The 600-foot level is not driven west of

characteristically tight, the workable ore in many places being only 3 to 4 inches in width; it is, however, composed almost wholly of sulphides of comparatively high grade.

A rough and not very persistent banding occurs in some portions of the vein. In many places coarse pyrite occurs along the walls with copper-bearing sulphides in the center; elsewhere the pyritic and the copper-rich portions form separate bands. At one place, for example, the hanging-wall portion of the vein is composed entirely of coarse pyrite, and the 2 to 4 inches next the footwall consists of pyrite and tennantite. A short distance away along the vein the two streaks merge. In a stope 25 feet above the 800-foot level and about 750 feet east of the shaft the lower 2 to 2½ inches of the vein is an irregular association of pyrite and gray quartz, the next 2 to 3 inches is mainly tennantite, and the upper 1 inch is pyrite and gray quartz. In spite of this banding all of the primary minerals are believed to belong to the same period of mineralization, for in many places they are intimately intergrown.

The ores of the Pittsburg mine belong to the pyritic type but are unusually rich in copper-bearing minerals. Some portions of the ore consist mainly of coarse pyrite with a little quartz gangue, but in others pyrite is associated with chalcopyrite, antimoniacal tennantite, and in places with some enargite. Microscopic study of polished sections of copper-rich ore from the 800-foot level showed that the pyrite, antimoniacal tennantite, and quartz are contemporaneous crystallizations and that with them, also contemporaneous, occur very minor amounts of chalcopyrite and galena. This is one of the few instances observed of the crystallization of galena contemporaneously with the minerals characteristic of the pyritic-ore type. According to Mr. Percy Alsdorf some quartz-tennantite ore from this mine developed globules of gold on its surface when roasted, indicating the possible presence of a telluride of gold.

As the Pittsburg vein is richer in primary copper minerals than most of the veins of this region, it is natural that it should be one of the few veins to show an important amount of enrichment in copper through the development of the rich copper sulphide chalcocite. Chalcocite was abundant only in the highest portions of the vein accessible for study (shortly above the 500-foot level), but minute amounts were noted just below the 700-foot level. In stopes 50 to 60 feet above the 500-foot level and about 460 feet east of the shaft the vein consists of 5 inches of pyrite, chalcopyrite, tennantite, gray quartz, and chalcocite; the ore texture is somewhat porous. A polished section showed that the chalcocite developed by metasomatic replacement of chalcopyrite and to a lesser degree by replacement of pyrite. The replacement began along the contacts of chalcopyrite with quartz or pyrite or along minute fractures traversing the chalcopyrite. Portions of the vein not far away show much black pulverulent chalcocite in vugs, and in places the ore is honeycombed with irregular vugs one-eighth to one-fourth inch across. According to miners working in this stope abundance of the black pulverulent chalcocite means an increase in copper but not in the precious metals. Ore from this chalcocite-bearing stope is said to have an average value of about $40 per ton, carrying about 1.5 ounces gold, 15 ounces silver, and 10 per cent copper.

In an underhand stope just below the 700-foot level about 550 feet east of the shaft the total width of the vein is only about 2 inches. A central band of chalcopyrite and a little tennantite 1 to 1½ inches wide is bordered on each side by one-half inch of silicified granite gneiss carrying pyrite. Shearing movements along the vein have produced minute fractures in the chalcopyrite and tennantite that have been filled with gray quartz.

Starting from the border of these minute quartz veinlets the chalcopyrite has been replaced by chalcocite, so that narrow veins of the latter mineral border the quartz. The development of chalcocite, however, is so slight in amount that the copper content of the ore can not have been greatly increased thereby. This is the greatest depth at which enrichment was noted in this mine.

The "tight" character of the Pittsburg vein indicates the absence of extensive postmineral movement along it. A small amount of postmineral movement, however, is indicated by the minute quartz veinlets described above and by shear planes in ore from other parts of the vein. This fracturing has sufficed to render the ore permeable to descending copper-bearing solutions, thus facilitating chalcocitization.

Sampling-works assays of 50 lots of smelting ore, aggregating 243 tons, shipped at various times from 1894 to 1909, inclusive, show gold, 0.45 to 12.72 (average 2.37) ounces; silver, 1.5 to 18.3 (average 7.52) ounces; copper, not to exceed 16.6 per cent. Similar assays of 92 lots of smelting ore aggregating 435 tons, shipped during 1910, show gold, 0.52 to 25.35 (average 5.77) ounces; silver, 2 to 22.65 (average 8.93) ounces; copper, 0.3 to 16.3 (average 6.65) per cent.

WEST NOTAWAY MINE.

The West Notaway mine is on the north side of Russell Gulch about 1 mile southeast of Central City, on a single vein which is the westward continuation of one of those developed by the East Notaway workings. The development consists of a shaft following the vein and connecting with levels at vertical depths of 110, 160, 230, 360, and 440 feet. The vein strikes on the average about N. 55°–60° E., and dips 60°–65° NW.

The ore is distinctly of two periods of mineralization. That of the first period consists predominantly of coarse pyrite. Where well exposed on the 440-foot level, 70 feet northeast of the shaft, the vein consists of three parallel bands of coarse pyrite three-quarters of an inch, 1 inch, and 6 inches wide. In many places the coarse pyritic ore has been brecciated and the spaces filled with later ore consisting of gray cherty silica carrying very fine grained pyrite and in places considerable tennantite. Both types of ore are also well exposed on the 110-foot level (see A, fig. 46), where there is a strong vein 1½ feet wide of coarse pyrite with some white quartz gangue. This vein has been fractured and in places is still only slightly cemented, but elsewhere the pyritic ore fragments are completely cemented by nearly black cherty silica carrying tennantite. Both types of mineralization are also shown in the stopes above the east end of the 230-foot level, where the main mineralization follows the north side of a dike of monzonite porphyry for 3 feet, north of which the schist is traversed by veins of fairly coarse pyrite. The porphyry, schist, and pyrite veins are traversed by irregular stringers of gray to brownish cherty silica carrying fine pyrite. Both types of ore distinctly cut the porphyry at several places in the workings, showing conclusively that they are of later origin.

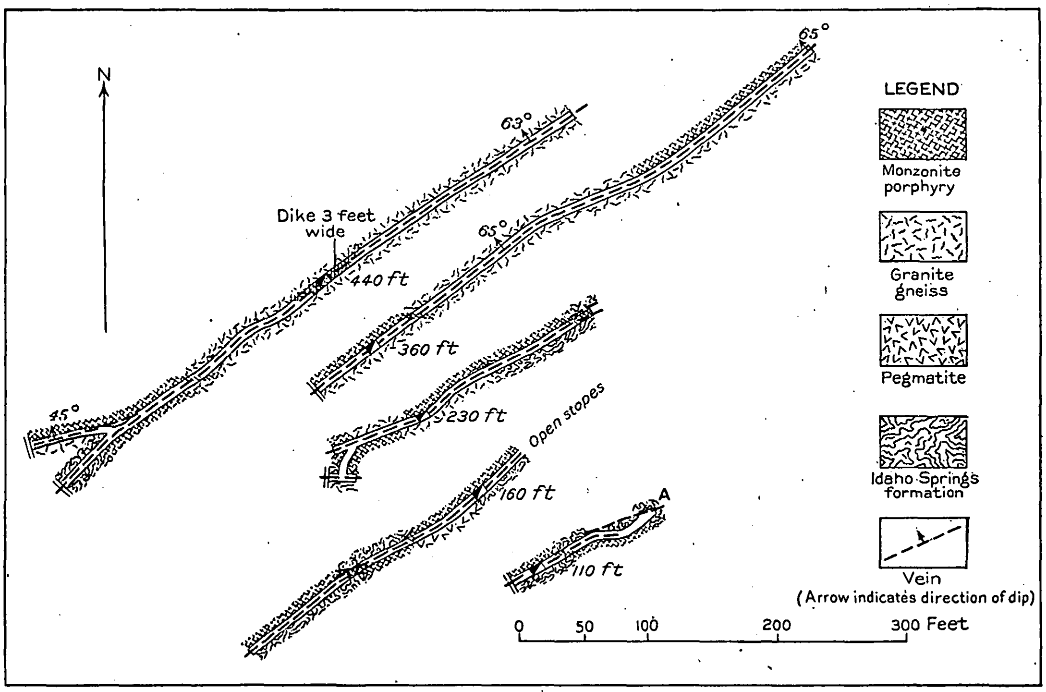


FIGURE 46.—Geologic plans of levels of West Notaway mine. Surveyed by hand compass and pacing. For convenience in comparing geology of successive levels the shaft intersections are placed in alignment, but as no survey was made of the shaft the distance between levels is not shown to scale.

The property is now being operated by lessees. All of the ore mined is shipped direct to the smelters. As in the East Notaway mine tellurides are present in the siliceous veinlets that cut the heavy sulphide ore of the first mineralization, and to their presence is mainly due the high gold value of much of the ore mined. As no tellurides were actually seen in ore available for study, the reader is referred to the description of the East Notaway mine for a discussion of their mode of occurrence (pp. 264–265).

Few of the sampling-works assays now available, for 1888 to 1910 inclusive, show a gold content less than 0.5 ounce or more than 7 ounces or a silver content less than 2 or more than 10 ounces. Copper varies from less than 1.5 to about 5 per cent. The following selected assays give some idea of the range in metal content:

Sampling-works assays of ore from the West Notaway mine.

Year.	Ore.	Gold.	Silver.	Copper.	Silica.
	Net lbs.	*Ounces.*	*Ounces.*	*Per cent.*	*Per cent.*
1888	3,862	3.15	6.30		
1893	4,670	1.50	6.70	3.8	
1895	6,319	2.97	8.00		
1897	11,042	.91	2.80		
1898	12,650	1.43	5.60		
1900	6,054	2.00	7.00	4.7	40
1905	11,958	.48	2.50		64
1906	11,229	.67	3.20	7.0	49
1908	5,043	7.34	4.50	2.55	

EAST NOTAWAY MINE.

The East Notaway mine is about a mile southeast of Central City on top of the ridge between Lake Gulch and Russell Gulch. It was first opened about 37 years ago and has been worked continuously by the present operating company for the last 14 years. The levels accessible for study were at vertical depths of 488, 555, and 651 feet and were served by an inclined shaft following what is termed the Shaft vein.

The geologic relations throughout most of the mine are very complex owing to the intrusion of irregular dikes of monzonite porphyry and to the presence of two distinct types of mineralization. The wall rocks are monzonite porphyry and schist of the Idaho Springs formation with more or less associated pegmatite. Geologic relations are most clearly exhibited on the 555-foot level. (See fig. 47.)

The north or Shaft vein consists predominantly of coarse pyrite, characteristically low grade, on which little mining has been done. As exposed in the 651-foot level near the shaft, this vein shows the following section:

Section of north vein of East Notaway mine.

	Ft.	in.
Footwall pyrite		1½±
Pegmatite, traversed by minute pyrite veinlets and carrying some disseminated pyrite	3	0
Pyrite in a white siliceous gangue		10
Silicified pegmatite		6
Gouge-filled fracture zone, carrying some disseminated pyrite	4	0

On the 488-foot level the Shaft vein is exposed for about 500 feet but is nowhere heavily mineralized, the pyrite stringers never exceeding 3 inches in width.

Crosscuts south from the Shaft vein on each level cut the Homestake and Notaway veins, which are closely associated. In an exposure about 130 feet east of the crosscut on the 651-foot level, which dips 55° N., the Homestake vein shows the following section:

	Inches.
Hanging wall, a 10-foot dike of monzonite porphyry.	
Postmineral slip plane.	
Gouge and brecciated pyrite	3
Coarse pyrite in a quartz gangue	6
Pegmatite, traversed by small pyrite stringers and carrying some disseminated pyrite	15

The Notaway vein differs entirely from the Homestake vein, in size, in value, and in mineral character. It is well shown at the 555-foot level about 120 feet east of the crosscut from the Shaft vein (*A*, fig. 47), where it consists of three or four subparallel stringers of cherty appearance (maximum width, 1½ inches) in a 4 to 6 inch zone. In other places the Notaway vein is represented by a single narrow veinlet. Small vugs are of exceptional occurrence and some of them are lined with silica of chalcedonic appearance.

In places, as along most of the 555-foot level east, the Notaway vein occurs alone, but elsewhere, as on the 555-foot level for 80 feet west of the crosscut (fig. 47), it lies in or along the Homestake vein and is mined with it. In such places the Notaway dark-gray cherty ore cuts sharply through the heavy pyritic Homestake ore and is plainly of later formation.

Both the Homestake and Notaway veins were formed later than the monzonite porphyry dikes, the evidence as to the Notaway being particularly clear. Eighty feet west of the crosscut, for example, on the 555-foot level (*B*, fig. 47) the Homestake vein goes into the south wall and the Notaway continues along the drift, cutting sharply through the dike of monzonite porphyry. The Homestake vein is later than the monzonite porphyry, but the relations have been masked in most exposures by postmineral movements that have crushed or shattered both ore and porphyry. The resulting breccia of ore fragments in crushed porphyry bears a deceptive resemblance to certain breccias formed when porphyry has intruded ore, but careful study reveals the true relations.

The ores of the Shaft and Homestake veins belong to the pyritic type and consist predominantly of pyrite in a gangue of quartz or altered wall rock. In the Homestake vein chalcopyrite and antimoniacal tennantite are present in a few places. The Notaway vein consists typically of 1 to 3 inches of dark-gray cherty-appearing silica, fine-grained pyrite, antimoniacal tennantite, and varying amounts of a telluride of gold and silver and native gold. A study of polished surfaces of the rich telluride ore, supplemented by an examination of a thin section by transmitted light shows that the predominant constituents near the border of the 1-inch veinlet are pyrite, antimoniacal tennantite, and microcrystalline quartz, all apparently contemporaneous. Toward the center of the veinlet the sulphides decrease in abundance and a telluride (sylvanite?) appears, associated in places with native gold. Most of the sylvanite occurs alone, but in places it is intergrown, apparently contemporaneously, with tennantite. The larger crystals of sylvanite are platelike or bladelike in form. The native gold in these specimens appears to be primary and not an alteration product of sylvanite.

The pyritic ore of the Shaft vein is everywhere below workable grade, its average value being about $3 per ton. Most of the ore of the Homestake vein is likewise below workable grade, but where chalcopyrite and tennantite are present its value may reach $200 per ton. The gold content of the Notaway vein is notably irregular. One shipment from the 555-foot level gave a gold content of 32 ounces, and the next, a shipment of similar appearance from the same stope, ran only 2 ounces. Another lot ran 27 ounces and the next, from an adjacent part of the stope, only 7 ounces. Such irregularity is evidently due to irregular distribution of the tellurides, in which most of the precious-metal content occurs. Where the Notaway vein traverses the Homestake it is necessary to mine both ores.

About one-third of the output of the mine is smelting ore and the remainder concentrating ore. According to the sampling-works assays the smelting ore shipped in 1909 showed gold, 0.39 to 11.6 (average 3.3) ounces; silver, 2 to 11.04 (average 5.44) ounces; copper, 6.71 per cent or less. Ore shipped in 1910 showed gold, 0.27 to 13.3 (average 2.52) ounces; silver, 1.8 to 15.25 (average 4) ounces; copper, 8.5 per cent or less.

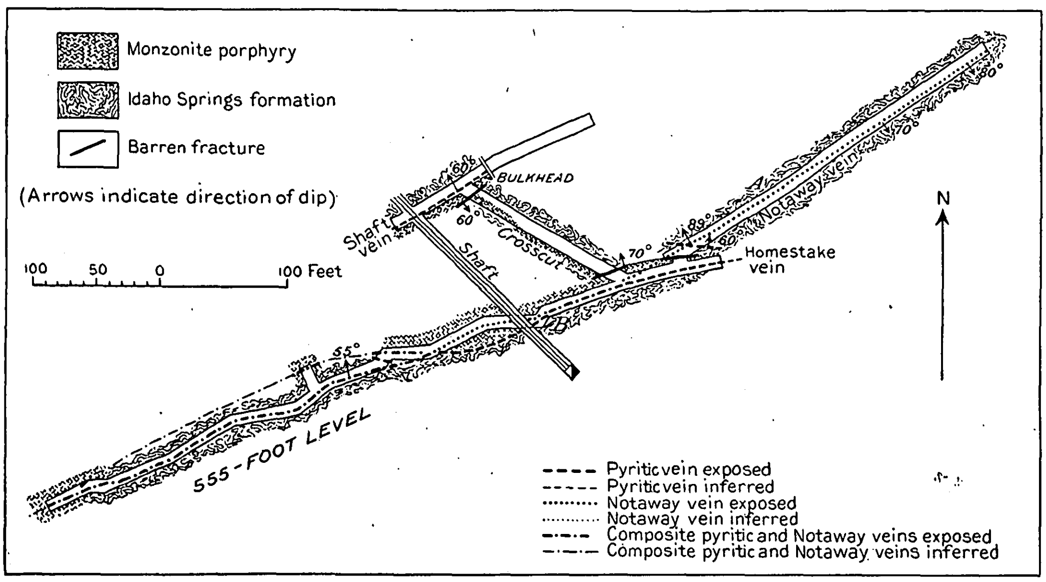


FIGURE 47.—Geologic plan of 555-foot level of East Notaway mine. Surveyed by hand compass and pacing.

The average metal content of the concentrating ore for 1910, as computed from the value of the amalgam and concentrates, was gold 0.18 ounce, silver 0.426 ounce.

GULCH MINE.

The Gulch mine, about a mile southeast of Central City and a short distance northeast of the East Notaway mine, is developed by a shaft 430 feet deep with short levels at depths of 80, 160, and 430 feet. The mineralization is greatest on the 430-foot level, and it is there that the geologic relations are best shown. The level cuts a 10-foot dike of monzonite porphyry 50 to 60 feet east of the shaft but elsewhere penetrates schist of the Idaho Springs formation. One wall of the porphyry dike is followed by a barren ½-inch veinlet of white quartz, the other wall by a 1½ to 2 inch veinlet of fine-grained pyrite of low value. Both the dike and the veins following its walls are cut by a tight ¼ to 2 inch vein of fine cherty-looking quartz, which carries chalcopyrite and fine-grained pyrite and is said to have averaged $2 per ton, mainly in gold, and exceptionally 28 ounces in gold; the drift follows this vein. Elsewhere on this level, notably in a winze 115 feet east of the shaft, the mineralization consists of coarse pyrite cut by fractures filled by cherty-looking gray silica, antimoniacal tennantite, and fine pyrite. These cherty veinlets are 1 inch and less in width and contain some vugs. They carry gold up to 2 ounces, probably tellurides, and are similar in appearance to the East Notaway vein as exposed in the East Notaway workings.

The following selected sampling-works assays of smelting ore from the Gulch mine show its considerable variation in metal content:

Sampling-works assays of ore from Gulch mine.

Date.	Ore.	Gold.	Silver.	Copper.	Silica.
	Net lbs.	*Ounces.*	*Ounces.*	*Per cent.*	*Per cent.*
June, 1904..	6,156	10.00	10.20	10.60	39
July, 1905...	7,866	.20	2.00	....	....
Nov., 1905..	3,103	4.20	6.80	9.00	30
Nov., 1905..	5,880	1.60	3.60	3.80	45
Sept., 1906..	4,856	8.74	8.00	2.50	....
Sept., 1906..	6,314	1.18	5.35	5.00	....
Aug., 1907..	8,500	1.60	5.40	6.30	....
July, 1908...	7,289	2.55	8.08	9.65	....

PEARCE OR MORRIS MINE.

The Pearce mine is on the northeast side of Russell Gulch a short distance above its junction with South Willis Gulch. The development work consists of a shaft 460 feet deep with short levels at vertical depths of 100, 200, 300, and 400 feet. The shaft follows the vein which strikes N. 70°–75° E. and dips in most places about 80° S. The predominant wall rock is schist of the Idaho Springs formation with some pegmatite. The vein, which is a true fissure filling, is predominantly of the pyritic type; on the 400-foot level 20 feet west of the shaft it consists of 1½ feet of pyrite and quartz, and at the bottom of the shaft it consists of 4 to 5 inches of coarse pyrite with some white quartz gangue. In the shaft between the 300 and 400 foot levels a little galena and sphalerite are associated with pyrite. On the 200-foot level a barren crosscut extends N. 30° W. for 85 feet from the vein, and on the 300-foot level a barren crosscut extends S. 35° E. for 70 feet from the vein.

The ore mined from this property is small in amount and its average value is said to have been about $12 per ton.

JUSTICE VEIN.

The Justice vein, which strikes northeast across the crest of Justice Hill, is developed by three shafts. The property had been idle for some years at the time of this survey, and none of the workings were entered. The ore on the dump was mainly of the pyritic type, consisting of pyrite, quartz, and some gray copper. Exceptionally a little galena and sphalerite were noted.

Sampling-works assays of 17 lots of smelting ore, aggregating 60 tons, shipped from the Justice mine between 1888 and 1910, show gold, 0.29 to 3 (average 1.33) ounces; silver, 3.4 to 22.6 (average 12.88) ounces; copper (wet), from less than 1.50 to 7.30 per cent; and silica, 29 to 50 per cent (in six lots). Similar assays of 15 lots of smelting ore, aggregating 50 tons, shipped from the St. Louis shaft on the Justice vein, show gold, 0.7 to 3.87 (average 2.11) ounces; silver, 3.8 to 19.2 (average 10.52) ounces; copper (wet), from less than 1.5 to 7.1 per cent; and silica, 28 to 73 per cent (in five lots).

WILLIS AND SOUTH WILLIS GULCHES AND PLEASANT VALLEY.

TWO-FORTY VEIN.

The Two-Forty vein is on the south side of Willis Gulch near the main road from Russell Gulch to the Frontenac mine, 2,000 feet southwest of the Saratoga shaft. It is developed by a shaft over 180 feet deep, with a 700-foot drift at 180 feet, and by two drift tunnels. The lower tunnel, 1,470 feet long, intersects the shaft 530 feet from the mouth and 90 feet below the collar. The upper tunnel starts 15 feet below the shaft house and runs west on the vein for 970 feet. The ground from the lower tunnel to the surface is practically all stoped for 400 feet west of the shaft, and above the upper tunnel the stopes continue 800 feet west of the shaft.

The vein is in Idaho Springs formation and is about parallel to the schistosity. It cuts diagonally across a bostonite porphyry dike near the face of the lower tunnel. The same porphyry is seen on the hanging wall of the vein 690 feet west of the shaft on this level and 350 feet west of the shaft on the level below. On the footwall a small mass of bostonite porphyry is exposed 490 feet west of the shaft on the lower tunnel level. Where the vein distinctly cuts the porphyry that rock is much altered, contains some disseminated pyrite, and is traversed by little veinlets of pyrite, offshoots from the vein.

The Two-Forty vein strikes about N. 63° E. and dips 48°–72° N., with an average of about 60° N. It ranges from 2 inches to 8 feet in width, with an average of 2 feet, and shows no branches in the workings accessible. The vein consists of crushed silicified schist carrying in practically all places abundant fine-grained disseminated pyrite. Most parts of the vein contain at least one stringer of coarse pyrite and gray quartz 1 to 8 inches in width, the average being about 2 inches. These sulphide streaks are seen near the foot and hanging walls as well as in the central part of the vein. A cross section of the vein is as follows:

Section of Two-Forty vein.

Hanging wall.	Inches.
Black gouge, containing crushed pyrite	$\frac{3}{4}$
Schist, crushed and silicified, with some disseminated pyrite	2
Pyrite, coarse, intergrown with a little gray quartz	1
Schist, crushed, silicified, with much disseminated pyrite	4
Pyrite, coarse, somewhat sheared	2
Schist, sheared, with abundant disseminated fine-grained pyrite	10
Gouge next the footwall.	

Postmineral movement has produced abundant blackened gouge containing fragments of pyrite throughout the length of the vein. In many places the massive sulphides are crushed. A little enargite is reported.

Two veins about parallel to the Two-Forty are shown by the development work. One south of the Two-Forty on the upper tunnel level which has been drifted and stoped for about 200 feet, is a 2 to 4 foot fracture, very similar in character to the Two-Forty. The second vein, which is exposed about 150 feet from the mouth of the lower tunnel, strikes N. 85° W. and dips 60° N. It is about 8 inches wide and is filled with crushed wall rock containing a little disseminated pyrite and traversed by lenses and stringers of coarse pyrite not more than 2 inches wide.

Lessees working on the Two-Forty vein in the lower tunnel report a few small pockets of coarse pyrite containing chalcopyrite in which the gold values are somewhat higher than in the average ore. The average content of smelting ore for 1910 was 0.95 ounce gold, 5.82 ounces silver, and 0.69 per cent copper. Sampling-works assays of 11 lots of smelting ore shipped from 1895 to 1905, show gold, 0.58 to 10.9 ounces; silver, 2.1 to 14.6 ounces; silica, 25 to 73 per cent. Few of the larger shipments contain more than 1 ounce gold and 7 ounces silver per ton.

SARATOGA MINE.

The Saratoga vein, which crops out on the ridge between Russell and Willis gulches, has been one of the most productive in the Central City district. It is developed by three shafts—No. 1, 700 feet deep; No. 2, 1,000 feet deep; and No. 3, 400 feet deep—and by the Saratoga lateral. No. 2 shaft, the only one now being operated, is vertical, connects with 10 levels, and is one of the few shafts in the district equipped with a cage. The Saratoga lateral, nearly 3,000 feet long, is on the level of the Argo tunnel, nearly 1,300 feet below the collar of No. 2 shaft. At the time of this survey mining was being done by the Saratoga Development Co. through the Saratoga lateral and by lessees on the sixth and tenth levels through No. 2 shaft. Most of the workable ore above the ninth level had been stoped out.

The sixth and tenth levels were the only parts of the upper workings that could be entered. The sixth level is open for about 320 feet east of the shaft but is caved just west of the shaft. In a stope 60 feet above the level the vein is 1 to 2 feet wide and consists mainly of pyrite and a little white quartz gangue. The vein walls are not sharp and there is much disseminated pyrite in the bordering gneiss. In places the main vein is paralleled by subsidiary veins from three-fourths inch to 5 inches wide. The dip is about vertical. Some of the pyrite crystals in this ore are as much as three-fourths inch in diameter.

In a raise about 50 feet above the tenth level and 340 feet west of the shaft the vein consists of about 5 feet of altered granite gneiss carrying abundant disseminated pyrite. Several inches of soft gouge lie next to each wall, and at one place a veinlet of gray quartz and pyrite traverses the center of the mineralized zone.

The Saratoga lateral for practically its whole length follows the vein. The wall rock is almost exclusively granite gneiss, though one dike of highly altered porphyry (probably monzonite) is cut about 2,850 feet from the Argo tunnel. For 800 feet from the tunnel the vein is barren or only feebly mineralized and no stoping of consequence has been done. Beyond this stopes occur at intervals. About 810 feet from the tunnel 6 inches to 1½ feet of coarse pyrite, exposed on the footwall of the drift, grades into granite gneiss carrying disseminated pyrite. About 2,900 feet from the Argo tunnel, in a stope where work was in progress at the time of this survey, there is a slip plane next the footwall, succeeded by 5 inches of nearly solid pyrite somewhat sheared in places, and by 2½ feet of granite gneiss cut by a network of minute pyritic stringers and carrying much disseminated pyrite. Samples of coarse pyrite and of granite gneiss carrying disseminated pyrite, collected by the writer from this stope, assayed, for the pyrite, gold 0.16 ounce, silver 1.84 ounces, copper 10 per cent, and for the granite gneiss, gold 0.07 ounce, with a trace of silver.

In general all the ore now exposed in the Saratoga workings is of the pyritic type, but a few old sampling-works assays show small amounts of lead. The gradual transition observed at several parts of the vein from solid pyrite into gneiss carrying more or less disseminated pyrite indicates that the vein was formed mainly by replacement, accompanied, however, by some fissure filling. The vein, though not in general high grade, is one of the most persistent in the district and has been stoped throughout large continuous areas. During periods when the mine was idle and before the workings were drained by the Argo tunnel the groundwater is reported to have stood at the fourth level.

The metal content of 1,019 tons of smelting ore shipped between 1893 and 1909, inclusive, as determined from sampling-works assays, was gold, 0.12 to 8.41 (average 0.90) ounces; silver, 1 to 13.90 (average 2.32) ounces. Copper was nearly always below the commercial limit of 1.5 per cent. The ore between the ninth and tenth levels is said to average about 1 ounce in gold, 2 ounces in silver, and 1 per cent copper.

The gross production of the mine is reported to be somewhat over $2,500,000. The company owns no mill.

TOGO VEIN.

The Togo vein, in Willis Gulch, just south of the Saratoga mine, is developed by a shaft 220 feet deep, with levels at 100, 150, 200, and 220 feet. The general strike of the vein is nearly east and west and the dip about 65° N.

At a depth of about 75 feet in a winze from the 100-foot level the vein shows next the hanging wall a band 2 feet wide of fluorite, white quartz, and fine-grained pyrite, succeeded by nearly solid galena, sphalerite, and some pyrite, in places 1½ feet wide. In a stope 40 feet above the 200-foot level the vein is about 1½ feet wide and shows galena, sphalerite, and pyrite, with some gray quartz gangue. A little secondary hematite occurs in ore from near the surface.

Sampling-works assays of four lots of smelting ore shipped from this mine in 1907 and 1910 are as follows:

Sampling-works assays of smelting ore from the Togo vein.

Ore.	Gold.	Silver.
Net pounds.	*Ounces.*	*Ounces.*
3,410	2.93	14.25
2,719	3.05	17.00
5,076	.87	4.00
3,878	1.59	13.46

Ore from a winze from the 200-foot level east is said to have run 1.4 ounces in gold and 90 ounces in silver.

HAZELTINE VEIN.

The Hazeltine vein, which trends slightly south of east across South Willis Gulch, is developed by two shafts, the Hazeltine east of the gulch and the Hazeltine Extension west of the gulch. Both of these were idle and the workings could not be entered. The ore on the dumps indicated that the vein was very similar to the Anchor vein in mineral character. Much coarse pyrite was present, some masses of this mineral being 8 inches across. Enargite was fairly abundant in association with the pyrite. Fluorspar was present, as were minor amounts of galena and sphalerite. Vugs are abundant in the pyritic ore, one observed being 1 foot in length parallel to the vein and 2 inches wide. Some quartz crystals in this vug are one-half inch in diameter.

FRONTENAC AND ADUDDELL MINES.

The Frontenac and Aduddell mines at the head of South Willis Gulch develop the same veins, are under a single management, and may appropriately be described together. In the present development the Frontenac and the Aduddell east shafts are used for hoisting and the Aduddell west shaft for ventilation. The Frontenac shaft follows the dip of the lode and connects with eight levels and one sublevel (between levels 3 and 4). The Aduddell shaft also follows the dip of the lode and connects with eight levels. The fourth level of the Frontenac workings connects with the fifth level of the Aduddell air shaft, which has the same elevation. The seventh level of the Frontenac connects through a rise with the fourth level of the main Aduddell shaft. Short drifts from the Argo tunnel on what is supposed to be the Frontenac-Aduddell vein system are described elsewhere (pp. 304–305). The mineralization in these drifts is feeble, and no stoping has been done.

In general the workings develop a compound vein system made up of two and in some places of several subparallel veins. The two principal veins are referred to as the North and South veins, but their identification in all parts of the mine is not certain. The average trend of the vein system is about N. 50° E. and the dip is 50°–80° NW.

The apex of the lode is in an area of Idaho Springs formation and pegmatite just northwest of a contact with granite gneiss. As the lode is followed downward it passes out of schist and into granite gneiss, which is the prevailing wall rock in most of the workings.

Both pyritic and galena-sphalerite ore types are present. The structure of one of the

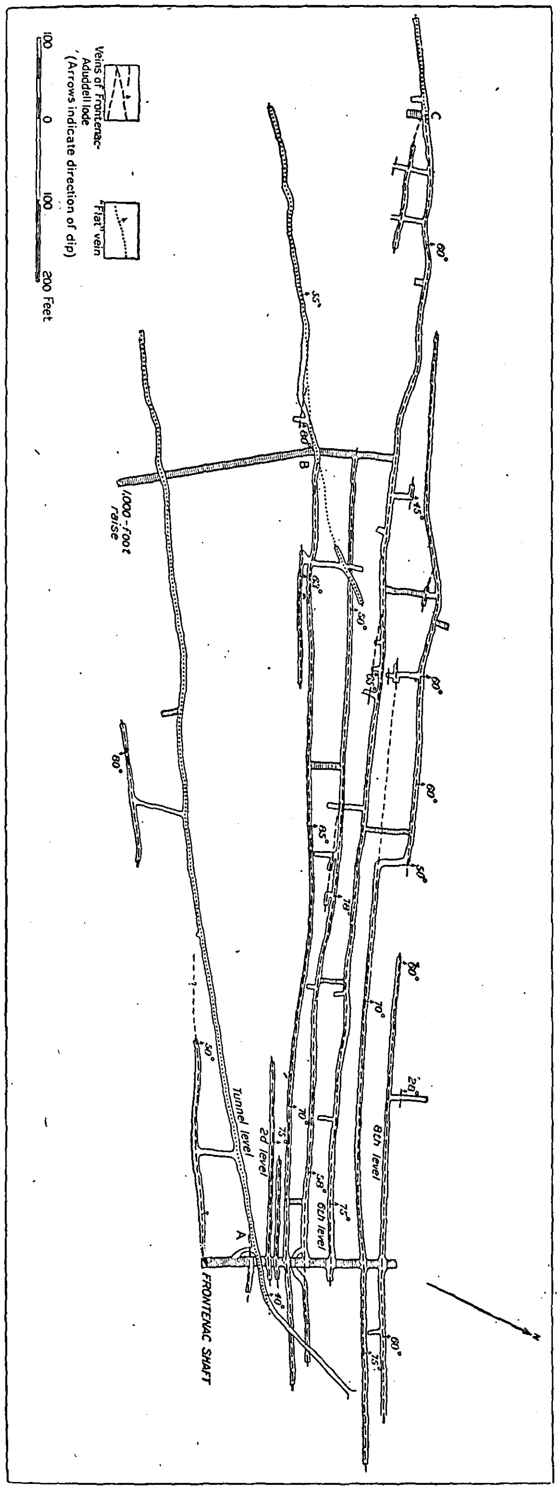


FIGURE 43.—Geologic plan of Frontenac mine above ninth level.

pyritic veins is well shown at the top of the rise connecting the eighth level of the Frontenac with the fifth level of the Aduddell. The vein here has a width of about 4 feet; its average width in the Frontenac eighth level east is 5 to 6 feet.

Section of pyritic vein in the Frontenac-Aduddell lode.

	Inches.
Hanging wall.	
Granite gneiss, sheared, carrying some crushed pyrite.	6
Granite gneiss, somewhat fractured and altered, traversed by a few small stringers of pyrite	14
Slip plane.	
Pyrite, cut by stringers of dark-gray cherty silica	2
Pyrite, coarse, nearly solid, cut by a few stringers of gray cherty quartz, some one-fourth inch in width	12
Footwall.	

Another good exposure of the highly pyritic ore is at the east face of the Aduddell fifth level, where the width of the vein is about 7 feet.

Section of highly pyritic vein in Aduddell mine.

	Ft.	in.
Hanging wall.		
Granite gneiss, more or less sheared, with numerous fragments of cherty silica in the upper portion, and of pyrite in the lower portion	2	0
Granite gneiss, carrying in places as much as 70 to 80 per cent (by volume) of pyrite		8
Granite gneiss, cut by several pyrite stringers, three-fourths inch or less in width, generally carrying some quartz	1	0
Pyrite, coarse, with some quartz gangue	1	0
Granite gneiss, more or less silicified, carrying varying amounts of disseminated fine pyrite	2	0

Vein structure where the mineralization is mainly of the galena-sphalerite type is well shown on the Frontenac seventh level in a stope about 1,125 feet west of the shaft, where the width of the vein varies from 4 to 7 feet.

Both types of ore are exposed on the eighth level of the Frontenac mine about 860 feet west of the shaft.

Section of vein in Frontenac mine, showing composite mineralization.

	Inches.
Hanging wall.	
Slip plane.	
Gouge	4–6
Galena, coarse, and reddish-brown sphalerite	3–5
Galena, sphalerite, and pyrite, more or less crushed	2
Pyrite, coarse, with a little white quartz gangue	12
Footwall of granite gneiss, carrying a little disseminated pyrite.	

In the preceding section the relations between the pyrite and the galena-sphalerite ore are not clearly shown, but elsewhere in the mine and in specimens from the ore bins and dumps the two types were commonly separated by sharp contacts, a relationship which accords with the evidence, obtained from neighboring mines, that the pyritic ore was fractured and the galena-sphalerite ore later introduced.

Throughout much of the Aduddell workings from the first level of the Aduddell air shaft down to the eighth level of the Aduddell main shaft a highly siliceous ore is found, in places alone and in places paralleling a vein of the pyritic type. Ore of this siliceous type is particularly well exposed along the footwall of the sixth level west. At the face of this level, about 170 feet west of the shaft, the vein is about 5 feet wide and appears to be mainly a replacement of the granite gneiss along a zone of fracturing rather than a true fissure filling. The more quartzose portions are in general richest in sulphides, and there is every gradation from such mixtures of quartz and sulphides into little-altered granite gneiss. Many of the portions richest in sulphides are, however, more or less veinlike in form, owing to the replacement having reached a maximum along a number of subparallel fractures. Pyrite is the predominant sulphide in most of the siliceous ore and is in some places the only one present. Elsewhere, however, galena, sphalerite, and some chalcopyrite are also present and are so intimately associated with the pyrite as to leave little doubt of their contemporaneity. Rhodochrosite is present in a few places as a gangue mineral. In general it seems probable that the siliceous ore is cogenetic with that of the Druid mine (see pp. 272–273) and is to be regarded as an uncommon phase of the second or galena-sphalerite mineralization.

In addition to the veins described above the Frontenac workings expose what is known as the Flat vein for nearly the whole length of the tunnel level. (See fig. 48.) The wall rocks as far as the 1,000-foot raise are schist of the Idaho Springs formation and pegmatite, and the vein is a pronounced fault zone only feebly mineralized with disseminated pyrite and a few small stringers of galena and sphalerite. Beyond the 1,000-foot raise the wall rock is wholly schist and the fault is much less coherent, the movement being distributed among many small slip planes parallel to the schist folia. This portion of the vein is hardly at all mineralized.

The Flat vein as exposed on the fourth level west of the Frontenac is in most places inclosed in walls of granite gneiss and is a very definite zone of gouge and brecciated wall rock.

6 inches to 1½ feet wide. Sulphides are present only as sparse disseminations. In the last 120 feet of this level the wall rock is schist of the Idaho Springs formation, and the fault breaks up into a zone 5 or 6 feet wide, through which there has been slipping between the schist folia but neither mineralization nor even noticeable alteration of the schist. Although the Flat vein has in places been slightly mineralized, much of the movement along it has been subsequent to its mineralization and to that of the Frontenac-Aduddell vein system. It cuts across the strike of the latter at a small angle (see fig. 48) and dips somewhat more gently in the same general direction. The contact between the Flat vein and the Frontenac-Aduddell system pitches very gently southwest. The crossings are shown in figure 48 at A on the tunnel level, B on the fourth level, and C on the sixth level, the exact position of the last being hard to determine because the two veins are nearly parallel. The main interest in the Flat vein centers in the fact that it displaces the workable veins of the Frontenac system, none of which have been found beyond it, though their continuation should lie above (or northwest) of the vein. The direction of movement along the Flat vein is, however, uncertain. If the north wall moved upward for a considerable distance with respect to the south wall, the continuation of the Frontenac veins may have been shifted upward to a point above the present surface and may have been entirely removed by erosion. A raise on the Flat vein above the tunnel level failed to find its continuation. If, on the other hand, the north wall of the Flat vein has moved down with respect to the south wall, or has moved up only for a short distance, then a crosscut driven northwest from some point well up on the Flat vein should find the faulted continuation of the Frontenac-Aduddell system. There is some slight evidence that the north wall of the Flat vein has moved downward with respect to the south wall, but it is far from conclusive. A drill hole or crosscut driven northwest from the Flat vein would appear, however, to be justifiable prospecting.

Postmineral displacement is not confined to the Flat vein, but in places has followed the veins of the Frontenac-Aduddell system, brecciating the ore and developing gouge. In some places the fractures have been healed with cherty silica, and in other places the matrix of crushed gneiss inclosing sulphide fragments has apparently been recemented by the solution and redeposition of portions of its own substance.

The mineral character of the ores may be summed up as follows: The mineralization is of the pyritic type, of the galena-sphalerite type, and composite. A highly quartzose ore found in portions of the Aduddell mine may be an uncommon phase of the galena-sphalerite mineralization. The characteristic minerals of the galena-sphalerite type of ore are galena, sphalerite, chalcopyrite, tennantite, and pyrite. Some enargite is reported to occur locally, probably (as in adjacent mines) in ore of the pyritic type. No evidences of downward enrichment were noted in any of the workings examined. Ore at a depth of 90 feet in the Aduddell air shaft was unoxidized.

According to Mr. H. P. Lowe, manager of the Frontenac-Aduddell property, 27,000 tons of smelting ore from the upper levels of these mines averaged $23.30 per ton. The smelting ore being obtained at the time of survey from the lower levels is estimated to average $25 per ton. Below the sixth level of the Frontenac about two-thirds of the value of precious metal content is in gold and one-third in silver; higher up the silver content was proportionately greater, possibly as a result of a small amount of downward enrichment in silver.

The value of the concentrating ore may be inferred from the results of a test mill-run on 3,209 tons of ore taken from all parts of the mine below the sixth level of the Frontenac. The net savings per ton were gold, $4.56; silver, $3.29; copper and lead, $0.50; total, $8.35.

The Gilpin County tramway carries the smelting ore to the sampling works at Blackhawk and the concentrating ore to the Frontenac and Iron City mills below Blackhawk. These mills are briefly described on pages 160–161.

The Frontenac mine is reported to have had a gross production of about $980,000 from above the fourth level, exclusive of the free-milling surface ore. The total gross production of both the Frontenac and Aduddell mines up to the fall of 1911 is estimated by Mr. Lowe at about $2,250,000.

The following selected sampling-works assays show the range of the smelting ore.

Sampling-works assays of ore from Frontenac-Aduddell mines.

Year.	Ore.	Gold.	Silver.	Copper.	Lead.	Zinc.	Iron.	Silica.
	Net lbs.	*Ounces.*	*Ounces.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1907	18,548	0.28	11.70	2.00	6.00	1.5		56
1909	65,010	.50	18.24	4.45	6.80	2.0		43
1909	94,265	.44	22.00	4.50	6.90			35
1909	93,063	.37	19.60	3.10	6.20			41
1907	19,144	.20	8.15	2.10				51
1908	108,720	.44	18.10	4.40		4.0	16	40
1894	18,669	.45	23.10	4.10			20	35
1894	4,930	.94	23.50	3.70				
1908	7,496	.47	19.80	1.85				
1909	20,660	.35	9.05	1.85				
1909	19,517	.20	13.15	2.65				
1909	19,790	.57	14.43	3.05				
1907	6,008	.52	12.00		5.00			
1907	9,752	.20	12.35		14.35	1.2		48
1907	14,066	.19	11.46		22.50	6.5		36
1907	22,893	.20	8.80		11.50	14.8		35
1907	18,533	.22	6.95					59
1909	45,407	.18	6.50					54
1908	12,682	.28	5.30					

DRUID MINE.

The Druid mine is not far from the head of South Willis Gulch, on the northeastward continuation of the Frontenac-Aduddell lode. The workings consist of the Druid shaft, 500 feet deep, connecting with eight levels, and the Searle shaft about 100 feet farther south, connecting with levels at depths of 60, 90, and 140 feet. Connection has been made between the Searle and Druid workings. At the time of survey mining was in progress by lessees in both sets of workings.

The wall rock down to the 350-foot level of the Druid workings is mainly schist of the Idaho Springs formation, but below this granite gneiss predominates. On the 50-foot level of the Druid shaft and the 90-foot level of the old Searle shaft, a dike of monzonite porphyry apparently striking east and west is exposed. It is not visible on the surface and is not cut on any of the other levels.

The Druid workings develop a series of subparallel mineralized fractures striking N. 40°–70° E., two or three being exposed on most of the levels, and dipping 55°–80° NW. Above the 400-foot level the shaft is vertical and is not on a vein; below this it follows the South vein of the Druid series.

The South vein is more regular and persistent than the others and is especially well exposed on the 150, 200, and 300 foot levels. It shows great variation in width, in a few places being narrow and nearly barren and elsewhere attaining the uncommon width of 11 feet. On the 150-foot level east, where it is 11 feet wide, it shows the following cross section:

Section of south vein in Druid mine.

	Ft.	in.
North or hanging wall.		
Slip plane, dipping 80° N., bearing slickensides which pitch 20° W		
Wall rock, soft, gray, crushed, barren		2–4
Quartz, gray, brecciated, carrying some fine pyrite		6
Wall rock, somewhat fractured, cut by many minute pyrite stringers		6
Pyrite, coarse, brecciated, the interstices being occupied by galena and sphalerite, associated with some quartz and barite		1–3
Schist, somewhat altered, cut by a few minute stringers of galena and pyrite	1	8
Wall rock, altered, carrying disseminated pyrite and traversed by irregular veins and lenses of pyrite, with a very little white quartz as a gangue. Many of the pyrite crystals measure one-half inch and a few 1 inch across	7	0

In one place on the 300-foot level east a vein of nearly solid pyrite 1 foot in width is cut by a network of minute stringers of gray quartz carrying some fine galena. In another place a stringer of galena and sphalerite cuts sharply across one composed wholly of pyrite at nearly a right angle, showing conclusively that it was formed later than the pyritic mineralization. In places on this level the galena-blende mineralization is very conspicuous, and one exposure shows 1 foot of vein material composed almost wholly of galena and sphalerite with only a few inclosed fragments of pyritic vein material or wall rock. Vugs are lined with quartz and with crystals of galena and sphalerite.

Ore similar to that of the Druid South vein was characteristic of the Searle vein lying nearly parallel to it but farther south.

The Druid veins north of the south vein are narrow and less persistent and in places are characterized by a different type of mineralization. This mineralization was exemplified in the principal ore shoot on the north vein, which, according to Mr. G. E. Collins, was irregularly pipelike in form and extended from the surface to the 300-foot level. This shoot widened greatly at intervals where certain layers of the gently dipping schists were replaced to an unusual degree by ore minerals. This type of mineralization is also represented by the ore of a new shoot, opened in 1912 subsequent to this survey, on the middle vein on the 150-foot level, where it was 30 feet in length and 2 feet in average width. According to Mr. Collins the ore is essentially a replacement of the more micaceous layers of the schist of the Idaho Springs formation by pyrite, galena, chalcopyrite, and sphalerite, named in order of their abundance. Most of it is highly siliceous. Similar ore was found in a small chamber stope, said to have been the most productive in the mine, just north of the Searle shaft on the 90-foot level, where the ore remnants still visible are mainly a replacement of certain schist layers by pyrite, though there are also some stringers of gray granular quartz and pyrite that clearly cut coarse pyritic ore. The same type of ore is found in what is known as the Svoldi lease on a vein distinct from the Searle but worked through the 90-foot level of the Searle shaft. This vein strikes N. 30° E., dips about 55° N., and appears to be cut off on the north by the Searle vein. Rich ore of the second, more quartzose type is confined so far as now known to the portions of the workings above the 300-foot level, where schist of the Idaho Springs formation is the predominant wall rock. The possibility of similar ore occurring as a replacement of granite gneiss should not, however, be lost sight of, for similar siliceous ore in the Aduddell mine (see p. 270) is in places a replacement of granite gneiss.

The occurrences of veinlets of quartz and pyrite cutting heavy pyritic ore near stopes which carried the siliceous ore and the occurrence locally of galena and sphalerite in the latter indicate that the siliceous ore is probably to be regarded as a phase of the second or galena-sphalerite mineralization, the mechanism of ore deposition being wall rock replacement rather than fissure filling. The siliceous ore of the Druid and Searle mines is probably cogenetic with that of the Aduddell mine, which also in places carries galena sphalerite and also rhodochrosite, minerals characteristic of the second mineralization.

As already intimated the ore of the Druid and Searle workings is of two types. The first, which constitutes the typical ore of the Searle vein and of the South vein of the Druid workings, is similar in general to the commoner ore types from the Frontenac and Aduddell mines, being a heavy sulphide ore bordered by more or less disseminated ore. Most of it is composite, consisting of earlier-formed heavy pyritic ore (pyrite and some chalcopyrite and enargite) and of later-formed ore (galena and sphalerite and some barite), which in many places occupies fractures in the pyritic ore or serves as a matrix for pyritic fragments.

The second or siliceous type of ore, which carries sulphides in much less abundance and is highly quartzose, is essentially a replacement of schist of the Idaho Springs formation by quartz and pyrite and in places also by galena, chalcopyrite, and sphalerite. The replacement has proceeded outward from narrow and in many places scarcely perceptible fractures, and so far as could be learned appears to affect the schist in preference to the granite gneiss and to affect the more micaceous folia of the schist in preference to the more quartzose.

Subsequent to both mineralizations movement took place along a number of the veins, as is shown by slickensided fracture planes on the walls or traversing the ore in many parts of the mine. This movement has not been in one direction only but in several, as is shown by one exposure, where a slip zone on the hanging wall shows horizontal slickensides on one layer and vertical ones on another. The cutting off of the siliceous ore of the Svoldi lease at the Searle vein may be due to such postmineral movement along that vein.

According to Mr. Collins, the coarse pyritic ore of the Searle and South Druid veins is characteristically low grade, carrying from 0.1 to 0.2 ounce of gold and 3 to 5 ounces of silver per ton. Somewhat higher values obtain when copper minerals are present, as in the enargite-rich ore which shows 0.15 to 0.25 ounce of gold, 12 to 18 ounces of silver, and 3 to 13 per cent of copper.

The second mineralization introduced galena and sphalerite and notably increased the content of the ore in both gold and silver. One assay of galena ore from the Searle vein on the 300-foot level gave gold 1 ounce and silver 108 ounces. A sampling-works assay on a shipment from the 300-foot level of smelting ore rich in galena and sphalerite showed gold 0.6 ounce and silver 70 ounces.

The richest ore of the mine is the siliceous type, which as already stated is in the main a replacement of the schist, and this ore has formed the main resource of the mine. According to Mr. Collins, the average metal content of the siliceous ore shipped from the Svoldi lease in April to July, 1911, inclusive, was gold 3.02 ounces and silver 30.17 ounces. The average composition of the siliceous ore shipped up to June, 1912, from the siliceous-ore shoot on the Druid middle vein was as follows:

Assay of siliceous ore from shoot of Druid middle vein.

	Ounces.
Gold	2.50
Silver	22.27
	Per cent.
Insoluble (mainly silica)	70.2
Iron	11.0
Sulphur	12.7
Copper	1.1
Lead	2.5
Zinc	1.2

An assay of a sample of siliceous ore collected by the writer from the Svoldi lease showed gold 1.66 ounces and silver 24.54 ounces.

KOKOMO MINE.

The Kokomo mine is on the east side of South Willis Gulch, at an elevation of 8,950 feet. The workings are on the northeastward continuation of the Frontenac-Aduddell-Druid lode, on a single vein striking about N. 55° E. and dipping about 70° NW. The development work consists of a shaft which follows the vein, with levels at depths of 200, 300, 400, and 500 feet. The 200-foot level was not accessible for study.

In mineral character the vein is very similar to those developed in the Druid workings. Certain portions are wholly pyritic, as on the 500-foot level about 170 feet southwest of the shaft, where 4 feet of coarse pyrite with very little gangue is exposed. Material of this kind is too low grade to mine. In other portions of the vein, as on the 400-foot level 200 feet west of the shaft, enargite is an abundant ore mineral. It is intimately intergrown with pyrite and the two are plainly contemporary.

In portions of the vein galena and sphalerite are present. None of this ore was seen in place, and specimens on the dump did not exhibit its relations to the pyritic ore. It consists of galena, sphalerite, gray quartz, and subordinate pyrite. One lot of this ore from the 500-foot level west averaged about gold 0.12 ounce and silver 2 to 3 ounces. Some fluorite has been found in the eastern portion of the vein, and according to Mr. Percy Alsdorf some tellurides of gold occur.

An interesting feature of the older drifts is the occurrence of incrustations of beautiful soluble salts on the timbers and wall rock. On the 400-foot level east of the shaft blue-green stalactites of iron and copper sulphates are locally present and some are 6 inches in length. In other places white crystals of alum coat the walls, having been deposited by sulphate waters descending through the vein and evaporating on the walls of the drift.

The following sampling-works returns give an idea of the range in value of the ore:

Sampling-works assays of ore from the Kokomo mine.

Year.	Ore.	Gold.	Silver.	Copper.	Lead.
	Net lbs.	*Ounces.*	*Ounces.*	*Per ct.*	*Per ct.*
1893	225	1.25	29.00		
1897	6,840	1.10	16.90		
1901	2,049	.18	12.80		11.50
1901	20,642	.34	13.70		7.00
1901	5,290	.32	15.70	5.00	
1902	1,330	.46	16.50	7.10	
1902	590	.32	24.60	4.00	

The last three lots probably represent ore-carrying enargite.

ANCHOR MINE.

The Anchor mine is on the southeast side of South Willis Gulch at an elevation of about 8,700 feet. At the apex the vein strikes slightly east of north and dips 45° to 65° N. The vein is developed by a shaft, which is about 500 feet deep on the incline, but which was idle at the time of this survey, so that the underground workings were not seen.

The ore most abundant on the dump was an irregular association of white to dark-gray quartz and pyrite. Another abundant type consisted of an irregular association of white quartz, white to pale-purple fluorite, and pyrite. Some specimens showed molybdenite in a finely divided state abundantly associated with quartz, fluorite, and pyrite; and one specimen, a $\frac{1}{2}$-inch veinlet, showed $\frac{1}{16}$-inch to $\frac{1}{8}$-inch bands of molybdenite inclosing a center which was largely quartz and pyrite. Other specimens showed abundant enargite intergrown with pyrite and fluorite and apparently contemporaneous; and still others showed chalcopyrite abundantly associated with pyrite. Some small occurrences of galena and sphalerite in a quartz gangue were noted, but their relationship to the other vein minerals was not clear. The smelter returns show that in some of the ore shipped they were abundant.

There are very wide variations in the value of the ore and the proportion of the metals present. A comparison of sampling-works assays on 40 lots of smelting ore shows that in most shipments the value is wholly in gold and silver. In this type of ore the gold commonly ranges from 0.2 and 0.7 ounce and the silver from 8 and 20 ounces. Another type of ore carries lead not exceeding 30 per cent and silver not exceeding 45.15 ounces. Copper is seldom sufficiently abundant to be paid for, being below 1.5 per cent in most of the ore, but exceptionally reaches 4.5 per cent. The average metal content of the smelting ore shipped in 1910 was gold, 0.44 ounce; silver, 12.8 ounces; lead, 3.2 per cent; and copper, 0.2 per cent.

The Anchor mine was opened about 1890, acquired by the present company about 1907, and worked by them continuously until the spring of 1911.

CHASE MINE.

The Chase mine is near the crest of the divide between Russell and South Willis gulches. The workings are mainly on the Chase vein, which was first developed through the Pullman shaft but is now worked solely through the Chase shaft 200 feet farther west. The Chase shaft, which follows the vein, is 500 feet deep and connects with seven levels, on six of which the workings develop only the Chase vein and its branches. On the 300-foot level there has been some development on the Bosen-Plume and Decatur veins.

The prevalent wall rock is Idaho Springs formation with minor amounts of pegmatite. Monzonite porphyry is exposed on the surface north of the shaft, in many places on the 400-foot level, and less abundantly on the 300-foot and 500-foot levels. Figure 49 shows the geologic relations in the 300-foot and 400-foot levels.

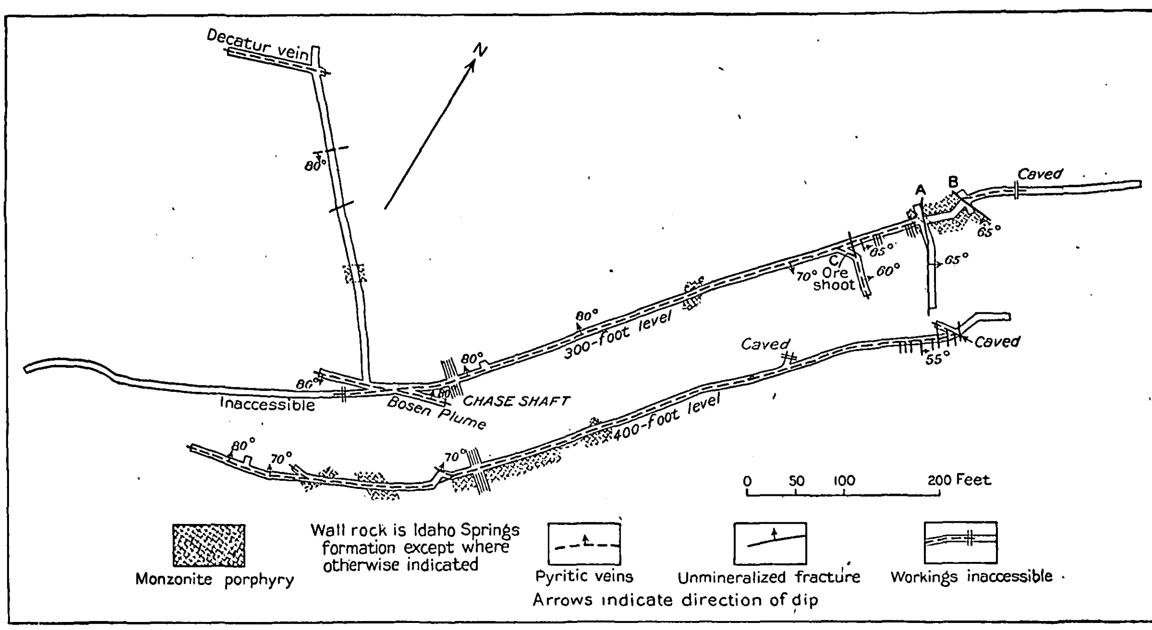


FIGURE 49.—Geologic plan of portions of the Chase mine.

The Chase vein occupies a persistent and well-defined fracture zone, striking northeast and varying from verticality to steep northwest or southeast dips. In a few places it consists of a narrow and barren fracture, but it is usually well mineralized. A characteristic exposure on the 300-foot level 240 feet east of the shaft shows the vein sharp walled and 6 inches wide. It consists mostly of coarse pyrite with some white quartz gangue. The schist walls carry disseminated pyrite in decreasing abundance for about 6 inches from the vein. The Chase vein is particularly well exposed in the stopes on the 500-foot level east, where it varies from 8 to 12 inches in width. It consists of cubical pyrite in coarse crystals, some of which are 2 inches across, lying in a white clayey matrix, which, when examined under the microscope, appears to consist wholly of small grains of quartz and minute flakes of sericite. Purple and green fluorite is abundant in places, and tennantite is exceptionally present. In one place there is nearly 3 inches of pure fluorite associated with very coarse pyrite. At another place on the 500-foot level the Chase vein shows 3 inches of pyrite traversed through its central part by a ½ to 1 inch streak of galena and sphalerite, probably a later mineralization.

It is noteworthy that wherever porphyry is associated with the vein the mineralization is later than the porphyry intrusion. What appears at first sight to be an exception to this rule is found on the 300-foot level east, where the vein is cut off by a body of porphyry 50 feet through. Close inspection shows, however, that the Chase vein penetrates the porphyry for 10 feet or so until cut off by a fault (A, fig. 49), and that the porphyry is bounded on the east by a fault plane (B, fig. 49). The vein east of this porphyry mass aligns with the Chase vein and has generally been assumed to be its eastward continuation. According to Mr. H. C. Willis, however, it is characterized by more coarse pyrite and fluorite and by much lower values than the Chase vein. The fault (A, fig. 49) is a strong one, showing locally 3 inches of gouge, and it is quite possible that the vein to the east may be the Decatur or some other vein faulted into alignment with the Chase.

Another feature of interest is the presence on the 300-foot and 400-foot levels, 450 to 500 feet east of the shaft, of a series of parallel mineralized cross fractures striking about N. 40° W. and dipping 40°–65° NE. For 100 feet west of the fault 15 to 20 of these veinlets from one-half inch to 5 inches wide are exposed in the south wall. Similar veinlets enter the north wall also, but these do not all correspond with those in the south wall. The cross fractures occupied by the veinlets were formed previous to the mineralization, and were mineralized at the same time as the Chase vein, for in places the sulphides can be traced continuously from the Chase fissure into these cross fissures. On the 300-foot level, at the place (C, fig. 49) where one of the cross veins just described is connected by a diagonal vein with the Chase vein, one of the best ore shoots of the mine extended for some distance above the level but not far below it.

In general, the best ore in the Chase vein seems to be that in which tennantite is most abundant. The presence of fluorite is not an indication of richness.

The Bosen-Plume vein (see fig. 49) has been developed by short drifts west of the shaft on the 300-foot level. As there exposed, it consists of from 1 to 7 inches of coarse pyrite and white quartz.

The Decatur vein is also exposed on the 300-foot level, where it is reached by a crosscut from the Bosen-Plume drift. It stands nearly vertical in most places. At the west face of the drift 3 feet of coarse pyrite and quartz, bordered by walls of sericitized schist which carry disseminated pyrite, is traversed by several subsidiary pyrite veinlets, giving a total width of vein of 5 feet. Postmineral movement along the walls of the vein has locally produced 2 to 3 inches of gouge and seams of crushed pyrite which traverse the main sulphide streak.

As is apparent from the description already given, the ore of the Chase mine is of the pyritic type, except for small amounts of galena-sphalerite ore in the Chase vein. The presence of fluorite in the Chase vein and of enargite in the Bosen-Plume is noteworthy.

At the time of this survey only smelting ore was shipped from the Chase mine. Sampling-works assays of 34 lots of smelting ore, aggregating 193 tons, shipped between 1893 and 1908, show: Gold, 0.29 to 8.2 (average, 1.98) ounces; and silver, 1.9 to 28.4 (average, 6.53) ounces. The average content of the smelting ore shipped in 1910, according to sampling works assays, was gold 2 ounces and silver 5 ounces. Few assays show more than 1.5 per cent copper, not enough to be paid for.

WAR DANCE MINE.

The War Dance mine, on the hill between Russell and Willis gulches, was originally worked for its sulphide ore, but in February, 1908, gold telluride ores of much higher grade were discovered close to the sulphide ore and have since formed the output of the mine. Some valuable telluride ore has also been recovered from the old dumps. The mine is developed by a shaft connecting with short levels at 80, 140, 200, 325, and 375 feet. The irregularity shown in the distribution of the high-grade ore is reflected in the notable irregularity of some of these levels.

The sulphide vein, though now exposed at only a few points in the mine, strikes in general northeast and is characterized by steep dips. It consists of pyrite and gray quartz with some tennantite. Enargite has also been reported. Vugs are common and are lined with crystals of these minerals. The vein is well exposed east of the shaft on the 325-foot level, where it strikes N. 30° E., is vertical, and is 3 feet in width. At the shaft on the 80-foot level it strikes N. 55° E. and dips 70° SE.

Though no galena and spahlerite were seen in this mine by the writer they are known to have been present in some of the ore, and lead and zinc appear in one of the assays. As in other mines of the district where these minerals occur in a vein predominantly pyritic, they were probably introduced at a later period of mineralization. Ore from the sulphide vein shortly below the 80-foot level assayed only 0.2 ounce gold and 30 ounces silver, whereas a ton lot of near-by telluride ore ran 20 ounces gold and 3.5 ounces silver.

The rich ore of the mine, in contrast to the sulphide ore, occurs along a complex network of fractures, some paralleling the sulphide vein and others being highly inclined to it. The characteristic minerals of this ore are purple fluorite, pyrite, and locally a pale-yellow telluride of gold in platelike crystals not more than 2 millimeters or so in length. Exploration, though mainly confined to the vicinity of the sulphide vein, has already shown that rich telluride ore may occur at some distance therefrom and along fractures, some of which are clearly not branches of the main sulphide vein and some of which cut across it. Though some evidence suggests a relationship between the sulphide and telluride mineralizations such a connection is by no means proved, and even if proved would not preclude the occurrence of valuable telluride ore along minor fractures at some distance from the main veins. The fluoritic ore is not confined to large fracture zones (see p. 114) but has developed in many places through replacement of the country rock by solutions entering along very minute fractures. It would seem to be the part of wisdom therefore to prospect thoroughly the ground for some distance on either side of the sulphide vein.

The fluoritic vein material occurs in two ways. It forms sharp-walled veins, as on the 375-foot level 30 feet southwest of the shaft, where it occurs in two parallel veins 7 and 4 inches wide. The 7-inch vein shows 1 to 1½ inches of white quartz next one wall, 5 inches of nearly solid granular purple and red fluorite, and one-half inch of gray quartz next the other wall. Near the contact between the quartz and fluorite bands occur some aggregates of pyrite whose maximum width is one-half inch. The other vein, parallel to the first, consists mainly of fluorite with a little pyrite through it, especially near the walls. Tennantite is found in places in these veins. Both veins send off numerous branches of fluorite and pyrite into the bordering schists. Some vugs in these branches are lined with crystals of quartz and pyrite, and the dark-gray schist bordering them has been bleached white. The material of such large fluoritic veins as those described above is characteristically of too low grade to pay for mining.

In the second mode of occurrence the fluorite and associated minerals form smaller veinlets or somewhat irregular replacements of the wall rocks. One such occurrence is shown on the 325-foot level 40 feet southwest of the shaft, where the wall rock is mineralized for a width of 4 to 5 feet by a network of veinlets carrying pyrite, fluorite, quartz, and in places gold telluride.

In a few places, as on the northeast drift of the 140-foot level, the fine-grained pegmatite wall rock has been brecciated, and more or less fluorite occurs in the matrix. At one point the brecciated zone is 3 feet in width.

It is clear that in general the tellurides are not abundant in either the sulphide vein material or the coarse fluorite but are characteristically found in the smaller veinlets and in the wall rock bordering coarse fluoritic veins. Assays in one place showed that the altered schist near a coarse fluorite vein averaged about $5 per ton in gold and that the coarse fluorite contained from a trace to $3 per ton in gold. The wall rocks in the mine are schist of the Idaho Springs formation and granite pegmatite, and valuable ore has been formed by the replacement of both.

In general it seems probable from the relations shown in this mine and in others in its vicinity that the fluoritic mineralization is closely related genetically to the development of the pyrite-chalcopyrite-gray copper veins. An exposure suggestive of such a connection occurs on the 250-foot level northeast of the shaft, where a vein 1½ feet wide consists mainly of pyrite and gray quartz with some tetrahedrite. The gray quartz gangue contains fluorite in some places, and quartz coats fluorite crystals that line a large vug.

All the telluride found in the mine is similar in appearance. It forms flakes or plates of pale brass-yellow color which frequently show numerous striations in one direction. In most of the ore now being mined the plates show no evidence either of decomposition or of deposition of gold.[1] In spite of this fact assays show marked variability in the ratios of gold and silver in the ore. The telluride was not analyzed, but from its physical characters and from commercial assays it appears to correspond most closely to sylvanite or krennerite. Its silver content is too high for calaverite.

The variable character of the telluride ore from this mine is shown by the following selected sampling-works assays:

Sampling-works assays of telluride ores from War Dance mine.

Year.	Ore.	Gold.	Silver.
	Net pounds.	*Ounces.*	*Ounces.*
1908	5,516	14.84	5.82
1908	6,491	2.96	3.30
1908	13,859	24.08	9.35
1909	7,732	6.87	2.90
1909	13,495	7.63	6.65
1910–11	2,640	41.00	10.53
	5,452	6.48	4.20
	9,360	21.88	56.72
	571	71.09	28.10
	8,510	26.26	11.18

[1] Lehner and Hall have shown that tellurides of gold can precipitate metallic gold from its solutions. See Am. Chem. Soc. Jour., vol. 24, p. 918, 1902.

The average value of over 1,000 tons of telluride ore shipped from the War Dance mine in 1911 is reported by the company to have been gold, 1.32 ounces and silver 1.78 ounces. Much of this ore was, however, obtained from picking over the old dump and was below the average of that obtained direct from the mine.

In sharp contrast to the above are the assays of ore from the sulphide vein.

Assays of sulphide ores from War Dance mine.

Ore.	Gold.	Silver.	Copper (wet).	Lead.	Zinc.
Net lbs.	*Ounces.*	*Ounces.*	*Per ct.*	*Per ct.*	*Per ct.*
2,724	0.43	69.00	7.50	....	....
1,402	.40	55.00	....	....	....
9,000	.55	31.00	5.20	....	....
13,130	1.20	62.00	8.90	14.00	3.50

SILVER DOLLAR VEIN.

The Silver Dollar vein is just west of the junction of Russell and Willis gulches. It strikes about N. 50° E. and appears to be the westward continuation of the Hampton vein. The development work consists of a shaft 185 feet deep with levels at 95 feet and 185 feet. The 95-foot level extends 35 feet west of the shaft, but has no east drift. The vein on this level strikes N. 45° E. and dips about 60° NW. At the face the vein is tight and 1½ feet in width.

The 185-foot level extends 340 feet west of the shaft. The dip on this level is 50°–55° NW. The drift east of the shaft is caved. In a stope near the face the vein has a width of 1 to 1½ feet and is between tight walls. It consists mainly of pyrite and enargite in nearly equal amounts. Vugs not exceeding 1½ inches across are common and are lined with crystals of quartz, pyrite, and enargite. In a stope 170 feet west of the shaft the vein which has a width of 2 feet, is mostly coarse pyrite next the walls with a central band about 1 foot wide composed of pyrite and abundant enargite. In all the polished sections of the ore studied these two minerals unquestionably belong to the same period of mineralization.

A little galena and sphalerite were present in some of the ore on the dump, but pyrite and enargite formed the great bulk of it. Fluorite was present locally, generally in vugs with quartz in the pyritic portions of the vein.

No reliable data were obtainable in regard to the value of the ore or the production.

HAMPTON MINE.

The Hampton mine is in Russell Gulch a short distance above its confluence with Willis Gulch. The vein, which appears to be the eastward continuation of the Silver Dollar, strikes about N. 50° E. and near the surface dips 70° NW. It is developed by a shaft, which was idle at the time of survey and was not entered. The ore on the dump showed double mineralization, first with coarse pyrite and later with pyrite, galena, and tennantite. Some of the later veinlets had a center of nearly white cherty silica, which appears to have been deposited in the last stage of the galena-tennantite mineralization. According to Mr. Percy Alsdorf some enargite is locally present in the ore from this mine.

POWERS VEIN.

The Powers vein, just northwest of the junction of Willis and Russell gulches, is developed by three shafts, one of which is equipped with shaft house and steam hoist. At the time of this survey the property had been idle for a number of years and could not be entered. The ore on the dump was similar to that of the Silver Dollar vein (p. 278), except that fluorite appeared to be slightly more abundant and to have replaced some of the minerals of the schist walls. Enargite and coarse pyrite are so intergrown in this ore as to show plainly that they belong to the same period of mineralization.

The following are sampling-works assays of smelting ore shipped between 1898 and 1907:

Sampling-works assays of ore from Powers vein.

Ore.	Gold.	Silver.	Copper.	Silica.
Net lbs.	*Ounce.*	*Ounces.*	*Per cent.*	*Per cent.*
6,511	0.28	22.00	19.10	36
6,028	.12	19.90	8.00	35
6,718	.20	20.20	16.00	32
9,978	.10	10.00	7.20	59
13,319	.08	1.70	15.30	30
4,334	.14	16.80	14.50	44
4,216	.12	12.86	11.60	44
1,290	.28	31.70	18.50	28
8,629	.22	21.70	16.90	24
1,468	.28	22.70	18.10	....

IROQUOIS VEIN.

The Iroquois vein was opened in the sixties but was not extensively operated. The present company, which has controlled the property since 1908, has done development work but has shipped very little ore. The vein, which trends northeast across Russell Gulch just above the mouth of Willis Gulch, is developed by a shaft, which was idle at the time of this survey and could not be entered. Some of the ore on the dump consisted wholly of coarse pyrite with a little quartz as gangue, but the most abundant ore consisted of galena and sphalerite, the latter in part resinous and in part dark colored. The relations between the pyritic and the galena-sphalerite ore were not clearly shown. Both types of ore are traversed by minute veinlets of quartz and cherty-looking silica which are distinctly later. Much fluorite, varying from colorless to green and purple, is associated with some of the pyritic ore. The fluorite, with some quartz, occurs in vugs in this ore and as veinlets cutting it and therefore appears slightly later. Some enargite is also reported.

Sampling-works assays of two lots of smelting ore, of 4,975 and 8,550 pounds, shipped from the Iroquois mine in 1910, gave respectively, gold 0.16 ounce, silver 10.9 ounces, lead 6.45 per cent; and gold 0.36 ounce, silver 12.7 ounces, lead 10.15 per cent.

PROSPECTS ON RIDGE BETWEEN ELKHORN GULCH AND PLEASANT VALLEY.

Some abandoned prospects near the summit of a hill about 1,000 feet southeast of the Moose mine lie within a large area of monzonite porphyry. No well-defined vein is recognizable on the surface, but the porphyry has been brecciated and is traversed in many directions by small seams (mostly under one-fourth inch in width) of green and pink fluorite with a little associated pyrite, chalcopyrite, and quartz. In other seams fluorite is rare or absent, only gray quartz, pyrite, and chalcopyrite being present.

Microscopic study indicates that the fluorite, quartz, and pyrite of the veins were formed contemporaneously. The only wall-rock alterations are sericitization and the development of a little fluorite. Inclusions, which are exceedingly abundant in the vein quartz, are in part arranged in bands and in part irregular; they show a liquid filling and a bubble but no solids.

HILL AND BUNK HOUSE VEINS.

The Hill and Bunk House veins are on the southeast side of Banta Hill. The two veins are developed by the Hill shaft, which is said to have a depth of 465 feet, but which was full of water below the 150-foot level at the time of this survey. The drifts at the 100 and 150 foot levels were also largely inaccessible.

The Hill shaft is sunk in the Idaho Springs formation just south of a large mass of monzonite porphyry, which is also exposed 70 feet west of the shaft on the 150-foot level. The Hill vein strikes N. 70° W. and dips 58°–60° SW. It is in most places a tight barren fracture, about parallel to the schistose structure, which continues across the schist-porphyry contact and is therefore younger than the porphyry. The Bunk House vein, which strikes N. 48° E. across the schistosity and stands nearly vertical, cuts the Hill lode about 50 feet west of the shaft on both levels. It is marked by a schist breccia a few inches to 4 feet wide that is barren except at the ore shoot.

Both the 100 and the 150 foot levels expose a spur which leaves the Hill vein 40 feet west of the junction of the Hill and the Bunk House and joins the latter 50 feet to the northeast. The principal ore body, which is in this spur and along the Bunk House vein where it is joined by the spur, contains 3 to 4 feet of more or less mineralized brecciated country rock cut by stringers of sulphides 4 inches in maximum width.

The ore consists of galena, light and dark sphalerite, and minor amounts of chalcopyrite and pyrite. These metallic minerals are accompanied by abundant white quartz, some barite, and exceptionally by fluorite. It is said that the Hill vein is mineralized in the porphyry beyond the schist contact on the 150-foot level. The porphyry on the dump does carry some disseminated pyrite and joints in this rock are coated with a film of the same mineral.

Some small shipments of very siliceous smelting ore made in 1900 and 1906 carried about 0.20 ounce gold, 20 ounces silver, 24 per cent lead, and zinc not exceeding about 4 per cent. A 30-ton mill on the property is now largely dismantled and does not appear to have seen much service.

MOOSE MINE.

The Moose mine, on the south side of Pleasant Valley at an elevation of about 8,850 feet, is developed by a shaft which was idle at the time of survey, so that the workings could not be seen. The mine is at the border of a large area of monzonite porphyry, and the wall rocks are porphyry and a breccia of schist, pegmatite, granite gneiss, and porphyry fragments. The ore belongs mainly to the pyritic type and seems in the main to be a metasomatic replacement of the matrix of the breccia. Much of the pyrite and chalcopyrite are exceedingly fine grained. An association of galena, sphalerite, pyrite, and chalcopyrite is present in certain specimens, which, however, are rather sharply distinct from the purely pyritic ore and were probably mineralized somewhat later. Rhodochrosite is very abundant in some parts of the mine, but it is uncertain whether it is associated with the pyritic or the galena-sphalerite mineralization.

BELLEVUE MOUNTAIN AND UPPER PART OF VIRGINIA CANYON.

CROWN POINT AND VIRGINIA MINE.

The Crown Point and Virginia mine is near the head of Virginia Canyon, the main shaft being at an elevation of about 9,300 feet. The workings could not be entered, but the mine maps show an inclined shaft dipping northeast and extensive workings apparently developing at least two veins. All the ore on the dump was of the pyritic type. The main or Crown Point vein has a strike along the outcrop of about N. 50° W. and a dip of about 75° NE. It is apparently the continuation of the Belman vein, which it should closely resemble in character. (See pp. 283–284.)

Sampling-works assays of 17 lots of smelting ore, aggregating 102 tons, shipped between 1897 and 1901, show gold, 0.24 to 3.72 (usually 1 to 2.50) ounces; silver, 1 to 12 (usually 3 to 6) ounces; copper (wet), 0.3 to 18 per cent; silica, 21 to 62 (usually 40 to 60) per cent.

The following are assays of concentrates shipped in 1901:

Assays of concentrates from Crown Point and Virginia mine, 1901.

Ore.	Gold.	Silver.
Net lbs.	*Ounces.*	*Ounces.*
22,280	1.35	3.70
21,710	1.12	2.80
39,142	1.39	2.05
34,666	1.06	2.20
4,543	1.88	4.00

The gross total production of the mine is said to have been about $500,000.

CLARISSA MINE.

The Clarissa shaft is 300 feet northeast of the Virginia Canyon wagon road and about 1,500 feet southeast of the Gilpin–Clear Creek county line. The shaft (see fig. 50) follows the Clarissa vein to the 30-foot level but below that level lies north of the vein, necessitating a 50-foot crosscut to the south on the 185-foot level.

The collar of the shaft is 200 feet west of the contact between granite gneiss and Idaho Springs formation. All the wall rock in the workings studied is granite gneiss except for the small areas of schist of the Idaho Springs formation shown in figure 50.

Three veins are shown by the development. From the strikes and dips of these veins their intersections should shift northeast with depth, and this is clearly shown to be the case in the mine workings. The Clarissa vein strikes on the average about N. 85° W. and dips about 65° N.; it is exposed in all of the levels. The Blue Bell vein strikes on the average about N. 45° W. and dips 55° NE. in the lowest level and 80° NE. in the upper levels. On the 70-foot level it joins the Clarissa about 80 feet east of the shaft, continues with it for about 30 feet, and then resumes its independent course. On the 135-foot level it is exposed in the crosscut about 60 feet east of the shaft. Its junction with the Clarissa is presumably somewhere in the inaccessible part of this level about 100 feet east of the shaft. On the 185-foot level the Blue Bell vein is cut in a drift about 25 feet east of the shaft and again 130 feet east of the shaft at a point where it joins the Clarissa vein, with which it runs for the last 70 feet of the drift. The East vein, possibly the Belman, strikes on the average about N. 50° W. and dips 60° NE. It is exposed in the extreme east end of the 70 and 135 foot levels and probably in the 30-foot level. It has not yet been cut by the east drift on the 185-foot level.

The mineralization is similar and probably contemporaneous in all three veins. Postmineral movement and possibly movement previous to mineralization has, however, offset the Blue-Bell fracture along the Clarissa fracture and offset the Clarissa along the East vein. The Blue Bell seems to have been offset along the Clarissa fracture for 30 feet on the 70-foot level and for at least 70 feet on the 185-foot level. The Clarissa in turn is sharply cut off by the East vein and the offset eastern portion has not yet been found. Slickensides striæ on the wall pitch 60° NW. On the 135-foot level, where the Clarissa vein is cut by the crosscut from the shaft, a mineralized fracture striking N. 25° W. and dipping 70° E. displaces the vein nearly 1 foot.

The Blue Bell vein has been stoped to some extent on all levels. The East vein has been stoped to an unknown height above the 135-foot level, and at the east end of the 70-foot level, where the stope is caved. In 1911 development was proceeding entirely through the lower tunnel level. Above the 70-foot level the old shaft is very small and can be used only for hoisting water; below this level it has been enlarged and retimbered. A new working way consisting of a winze from the 135-foot to the 185-foot level has been sunk entirely on the Clarissa vein.

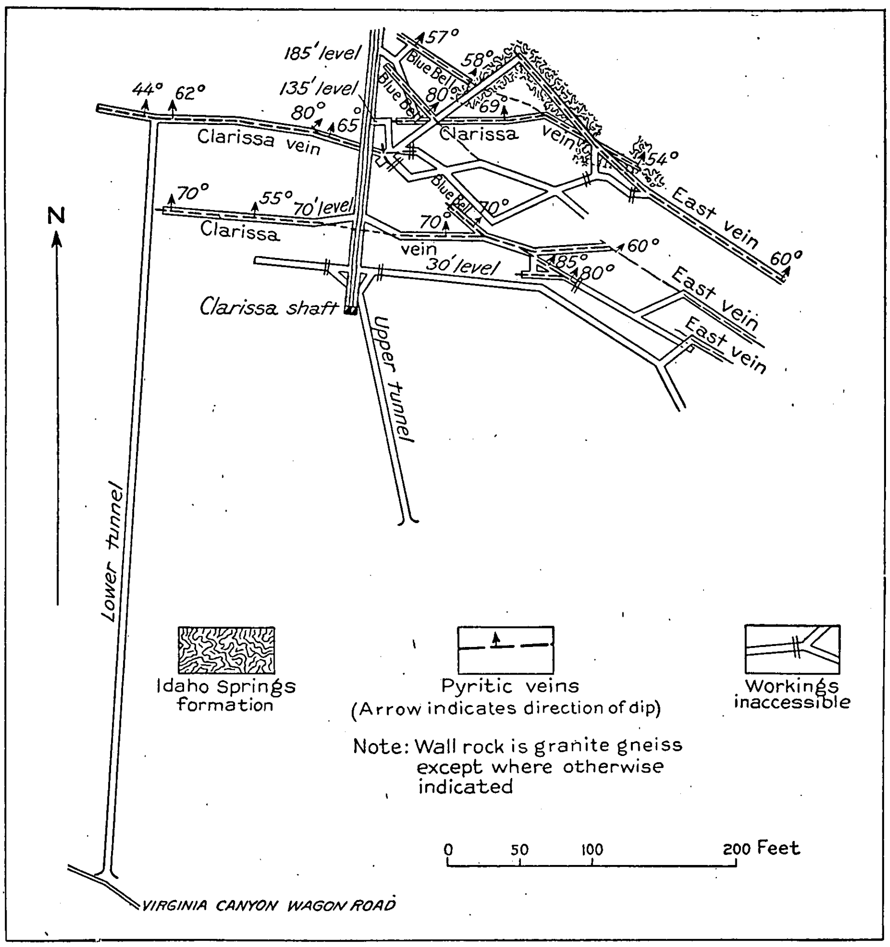


FIGURE 50.—Geologic plan of portions of the Clarissa mine.

The ore from the stopes above the 70-foot level is said to have carried some galena, but that shipped in 1909–10 from the lower levels carried only gold, silver, and copper in valuable amounts. The average assay value of this ore was 1.15 ounces gold, 5.58 ounces silver, copper less than 1 to 2.7 per cent. Some ore assayed as high as 3 ounces gold and 9 ounces silver and other ore as low as 0.66 ounce gold and 2.7 ounces silver. Where the copper content is low the precious-metal content is low also.

FAIRMONT TUNNEL.

The Fairmont tunnel is on the southwest slope of Pewabic Mountain at an elevation of a little over 9,250 feet. (See fig. 51.) The first vein cut in the tunnel is 265 feet from the portal and is in general narrow, showing from 1 to 2 inches of galena, sphalerite, and pyrite. It has been stoped somewhat for 40 feet east of the tunnel.

The second or main vein is cut about 430 feet from the portal. In the stope near the east face of the drift this vein ranges from 1½ inches to 1 foot in width and shows solid galena and resin sphalerite, some of the sulphide crystals being 1 inch in diameter. At a point about 120 feet west of the tunnel a portion of the vein goes into the south wall, following the contact between the schist and a dike of bostonite porphyry; 3 inches of solid sulphides are exposed here. West of this point the drift is mainly in porphyry and follows a post-mineral fracture plane and several small galena-sphalerite veinlets. The veins in one place cut the porphyry sharply and are plainly younger; elsewhere these relations have been obscured by movements which fractured both ore and porphyry. The porphyry dike cut by this drift is probably the one exposed in the main tunnel. This vein has been worked through stopes and winzes for most of the length of the drift.

A third vein is cut about 650 feet from the portal. It is narrow and in places consists only of a few inches of gouge but elsewhere shows several veinlets of galena, sphalerite, and pyrite from one-half to 1 inch across. Some of these have been crushed by postmineral movements parallel to the vein.

As shown by the underground studies and by examination of the dump most of the ore is of the galena-sphalerite type. Small vugs are very common and are usually lined with crystals of white quartz, some of which are transparent. Some of the ore is a breccia of schist fragments cemented by sulphides and quartz, and some of the schist fragments carry pyrite either irregularly disseminated or arranged in narrow bands. The veinlets of galena and sphalerite truncate these bands sharply, a relation which proves some mineralization with pyrite previous to further fracturing and mineralization with galena, sphalerite, and pyrite.

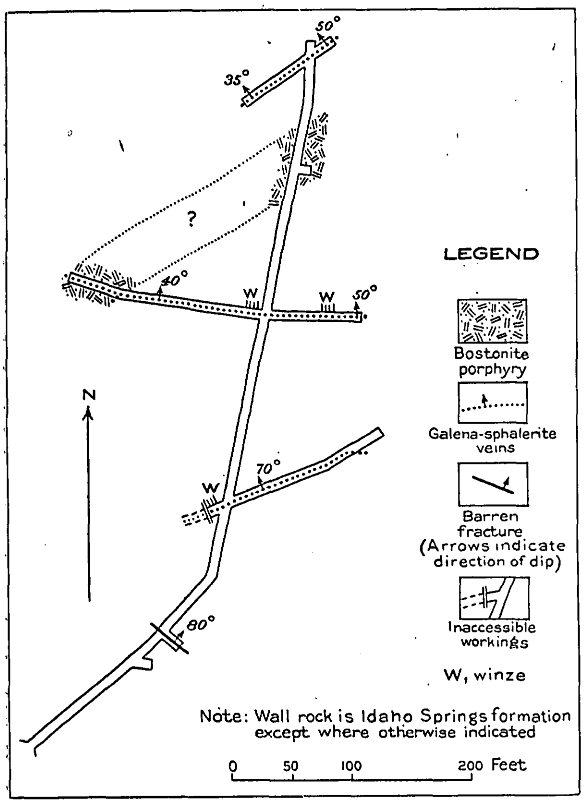


FIGURE 51.—Geologic plan of Fairmont tunnel. Surveyed by hand compass and pacing.

No data were obtained in regard to the value of the ores.

BELMAN VEIN.

The Belman vein, which is exposed on the surface at the head of Virginia Canyon near the west base of Pewabic Mountain, is developed by several shafts now abandoned. It has also been cut at a vertical depth of about 1,675 feet by the Big Five tunnel, which connects with drifts in both directions, aggregating 800 feet in length. (See Pl. XXI, *B*, in pocket.) In these drifts the vein strikes N. 67° W. and dips 60°–70° NNE. The tunnel cuts an important ore shoot, which extends eastward about 180 feet and westward at least to the end of the drift (420 feet). Stopes on this shoot are 110 feet in maximum height. The drifts have been run on the footwall side of the vein, and its total width is seen only where the tunnel crosses it. The section of the vein here is as follows:

Section of Belman vein in Big Five tunnel.

	Ft.	in.
Gouge, on footwall		½
Schist, crushed, carrying small lenses of pyrite and more or less disseminated pyrite		3
Veinlet of quartz, pyrite, and chalcopyrite		2
Gouge		2
Pyrite and chalcopyrite with a little quartz as gangue		7
Quartz, cut by stringers of darker quartz (maximum width, one-half inch), carrying pyrite and chalcopyrite	2	6
Tight slip plane.		
Quartz, heavily mineralized with pyrite and chalcopyrite	2	0
Gouge, on hanging wall		1

The schist for 30 feet above this vein is cut by many parallel slip planes, is considerably altered, and contains abundant disseminated pyrite. A well-marked fracture zone separates this altered schist from the schist which is little altered and unmineralized.

The footwall pay streak of the Belman vein ranges from 3 to 9 feet in width and shows very similar characters throughout. Commonly, it contains 2 or 3 bands, 2 to 14 inches wide, of good pyritic ore in a filling of quartz or of silicified crushed schist that contains only disseminated pyrite. Chalcopyrite is subordinate in all of the ore; it is said that little or none occurs in the backs of the stopes east of the tunnel, and that the ore is much poorer than that in the shoot west of the tunnel, where chalcopyrite is more abundant. Tennantite is said to have been found in some of the richest ore, generally associated with the chalcopyrite and with dark-gray quartz.

Postmineral movement has produced slickensides in the ore and crushed the pyrite and quartz. The slickensided faces show polished pyrite in a few places, but are generally blackened by the crushed pyrite.

Figures for computing a satisfactory average for the metal content of the vein are not available, but 13 sampling-works assays of smelting ore recently shipped show gold, 0.52 to 1.16 ounces; silver, 2.2 to 6.4 ounces; copper, from less than 1.5 to 3.55 per cent; silica, 45 to 62 per cent; and iron, 16.5 to 26.9 per cent.

LAKE AND WINDSOR CASTLE VEINS.

The Windsor Castle shaft is on the east side of Virginia Canyon just above the Two Brothers tunnel at an elevation of 8,850 feet. The connecting Lake lower tunnel starts near by at the side of the main wagon road. (See fig. 52.)

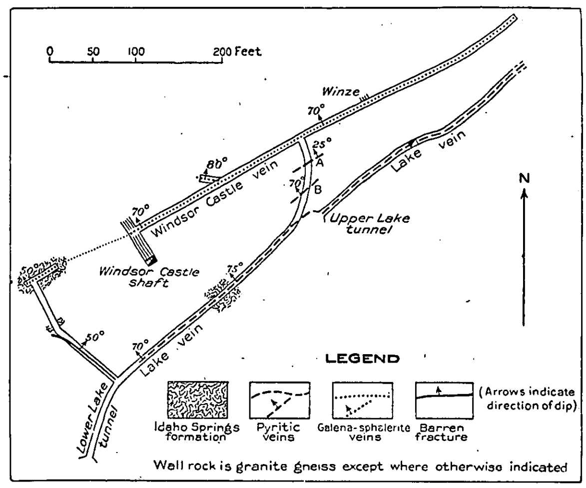


FIGURE 52.—Plan of Lake tunnel and connecting workings on the Windsor Castle vein. Surveyed by hand compass and pacing.

The Windsor Castle vein was examined on the lower tunnel level and for a short distance below it in the shaft. It is a strongly and evenly mineralized vein which has been stoped for most of its length as exposed on the tunnel level. Several excellent exposures show a width of 1½ feet of nearly solid sulphides—pyrite and sphalerite in nearly equal amounts and subordinate galena. This portion of the vein is sharp walled and appears to be a true fissure filling. The wall rock, however, carries disseminated pyrite for 1 to 2 feet from the vein proper.

The Windsor Castle vein appears to be the eastward continuation of the Bald Eagle vein. According to Mr. Hal Sayre, owner of the property, no large amounts of rich silver minerals were found in any part of the Windsor Castle vein.

Sufficient figures for computing a satisfactory average of the metallic content of the ore are not available, but sampling-works assays of seven lots of smelting ore aggregating about 30 tons, shipped from 1897 to 1909 inclusive, show gold, 0.08 to 0.68 ounce; silver, 8.4 to 23 ounces; copper (wet), from less than 1.5 to 2.8 per cent; lead, 4 to 16 per cent; zinc, 5 to 16 per cent.

Veins marked A and B in figure 52 and the Lake vein are not heavily mineralized where exposed in these workings. The vein at A is tight, showing 1 to 2½ inches of gray quartz carrying some pyrite. The vein at B shows 4 inches of gray quartz and silicified granite gneiss carrying pyrite. The Lake vein as exposed in the lower tunnel has not been stoped and is not heavily mineralized. Locally it is barren, but elsewhere it shows for a width of 2 to 4 inches a little pyrite in altered wall rock or gray quartz. In the upper tunnel, which is about 700 feet long, the Lake vein is in the main very soft and wet, consisting of 1 to 3 feet of crushed and decomposed wall rock, locally carrying a little disseminated pyrite. Small bands of dark-gray quartz carrying some pyrite occur locally, and it is reported that some lead ore has been obtained. Local stoping has been done in the tunnel.

What is said to be the Lake vein is cut by the Big Five tunnel about 8,345 feet from the portal at a vertical depth of 1,150 feet. (See Pl. XXI, *B*, in pocket.) Drifts on the vein extend 420 feet east and 250 feet west of the Big Five tunnel. The average strike is about N. 80° E., and the dip 32°–52° N. The Windsor Castle vein is not recognized in the Big Five tunnel, and it may join the Lake vein above the tunnel level. The wall rock is schist of the Idaho Springs formation except at the face of the west drift, where a little monzonite porphyry is exposed. The principal alterations produced in this porphyry by the mineralizing solutions are the development of sericite and pyrite. The mineralization is stronger than in the Lake upper workings and is wholly pyritic. Considerable stoping has been done. The vein is a strong fracture zone, in places 5 feet wide, including much crushed schist and one or more slickensided fracture planes. The crushed schist has in most places been greatly altered and carries disseminated pyrite. In many places it is traversed by bands not more than a foot wide of quartz carrying pyrite and in a few places by veinlets of coarse pyrite not more than 4 inches wide.

At the face of the east drift the Lake vein shows the following detailed sections:

Section of Lake vein on the Big Five tunnel level.

	Inches.
Footwall.	
Tight slip.	
Schist, crushed, bleached, carrying disseminated pyrite and cut by a network of veinlets of quartz and pyrite one-eighth inch and less wide	24
Tight slip plane.	
Schist, silicified, carrying a large amount of fine disseminated pyrite	6
Quartz and coarse pyrite	12
Schist, carrying abundant disseminated pyrite	6
Slip plane with gouge	2
Hanging wall.	

The gross production of the properties is said to be between $250,000 and $350,000.

TWO BROTHERS TUNNEL AND BALD EAGLE VEIN.

The Two Brothers tunnel, which starts in Virginia Canyon at an elevation of about 8,740 feet, extends generally westward for about 1,300 feet and then northwestward for about 1,100 feet to the Specie Payment vein. It cuts several veins and follows one for several hundred feet. The wall rock is principally granite gneiss, but in a few places is schist of the Idaho Springs formation.

About 500 feet from the portal the tunnel cuts the Bald Eagle vein, which is probably a continuation of the Windsor Castle vein. A short drift north from the tunnel connects with a shaft on this vein. As exposed in this drift the vein strikes northeast and shows numerous stringers of galena, sphalerite, and pyrite through a width of about 4 feet of granite gneiss. Disseminated pyrite is abundant between the stringers.

Sufficient data are not at hand for satisfactorily computing the average tenor of the ore from the Bald Eagle vein, but sampling-works assays of seven lots of smelting ore, aggregating 11 tons, shipped in 1888 and 1889, show gold, a trace to 0.3 ounce; silver, 12 to 172 ounces; lead, 5 to 10.8 per cent; zinc, 6 to 17 per cent. The high silver values in certain shipments were probably due to downward enrichment.

Between 800 and 1,250 feet from the portal the Two Brothers tunnel follows a fracture zone, 1 inch to 2 feet wide, which strikes nearly east and west and dips steeply north. Most of this fracture zone is barren, but a few parts of it contain sharply bounded veinlets of sphalerite and galena one-fourth to one-half inch across.

A little over 1,900 feet from the portal the tunnel cuts a dike of monzonite porphyry. A hundred feet farther in a mineralized fracture zone 2 to 4 feet wide strikes nearly east and west and dips 50° N. This zone includes two 3-inch veins of nearly solid galena and sphalerite with some pyrite, one next to the hanging wall and the other next to the footwall. Between these veins and for a short distance outside them the granite gneiss carries some disseminated pyrite.

The workings on the Specie Payment vein on the Two Brothers tunnel level were inaccessible at the time of this survey. They are briefly mentioned on pages 286–287.

MONA VEIN.

The Mona vein is developed by the Mona tunnel, the portal of which is on the east side of Bellevue Mountain at an elevation of about 9,100 feet. The tunnel, which follows the vein, was caved about 400 feet from the portal. The vein as exposed in the 400 feet accessible strikes about N. 75° E. and dips 60°–65° N. In its narrower portions it shows 1 to 2 inches of somewhat sheared schist carrying fine disseminated pyrite. In other places it broadens to 2½ or 3 feet, mostly of fractured and somewhat silicified schist carrying disseminated pyrite, but including veinlets of galena, sphalerite, and subordinate pyrite and chalcopyrite from 1 to 2½ inches wide on both the hanging and foot walls. In one part of the vein a 2-inch band of gray quartz containing finely granular pyrite ("steel" pyrite) and chalcopyrite is bordered next the hanging wall by a one-fourth to 1 inch veinlet of resin sphalerite and some chalcopyrite which, a little farther along, shifts to the footwall and in doing so cuts across the quartz-pyrite band. In harmony with evidences elsewhere this probably indicates that the quartz-pyrite mineralization was somewhat the earlier. Few data are at hand in regard to the value of the ore from this vein, but the following sampling-works assays record the metal content of a few shipments:

Sampling-works assays of ores from Mona vein.

Year.	Ore.	Gold.	Silver.	Copper (wet).	Silica.
	Net lbs.	*Ounces.*	*Ounces.*	*Per ct.*	*Per ct.*
1904	877	2.10	7.00		
	12,066	1.71	9.10		50
	5,300	4.85	22.40	4	44
	1,300	3.32	16.00	3	53
1908	7,000	.32	3.00		
	6,830	1.49	7.20		
	4,950	.46	21.00		

SPECIE PAYMENT VEIN.

The Specie Payment vein outcrops on Bellevue Mountain. (See fig. 53.) The main inclined shaft descends 585 feet on the vein and the "Gasoline incline" 380 feet. The Two Brothers tunnel cuts the vein over 1,000 feet below the collar of the main shaft and connects with over 1,400 feet of drifts on the vein, mainly on the tunnel level but in part on a level 145 feet below. The drifts on the Two Brothers level could not be entered on account of bad air; and the Wolverene tunnel, which is probably also on the Specie Payment vein, was unsafe on account of caving. Observations were therefore confined to the main shaft and Little Annie workings.

These workings show two main veins—the Specie Payment vein, which has a strike of about N. 60° W. in the upper workings, shifting to N. 80° W. in the Two Brothers tunnel workings, and an unusually variable dip of 15°–75° N. (average about 40° N.); and the Cross vein, which strikes N. 70 to 80° E. and dips 30°–75° N. These two veins intersect without notable displacement of either. The intersection is well exposed on three of the levels connecting with the Gasoline incline and on both of the levels connecting with the Two Brothers tunnel.

The Specie Payment vein is commonly well defined. In its leaner portions it shows either several nearly parallel unmineralized fractures or else narrow quartz-pyrite veinlets distributed through 6 inches to 2½ feet of more or less altered wall rock. The wall rock near these fractures and veinlets generally carries pyrite in small disseminated crystals. In its more heavily mineralized portions the vein carries principally pyrite and chalcopyrite, with galena and sphalerite in minor quantities. As compared with most of the veins of this vicinity the Specie Payment vein shows an uncommon abundance of quartz and an uncommon number of vugs. A few descriptions of heavily mineralized portions illustrate its character. In a winze on the first level below the Little Annie tunnel (A, fig. 53), the vein is 3 feet wide. It shows next the hanging wall a 6-inch band of pyrite, chalcopyrite, and quartz in nearly equal amounts. Small fractures in this portion of the vein show thin films of what appears to be chalcocite. Below comes 2 feet of schist carrying disseminated pyrite and chalcopyrite; and finally, next the footwall, is 6 inches of gray quartz and pyrite traversed by stringers of galena, sphalerite, chalcopyrite, and pyrite. The character of a polished specimen from this part of the vein when examined under the microscope has already been described on page 113. Free gold is reported to occur locally in white quartz in this part of the mine.

Ore from the bins at the Two Brothers tunnel, said to come from the Specie Payment vein, is uncommon in carrying abundant bornite. A polished specimen of this ore shows minute stringers of bornite with accompanying chalcopyrite and galena occupying sharp fractures in the pyrite. Because it is later than the pyrite ore and carries some galena, the bornite-rich ore is regarded as an unusual phase of the later mineralization. Subsequent to both mineralizations there was further fracturing and an introduction of gray quartz.

In a stope on the 360-foot level 130 feet east of the main shaft the vein shows 7 inches of gray quartz and pyrite in about the proportion of 2 to 1. Above this for 2½ feet pyrite is disseminated in pegmatite of the wall.

In most of the exposures described above pyritic mineralization is predominant, but on the 440-foot level the principal minerals are galena, sphalerite, and chalcopyrite. About 110 feet east of the shaft the vein shows in places 2 inches of solid galena and sphalerite associated with pyrite and chalcopyrite. Quartz is common as a gangue and is associated principally with the pyrite and chalcopyrite. Near the shaft on this level the vein is 6 inches wide and consists of several veinlets of white quartz (2 inches in maximum width), carrying a little pyrite and chalcopyrite, and traversed by irregular bands of galena and sphalerite.

The vugs of the vein are commonly lined with quartz crystals, in places accompanied by crystals of pyrite and chalcopyrite. It is particularly noteworthy that small crystals of resin sphalerite are deposited on some of the quartz and pyrite crystals, in places completely coating them. A specimen from the 360-foot level showed this feature. A specimen from the Two Brothers tunnel level, seen in a private collection, showed quartz crystals in a vug beautifully plated at their tips with pyrite.

A number of minor veins, which have not proved to be of commercial importance, are exposed near the east end of the Little Annie tunnel level. (See fig. 53.) They are pyritic, but the widest pyritic streak observed was only 2 inches. They lie about parallel to the schist foliation and are nearly parallel to the Cross vein in strike.

Another minor vein, lying a little below the Specie Payment vein and dipping about 65° NE., is exposed on the fifth or 440-foot level, for 220 feet southeast of the shaft to a point where the drift is caved. Some of the drifting on the fifth level beyond the cave

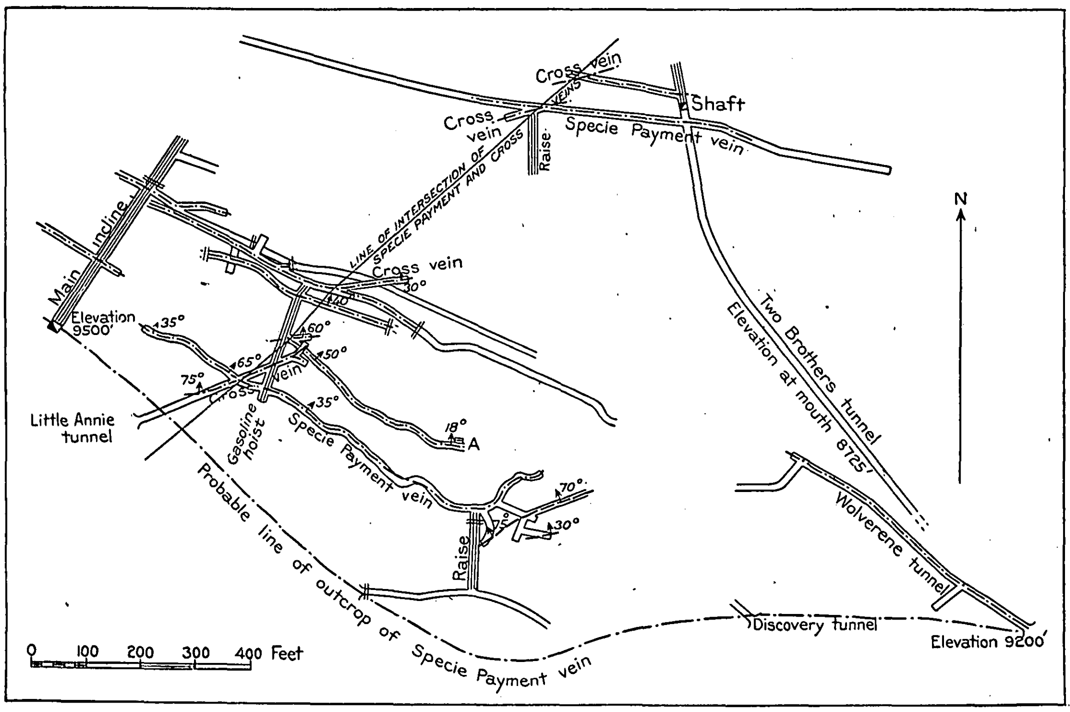


FIGURE 53.—Geologic plan of a portion of the workings on the Specie Payment and adjacent veins.

The Cross vein is dominantly pyritic and narrower than the Specie Payment vein. In a few places it carries some galena and sphalerite. As exposed in the Little Annie tunnel, 140 feet from the portal, it shows 1½ to 2 inches of pyrite in a gray quartz gangue, beneath which there is 1 foot of schist carrying disseminated pyrite. As exposed on the first level below the Little Annie tunnel it shows 2 to 3 inches of gray quartz carrying pyrite and chalcopyrite. Vugs lined with quartz crystals are numerous. The vein nearly everywhere shows evidence of postmineral movement in brecciation and in the presence usually of an inch or so of gouge next the hanging wall.

appears from the map to have followed this vein. In places this vein is a nearly barren fracture plane 2 to 6 inches in width, but in other places it is fairly well mineralized with pyrite and chalcopyrite in a gray quartz matrix. No stoping has been done on it.

The Specie Payment vein was discovered in 1875, was first opened in 1876, and was acquired by the present company in 1903. At the time of this survey some work was being done by lessees in both the Two Brothers and Little Annie workings. The records of output are incomplete, but the total gross production is estimated by the company at about $1,500,000. Oxidized ore from the early workings carried much free gold and very little silver. In the unoxidized ores the highest gold and silver content is commonly found in the chalcopyrite-rich portions, though some of those high in pyrite or in galena have proved rich and sphalerite is said to carry gold in places.

The metal content of 124 lots of smelting ore, aggregating 506 tons, as determined from sampling-works assays, was gold, 0.32 to 7.09 (average 1.88) ounces; silver, 0.7 to 37 (average 5.8) ounces. In most lots copper was not present in sufficient amounts to be paid for, but in a few it ran as high as 7 per cent, although 3 to 5 per cent was more common. Lead and zinc are recorded only exceptionally. Silica ranges from 42 to 75 per cent.

The average value of the concentrating ore shipped in 1910 was gold, 0.35 ounce; silver, 3.7 ounces; lead, 1.6 per cent; copper, 0.4 per cent.

CHAMPION-TRIO MINE.

The Champion shaft, on the summit of Bellevue Mountain at an elevation of a little over 9,600 feet, is about 1,130 feet deep on a northward-dipping vein. The Trio drift tunnel, starting in Virginia Canyon at an elevation of about 9,150 feet, is about 1,000 feet long and connects by a raise with the 655-foot level of the shaft workings.

None of the workings were accessible at the time of this survey, but according to the stope maps available most of the ore extracted came from the shaft workings above the 655-foot level. Between the surface and the 451-foot level the stoping is confined to the vicinity of the shaft, but between the 451-foot and 655-foot levels the stopes extend roughly 400 feet west and 500 feet east of the shaft.

The tenor of the ore is extremely variable and for that reason no satisfactory average value can be given. The following selected sampling-works assays give some idea of variations:

Sampling-works assays of ore from Champion-Trio mine.

Ore.	Gold.	Silver.	Copper.
Net pounds.	*Ounces.*	*Ounces.*	*Per cent.*
10,840	1.41	34.50	3.6
5,500	2.50	3.00	....
7,820	6.64	10.00	3.0
14,360	.94	18.50	4.0

In 68 lots of smelting ore, shipped from 1888 to 1911 inclusive, the range in metallic content, according to sampling-works returns, was gold, 0.2 to 6.64 ounces; silver, 1 to 34.5 ounces; copper, from less than 1.5 to 7.2 per cent.

SEATON MOUNTAIN, GILSON GULCH, AND THE LOWER PART OF VIRGINIA CANYON.

EAST LAKE TUNNEL AND OWATONNA VEIN.

The East Lake tunnel is on the south slope of Pewabic Mountain at an elevation of 8,500 feet. It is a nearly straight tunnel about 550 feet long driven on a vein striking on the average N. 50° E. and dipping northwest. A crosscut 30 feet in length running westward from this tunnel connects with the Owatonna shaft workings. The workings are all in schist of the Idaho Springs formation and pegmatite.

One of the best exposures of the East vein, on which the tunnel is driven, is at the face, where it dips 50° NW. Idaho Springs schist for a width of 6 feet is more or less altered and impregnated with small grains of pyrite, which in places forms about half of the rock. Near the footwall are two veinlets, one-half and 1 inch wide, which consist of galena and sphalerite in a gray quartz matrix. A small branch vein joining this vein about 160 feet from the portal is said to have assayed gold, 0.21 ounce; silver, 42 ounces; copper, 2.5 per cent.

No important production has yet been reported from the East vein.

The west or Owatonna vein, which is connected with the East Lake tunnel by a crosscut, is best exposed on a level 40 feet or so above the tunnel. This vein, which strikes N. 50°–60° E. and dips 45°–50° NW., shows two nearly parallel portions. The upper portion, which the shaft follows, consists of 2 to 5½ feet of more or less altered schist and pegmatite traversed by galena, sphalerite, and subordinate pyrite in veinlets which are rarely over 2 inches wide, but which exceptionally unite in lenses of nearly solid sulphides as much as 1 foot in width. In many places the sulphides form the matrix of a breccia of schist fragments. One to two inches of gouge is commonly observed next the hanging wall. The lower portion of the Owatonna vein is exposed at the northeast end of the same level, where it is reached by a 15-foot crosscut from the upper or shaft streak. As exposed in the face this is a tight 8-inch vein of galena, sphalerite, and pyrite, with here and there a little gangue quartz. The upper and lower branches of the Owatonna vein probably merge at no great distance northeast of these workings.

Fifteen lots of smelting ore from the Owatonna vein, aggregating 117 tons, shipped between 1897 and 1910, show, according to sampling-works assays, gold, 0.12 to 0.5 (average 0.23) ounce; silver, 5.7 to 58.8 (average 27.57) ounces; lead, 36 per cent or less; and zinc, 25 per cent or less. Lead commonly is slightly in excess of zinc.

SUN AND MOON VEIN.

The Sun and Moon vein outcrops at the head of Gilson Gulch near the Gilpin-Clear Creek county line. It is developed by three shafts called, from east to west, the Minott, the Sun and Moon, and the Garden. The Sun and Moon shaft connects with only small and unimportant developments. The Garden shaft has nine levels. The Minott is the main shaft and has twelve levels. From the twelfth level, at a point about 450 feet east of the Minott shaft, another shaft with seven levels descends to the Argo tunnel lateral, which alone was accessible at the time of this survey.

On the surface, and presumably in most of the workings above the Argo tunnel level, the wall rock is granite gneiss, but on the Argo level it is schist of the Idaho Springs formation with a little monzonite porphyry, granite gneiss being present only for 100 feet or so east of the shaft. The vein in general follows the foliation of the schist. A large area of monzonite porphyry crops out just east of the shaft. Although the vein was certainly formed later than this porphyry it is not traceable on the surface for any considerable distance into the porphyry.

The vein was studied in the Argo lateral for 1,825 feet east of the Argo tunnel, beyond which the drift was flooded. The strike averages about N. 60° E. and the dip is about 50° NW. In most exposures the vein shows 6 to 12 inches of sheared and altered schist, locally somewhat silicified and commonly carrying disseminated grains of pyrite. In places the fracture zone is entirely unmineralized. For about 500 feet east and west from the shaft the lateral exposes at intervals a dike of monzonite porphyry 1½ to 5 feet wide, which is nearly parallel to the vein. The vein is younger than the dike, cutting across it in several places as the mineralized fracture shifts from one wall of the dike to the other. Veins of solid pyrite from a fraction of an inch up to 6 inches in width are present in a few places along the walls of the fracture zone or along the wall of the monzonite dike. In most places the wall rock next such coarse pyrite carries disseminated pyrite in increasing amounts as the vein is approached. Where the vein is cut by the Argo tunnel the hanging wall is a nearly barren sheared zone 1 to 1½ feet in width. Below this and separated from it by 6 feet of unmineralized schist is 5 feet of fractured and somewhat silicified schist carrying pyrite in small disseminated grains.

As indicated in the above descriptions the mineralization of the Sun and Moon vein in the Argo lateral is wholly of the pyritic type. Although the upper workings on the vein were not accessible the character of the ore on the dumps and the records of the ore shipped show that much of it carried galena and some sphalerite. The vein therefore affords another example of the passage in depth of a composite into a purely pyritic vein. (See p. 102.)

Postmineral movement has taken place along the vein, as is shown by the presence in places of angular fragments of pyritic ore in a matrix of crushed but unmineralized rock, but it is not always easy to distinguish its effects from those of movements previous to mineralization. In one place the fragments in a friction breccia were well rounded.

The mine is at present operated under the leasing system. Practically all of the ore shipped goes direct to the smelters, the company owning no mill. The average metallic content of the ore is said to be about gold 1 ounce, silver 20 ounces, copper (wet) 2.5 per cent. Sampling-works assays of 54 lots of smelting ore, aggregating 836 tons, shipped in 1908 and 1909, show gold, 0.4 to 8.25 (average 1.31) ounces; silver, 3.81 to 37.7 (average 14.49) ounces; copper (wet), from less than 1.5 to 6.9 per cent; lead, none to 13 per cent; zinc, none to 8 per cent. The total gross production is said to be about $2,000,000.

SANTA FE VEIN.

The Santa Fe vein, near the head of Gilson Gulch, at an elevation of about 9,250 feet, strikes about N. 60° E. and dips about 60° N. It is developed by several shafts, of which the deepest, the Santa Fe, is down about 320 feet and connects with 4 short levels. The workings could not be entered at the time of this survey, but an examination of the dump showed that the ore was mainly if not entirely of the galena-sphalerite type.

Sufficient data are not at hand for computing the average value of the ore. Sampling-works assays of 16 lots of smelting ore aggregating 91 tons, shipped between 1888 and 1904, show gold, 0.25 to 4 ounces; silver, 2.7 to 38 ounces; copper (wet), not more than 2.3 per cent; lead, not more than 20 per cent; zinc, not more than 5 per cent.

The property is said to have had a gross production of $100,000.

DE LESSEPS TUNNEL.

The De Lesseps tunnel, near the village of Gilson Gulch, at an elevation of about 8,900 feet, is about 440 feet long, the first 50 feet being crosscut and the remainder on a vein with a general N. 80° E. strike and a dip of 60°–70° N. About 320 feet from the portal the tunnel connects with a shaft. A second vein trending about N. 75° W. and dipping 60° N. joins the main vein from the west 20 feet from the face of the tunnel. The stopes are rubble filled and little could be seen of the character of either vein. In many places they are practically barren, showing only 6 inches to 1½ feet of fractured and silicified granite gneiss. The ore found was of the galena-sphalerite variety. A sampling-works assay of 16,508 pounds of ore shipped about 1893 shows gold, 1.03 ounces; silver, 32 ounces; lead, 11.5 per cent; zinc, 12 per cent.

GEM-FREIGHTER'S FRIEND LODE.

The veins developed in the Gem and the Freighter's Friend mines form part of a well-defined system of mineralized fractures that outcrop on the summit of Seaton Mountain, extending slightly south of east from the Main Trunk claim to the Franklin and Freeman claims. The system includes a number of subparallel branching fractures whose mutual relations could not be accurately worked out from the exposures available. The Silver Age tunnel level connects with the fourth level of the Freighter's Friend shaft, but access was not gained to this part of the workings.

The Gem workings consist of a shaft inclined to the north and connected with levels numbered from 1 to 18. An interval has been left for levels Nos. 10 and 15, but they have not yet been driven. On account of the age and caved condition of the workings little could be seen above the ninth level. The Gem lode was cut by the Argo tunnel in 1900 about 7,860 feet from the portal and in 1903 a raise was completed connecting the Argo level with the shaft workings. The elevation of the collar of the Gem shaft is 9,026 feet, and that of the Gem lateral on the Argo tunnel level is 7,606 feet, a vertical difference of 1,420 feet. A winze and short level below the Argo level increases the total vertical extent of the workings to 1,504 feet; their extent measured along the dip of the lode is about 1,900 feet.

The workings of the Freighter's Friend mine were not accessible for study; they consist of the Freighter's Friend shaft and five levels driven from it.

The average strike of the Gem lode is about N. 70°–75° W. and its dip is 35°–80° N. (average about 50° N.). The prevailing wall rock is granite gneiss, but monzonite porphyry is abundant on the ninth, thirteenth, seventeenth, eighteenth, and Argo tunnel levels, particularly west of the shaft. On the ninth level about 400 feet west of the shaft the monzonite contains feldspar phenocrysts, some of which measure 2 by 2½ inches. The porphyry is distinctly earlier than the mineralization.

The lode taken as a whole is remarkable for its width and compound character. Though in some places composed apparently of a single well-mineralized vein, in most of the workings it consists of two nearly parallel veins 20 to 30 feet apart. This compound character is a feature also in the Franklin and Silver Age workings. From the surface to about the ninth level the shaft in general follows the footwall vein and below the ninth level the hanging-wall vein, which, as indicated by the amount of development on it, becomes increasingly important with depth. One of the best and most easterly exposures of the footwall vein is on the eleventh level, about 800 feet east of the shaft.

Section of footwall vein on eleventh level of the Gem mine.

	Ft.	in.
Hanging wall.		
Granite gneiss, somewhat sheared	1	0
Pyrite, coarse, cut by a network of rhodochrosite veinlets not more than 1 inch wide, which are plainly later than the pyrite	1	0
Quartz, gray, carrying disseminated grains and small irregular veinlets of pyrite		6
Pyrite, coarse, cut by rhodochrosite veinlets		4
Aggregate of gray quartz, galena, pyrite, and chalcopyrite	3	0
Slip planes showing horizontal slickensided footwall.		
	5	10

In contrast to the size and extensive mineralization of the footwall vein at the locality just described is its appearance in a crosscut 80 feet west of the shaft on the eighteenth level, where it consists of 4 feet of crushed granite gneiss containing only disseminated pyrite and a few small stringers of quartz and pyrite.

Although the Freighter's Friend workings are on the same general lode as those of the Gem mine, the two mines have not been connected and the exact correspondence between individual veins within the lode is not known.

Mineralization in the Gem mine is dominantly pyritic but in many places comprises other sulphides. The occurrence of sphalerite and chalcopyrite in rhodochrosite veinlets cutting coarse pyrite has already been recorded. On the fourteenth level the footwall vein 300 feet west of the shaft exhibited a one-eighth inch veinlet of quartz and galena cutting obliquely across a 5-inch band of quartz carrying fine pyrite. At one place on the Argo tunnel level small veinlets that consist mainly of enargite, quartz, pyrite, and galena, with subordinate amounts of very fine grained chalcopyrite, rhodochrosite, and bornite, cut quartz-pyrite ore. Small enargite crystals were observed on the faces of pyrite crystals in the pyritic ore.

These relationships add to the evidence already set forth (pp. 112–114) of two periods of mineralization. The minerals of the second period observed in this mine are galena (in part "steel" galena), sphalerite (both dark-colored and resinous), tetrahedrite, enargite, rhodochrosite, and bornite. Chalcopyrite, pyrite, and quartz, and possibly tetrahedrite, are common to both mineralizations in this mine.

A pocket about 100 feet long by 100 feet high near the Gem shaft on the twelfth level carried tellurides of gold. A specimen from this ore shoot showed sylvanite in a gray quartz matrix.

As far as could be learned the minerals characteristic of the second period of ore formation are more abundantly present in the Freighter's Friend than in the Gem workings, thus forming a transition to the purely galena-sphalerite type of ore characteristic of the Franklin and Silver Age workings.

Because of the diversity in the mineral character of the ore from various parts of this lode a better idea of the value of the ore may be gained from a separate consideration of the different types than from general averages. From an inspection of the complete record of smelter returns from 1897 to 1910, inclusive, the following summary of the values of the different types of ore may be made:

The pyritic ores, consisting largely of pyrite with very subordinate chalcopyrite, are quantitatively the most abundant. In most of the smelting ore of this type the gold content lies between 0.3 and 3 ounces (generally less than 1 ounce) per ton, and the silver between 5 and 30 ounces per ton. Unusually high gold values are commonly accompanied by unusually high silver values. Copper, although generally below the commercial limit of 1.50 per cent, reaches 5 per cent in a few places. These figures take no cognizance of exceptional values.

Smelting ores showing lead in quantities sufficient to be paid for (over 5 per cent wet) are more abundant in the Freighter's Friend than in the Gem mine, from which in certain years no lead ores were shipped. The lead in some shipments reaches 65 per cent and the zinc 23 per cent. A comparison of the silver values in the pyritic and lead ores indicates that much of the galena is not highly argentiferous, although it is more so than the pyrite. The precious metals seem on the whole to be most closely associated with the copper minerals, as is suggested by the following assays:

Assays of ores from the eleventh level east in the Gem mine.

	Gold.	Silver.	Copper (wet).	Lead.	Zinc.
	Oz.	*Oz.*	*P. ct.*	*P. ct.*	*P. ct.*
Pyritic ore	0.28	7.85			
Cupriferous pyritic ore	.93	17.60	2.30		
	1.30	19.30	4.10		
Lead ore	.25	15.80		23.45	9.35

The following assays are of samples of various types of ore collected by the writer:

Miscellaneous assays of ores from the Gem mine.

Number.	Gold.	Silver.	Copper.	Lead.	Zinc.
	Ounces.	*Ounces.*	*Per cent.*	*Per cent.*	*Per cent.*
1	2.00	11.44	0.54		
2	.08	5.40			62.22
3	.06	7.30	.48	65.50	
4	1.10	22.62		12.20	24.17
5	.07	.33			

1. Ore, mainly of coarse pyrite, from an underhand stope 100 feet west of the Gem shaft on the twelfth level. Sylvanite has been identified in this part of the mine and may be the cause of the uncommonly high value of this sample as compared with most of the coarse pyritic ore of the mine.

2. Resin sphalerite picked from ore carrying galena, sphalerite, tetrahedrite, and a little pyrite and chalcopyrite; from the same locality as No. 1.

3. Ore, mainly fine-grained galena (some "steel" galena) and chalcopyrite with some pyrite, from the Gem South vein on the Argo lateral about 250 feet east of the shaft.

4. A sphalerite concentrate from ore from the eleventh and twelfth levels. It originally contained some galena, pyrite, chalcopyrite, rhodochrosite, and quartz, but was picked over to free it as far as possible from these minerals. Its high content in precious metals is in marked contrast with the sphalerite of No. 2 and is possibly due to the admixed galena.

5. Coarse pyrite of the first mineralization, traversed by veinlets of rhodochrosite belonging to the later mineralization, from the eleventh level, about 800 feet east of the shaft.

FRANKLIN VEIN AND SILVER AGE TUNNEL.

The Franklin vein, which was discovered in 1865, is traceable on the surface from the village of Gilson Gulch eastward to the vicinity of the old Freeman shaft as a continuous well-defined lode. From this point eastward to Silver Age Gulch a number of slightly divergent veins are exposed in the Silver Age tunnel. The apparent position of their outcrops is shown on Plate VI (in pocket), but their relations to each other and to the Franklin vein could not be completely worked out on account of the inaccessibility of many of the old workings. West of Gilson Gulch the Franklin vein probably merges with one of the veins opened in the Freighter's Friend and Gem workings, but the precise relations are not known.

The Franklin vein was seen only in the Franklin shaft, which is 200 feet deep and has short levels at 100, 135, and 200 feet. The Silver Age tunnel starts in Silver Age Gulch at an elevation of 8,440 feet. An inclined shaft at the tunnel mouth connects with levels 100 and 200 feet below the tunnel but could not be entered. The tunnel workings, which were studied to a point 75 feet west of the Freeman shaft, are shown in figure 54.

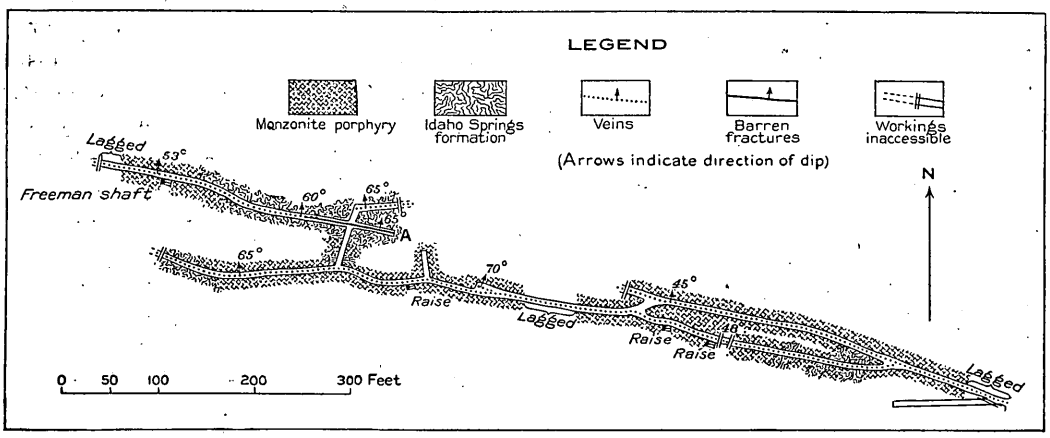


FIGURE 54.—Geologic plan of Silver Age tunnel. Surveyed by hand compass and pacing.

The French Flag shaft, which appears to be on a continuation of the Franklin–Silver Age lode, is on the east side of Silver Age Gulch at an elevation of about 8,500 feet. The dip of the vein at the surface is about 45° N. The workings are inaccessible.

As exposed in the Franklin shaft and connecting levels the Franklin vein dips 50°–60° N. Its width is commonly 1 to 1½ feet. The wall rock in most places is granite gneiss with a few dikes of monzonite porphyry. At the west face of the 200-foot level the vein cuts sharply through a 1-foot dike of monzonite porphyry, than which it is clearly later. The 135-foot level east exposes two nearly parallel veins about 20 feet apart, between which the wall rock is traversed by galena, sphalerite, and pyrite in numerous small stringers, few of which are over one-fourth inch wide and all of which are very irregular in trend.

In the Silver Age tunnel three principal veins are exposed. For 400 feet from the mouth the main drift follows a vein which is generally lean and on which only a small amount of stoping has been done. In one of the more heavily mineralized portions, 320 feet from the portal, the vein is 1 foot wide, consisting of 6 inches of crushed porphyry next the footwall and above 6 inches of gray quartz containing fine-grained galena and sphalerite. This may be the same vein exposed farther in A, figure 54, although at that point it shows no mineralization but is merely a zone of fracturing, within which the schist shows some silicification.

What may be termed for convenience the south vein diverges from the vein just described about 120 feet from the portal and is exposed continuously for about 760 feet. For the first 500 feet or so it has been stoped extensively, but beyond 500 feet it is a barren fracture zone 6 inches to 2 feet in width, mainly in altered porphyry. In an exposure of one of the more mineralized portions, about 540 feet from the portal, the vein is 2 feet wide and consists of brecciated and silicified porphyry traversed by several stringers of quartz carrying fine-grained galena and sphalerite and some pyrite.

The northern vein, which is exposed in the drifts near the Freeman shaft, is larger and more heavily mineralized than the others and is evidently the main vein opened in the Franklin shaft workings. It is followed by the Silver Age tunnel for over 1,200 feet west of the Freeman shaft, but this portion of the mine was inaccessible. About 200 feet east of the Freeman shaft it is 7 inches wide and shows bands of galena and resinous sphalerite with subordinate pyrite and chalcopyrite alternating with bands that are mostly quartz. Vuggy portions show what appear to be pseudomorphs of quartz after barite. At another point the vein shows a 1 to 2 inch streak of rhodochrosite containing specks of pyrite, galena, and gray copper. The vein has been stoped continuously for 225 feet east from where the drift is caved.

The mineralization throughout nearly all of the Franklin and Silver Age workings is of the galena-sphalerite type. As exposed in the Franklin shaft workings the ore of the Franklin vein is an irregular aggregate of galena, sphalerite, and pyrite in a gangue either of gray quartz or of pink rhodochrosite or both. The rhodochrosite plainly crystallized contemporaneously with the sulphides and in places is the most abundant vein mineral. A little tetrahedrite was observed in small vugs. In a few places galena and sphalerite form a very fine grained aggregate. Vugs are common in the more quartzose parts of the vein. More or less crushed wall rock generally forms either the hanging wall or the footwall of the vein and in places is 1 foot in width. At one place on the 200-foot level east the hanging wall is followed by a band of gray flinty quartz 1 to 5 inches in width, which was formed later than the main mineralization and contains angular fragments of the ore.

A small amount of ore seen in bins at the mouth of the Silver Age tunnel consists mainly of gray quartz and pyrite with some small stringers and lenses of galena which appear to be later. The presence of such composite ore shows that there was some ore deposition along this lode in the earlier or pyritic mineralization.

According to Hollister [1] the ore taken from the upper portions of the Franklin vein in 1867 was mainly valuable for its silver (though also carrying considerable copper) and yielded assays of \$100 to \$150 per ton, the average market price of silver being \$1.33 per ounce. There can be no doubt that the high silver content of the upper portions of the lode was the result of downward enrichment. In the present workings little evidence of enrichment was observed. On the 135-foot level of the Franklin shaft workings fractured wall rock near the main sulphide vein is reported to have carried wire silver in seams and vugs and to have been richer than the sulphide ore. This silver was probably dissolved from the oxidized zone and redeposited by descending waters.

Sampling-works assays of 130 lots of galena-blende smelting ore, aggregating 1,374 tons, shipped from this property from 1888 to 1910 inclusive, show gold, 0.05 to 1.52 (average 0.146)

[1] Hollister, O. J., The silver mines of Colorado, p. 70, 1867.

ounces; silver, 4 to 161 (average 22.74) ounces; lead, 38 per cent or less; zinc, 18 per cent or less; and silica, 67 to 82 per cent (6 determinations only). The high silver content of some of these shipments is indicative of enrichment. Several small shipments in 1910 which assayed, according to sampler returns, 0.28 to 1.2 ounces gold and 1 to 1.7 ounces silver, probably represent the pyritic type of ore.

The company owns two mills, the Wilkie and Silver Age, in the valley of Clear Creek below Idaho Springs, power being furnished by a hydroelectric plant. These mills are capable of treating 60 tons of ore per day.

HUDSON-BURR TUNNEL.

The portal of the Hudson-Burr tunnel is in Silver Age Gulch at an elevation of about 8,500 feet. The workings were blocked at the mouth and only the dump could be studied. On the dump two types of ore were observed, one showing galena, sphalerite, pyrite, and subordinate chalcopyrite in a gangue of quartz and siderite and the other showing only coarse pyrite in a quartz gangue.

Some of the pyritic vein material shows minor amounts of galena, sphalerite, and chalcopyrite. A polished specimen 3 inches wide, the entire width of a vein, showed, when studied under the microscope, an irregular central band of coarse pyrite 1 to 1½ inches wide bordered on either side by three-fourths to 1 inch of light-gray quartz. The pyrite had been brecciated, a feature especially clear when the polished surface was etched with nitric acid, and along small cracks traversing the pyrite and in small irregular spaces between pyrite fragments galena, sphalerite, chalcopyrite, and clear calcite had been deposited. The relations were entirely clear and indicated beyond any question that composite mineralization had taken place, first with quartz and pyrite and later with galena, sphalerite, and chalcopyrite.

METROPOLITAN TUNNEL.

The Metropolitan tunnel, at an elevation of 8,600 feet on the east side of Boomerang Gulch, follows for about 1,850 feet a vein which strikes generally N. 60° E. and dips 35°–55° NE. The wall rock is schist of the Idaho Springs formation and monzonite porphyry. At some places the mineralization consists of stringers of gray quartz bearing pyrite which traverse schist carrying disseminated pyrite. Locally, however, veinlets up to 2 inches wide of galena, sphalerite, and subordinate pyrite in a gray quartz gangue occur. An interesting feature is the occurrence of a few 1 to 2 inch bands of soft white sericite, which represent an extreme phase of metasomatic alteration by the mineralizing solutions. No mining is now being done in this tunnel.

Six lots of ore from this mine shipped in 1911 showed the following metal content:

Assays of ores from the Metropolitan tunnel.

Ore.	Gold.	Silver.	Lead.	Zinc.
Net lbs.	*Ounces.*	*Ounces.*	*Per cent.*	*Per cent.*
1,920	1.40	17	....	....
2,470	1.95	64	....	....
5,150	.52	14.50	....	....
4,650	1.24	41.00	11	27
2,470	.55	25.00	....	....
6,790	.20	11.50	6	13

SEATON VEIN.

The Seaton vein was first developed through a shaft on the south side of Seaton Mountain at an elevation of about 8,900 feet, but since 1900 has been worked through the Foxhall tunnel. It is also cut by the Tropic tunnel about 680 feet from the portal and 250 feet vertically below the surface. Drifts on it from the Tropic tunnel break into the workings of the Pine Shade shaft, which connects with 7 levels, all inaccessible except that from the Tropic tunnel. The Seaton vein is also cut by the Argo tunnel at a vertical depth of about 1,200 feet at about the point (6,980 feet from the portal), where it should be cut if its average dip of 60° N. in the upper workings persists to the tunnel level.

The Seaton shaft follows the vein to a vertical depth of 450 feet. It has six levels, the lowest of which (seventh) connects through a 100-foot raise with the workings in the Foxhall tunnel level. About 450 feet east of the main shaft a subsidiary shaft is sunk from the tunnel level for a vertical depth of 220 feet. A room for hoisting engine and head frame has been excavated at the top of this shaft and the ore is trammed out through the tunnel. Three levels connect with this subsidiary shaft. All the levels connecting with the main shaft are inaccessible except the sixth, which can be reached by the raise from the tunnel. The writer's observations, therefore, were confined to the portions of the workings below 450 feet in vertical depth.

On the surface the vein can be traced with certainty for only a short distance west of the Seaton shaft, but to the east it can be followed for 1,000 feet beyond the Pine Shade shaft to the southeast nose of Seaton Mountain overlooking Gilson Gulch. The same, or a closely parallel lode, probably extends across Gilson Gulch. As shown on the surface the Seaton vein appears to join the Tropic vein near the Pine Shade shaft, and the Tropic is probably to be regarded as a branch from the Seaton lode.

The Seaton is a strong vein dipping 45°–80° N. (average about 60° N.). Throughout the portions studied the wall rocks are schists of the Idaho Springs formation, with small lenses of pegmatite, and the vein in general lies parallel to their foliation though occasionally cutting across it at small angles. The vein is in places barren but elsewhere is heavily mineralized. One portion, 130 feet east of the Foxhall tunnel, shows 1 to 2 inches of crushed schist and pegmatite wholly unmineralized. Other portions show pyrite as the only mineral sparsely disseminated in small grains through crushed and altered schist. These sparsely pyritic portions have not been worked. The workable portions of the vein carry galena and sphalerite and minor amounts of other minerals, in places in a single sharp-walled vein but more commonly in a network of small sub-

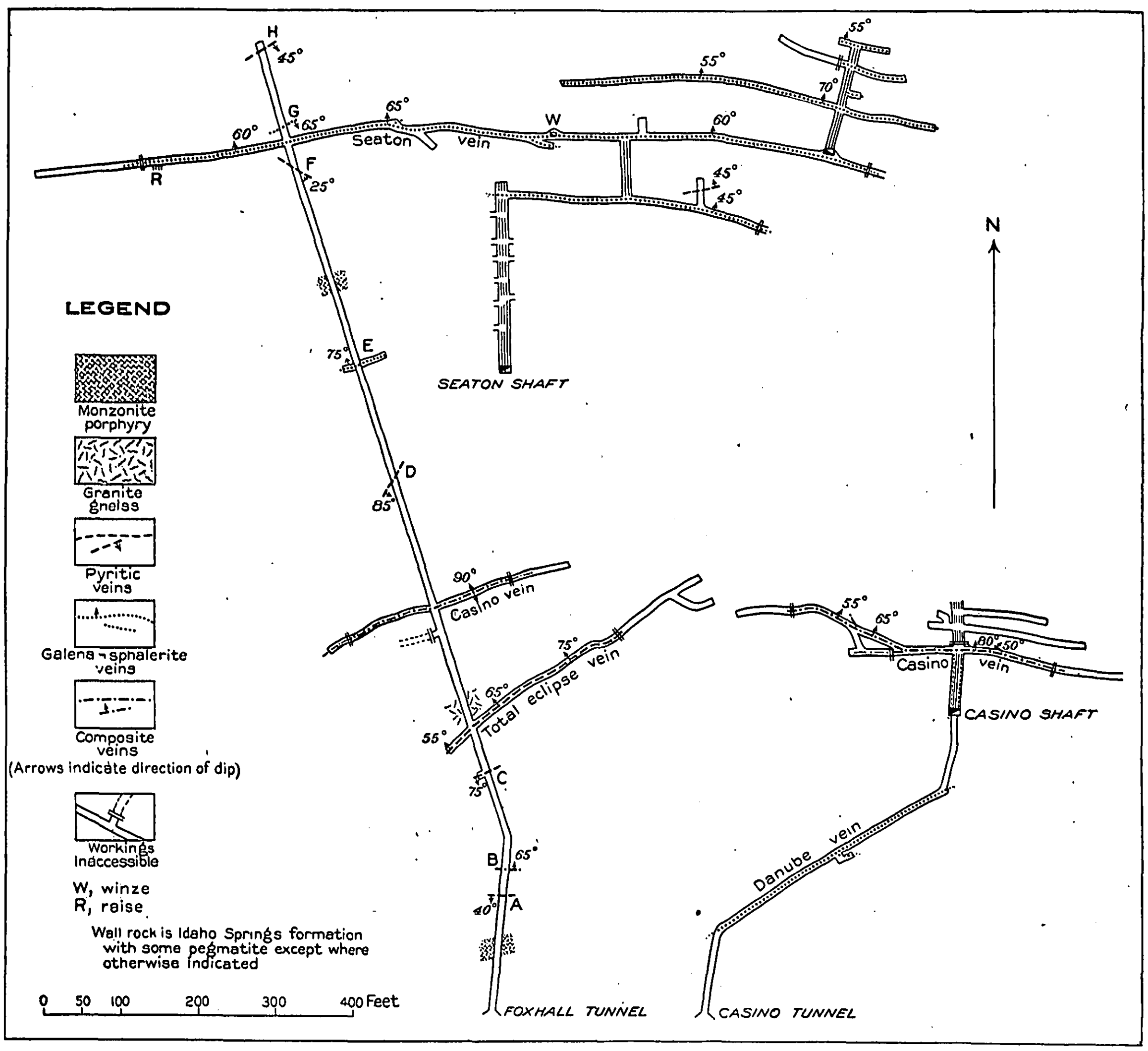


FIGURE 55.—Geologic plan of Foxhall tunnel and of Seaton and Casino mines.

parallel veins bordered by schist or pegmatite carrying more or less disseminated pyrite. Only rarely do the walls contain disseminated galena or sphalerite. The vein, including the gangue and disseminated material, reaches a width of 5 feet in its stronger portions, but more commonly measures 1 to 2 feet. As exposed in a winze 330 feet east of the Foxhall tunnel it shows 3 inches of gouge next the footwall, a 5-inch band of galena, sphalerite, and subordinate pyrite and quartz, a small fracture seam, and 4 inches of somewhat altered schist and pegmatite carrying disseminated fine pyrite. The galena forms crystals locally 1 inch in diameter though commonly smaller. Twenty feet east of the shaft in a stope between the eighth and ninth levels the vein has a width of 5 feet and includes a stringer of gray quartz, one-half to 1 inch wide, carrying abundant pyrite, which is cut sharply at 60° by veinlets of galena and sphalerite which are plainly younger. Similar evidence of two mineralizations (a relatively unimportant pyritic mineralization followed by a very considerable galena-sphalerite one) is found in the winze, 330 feet east of the Foxhall tunnel, where a 2-inch quartz-pyrite vein is cut nearly at right angles by the main galena-sphalerite vein. The appearance of the vein in the Tropic tunnel workings (see fig. 56) is described on page 298. On the Argo tunnel level many portions of the vein show only pyrite. Some of the abundant disseminated pyrite in portions of the vein may also belong to the earlier mineralization.

On the Argo tunnel level the drifts on the Seaton vein are caved 70 feet east and 170 feet west of the tunnel. (See Pl. XXI, *A*, in pocket.) Within the 240 feet available for study the vein dips 55°–60° N. West of the tunnel the vein is practically barren, and east of it the largest amount of mineral observed was a 4-inch streak of quartz and pyrite with small local vugs. In one place a little galena was observed with the pyrite, and smelter returns for this lateral show that much of the ore was rich in both lead and zinc.

Some postmineral movement along the vein is shown in several places by crushed and sheared ore.

The dominant minerals of the main mineralization are galena and sphalerite. The galena commonly forms crystals one-fourth to one-half inch in size but in a few places is of the fine steel-galena variety and carries some local antimony. The sphalerite is locally of the resinous variety but is commonly dark. Pyrite is subordinate and chalcopyrite rare. Quartz is the common gangue mineral, but some rhodochrosite is found locally. One specimen showed crystals of rhodochrosite as much as 2 inches across intercrystallized with pyrite and evidently of primary deposition. Tennantite in small fragments was observed on the shaft dump but was not seen in place. Some of the best values in silver in the lower parts of the mine are said, however, to have been found in tennantite-rich portions of the lode. A specimen of "gray copper" (presumably tennantite) from shortly below the tunnel level assayed 1 ounce in gold and 118.4 ounces in silver. Zinc ore from the same part of the mine assayed 0.32 ounce in gold and 25.9 ounces in silver.

Specimens from the older shaft workings seen in private collections show undoubted enrichment in silver with the development of ruby silver, argentite, and native silver. The richest ore of the mine is said to have come from the fifth level (315 feet vertical depth), but one specimen from the sixth level (450 feet vertical depth) showed wires of native silver deposited on the quartz crystals in a small vug, indicating that silver enrichment locally extended to that depth.

Sampling-works assays of 27 lots of smelting ore, aggregating 202 tons, shipped from the Seaton mine between 1902 and 1910, show gold, 0.12 to 2.35 (average 1.13) ounces; silver, 7.5 to 105 (average 39.66) ounces; copper (wet), 2.55 per cent or less; lead, 26.4 per cent or less; zinc, 24 per cent or less. A former operator estimates the average value of clean smelting ore between the fifth and seventh levels at gold 1.6 ounces, silver 55 ounces, lead 22 to 25 per cent, zinc 18 per cent.

A test run made in the Dover mill on 25 tons of material from the Pine Shade dump yielded a nearly pure galena concentrate, which assayed gold, 5.36 ounces; silver, 20.90 ounces; and lead, 66.50 per cent. Zinc concentrates weighing 11,900 pounds, shipped in 1910, assayed gold, 0.55 ounce; silver, 20 ounces; lead, 7.50 per cent; zinc, 27 per cent. These assays indicate that the gold values are considerably higher in the galena than in the sphalerite. Sampler returns from ore shipped from the Seaton lateral in the Argo tunnel level show lower values than ore from the Shaft and Foxhall tunnel workings, an estimated average for about 45 tons being gold, 0.5 ounce; silver, 25 ounces; lead, 20 per cent; zinc, 15 per cent. Silver contents considerably higher than those recorded above were characteristic of the enriched ores in the upper levels. Raymond[1] states, for example, that ore obtained just below the oxidized zone in 1871, containing sphalerite and galena in the proportion of 3 to 1 and some "gray copper," assayed 100 to 243 ounces in silver.

TROPIC TUNNEL.

The Tropic tunnel, which was started in 1900, runs N. 18° W. for about 1,600 feet under the eastern end of Seaton Mountain from an elevation of 8,575 feet near the head of Buttermilk Gulch. The first 1,000 feet cuts schist of the Idaho Springs formation and the last 600 feet is in granite pegmatite and granite gneiss with some schist. (See fig. 56.) At 600 feet from the mouth the tunnel cuts a monzonite porphyry dike 45 feet wide.

The Tropic tunnel cuts three main veins—the Gem, the Tropic, and the Seaton-Pine Shade and several smaller mineralized fractures. The Gem vein, as exposed by the Tropic tunnel, is at least 20 feet wide. The drift follows its footwall portion (fig. 56), which consists of crushed altered granite gneiss, heavily impregnated with pyrite and traversed by numerous stringers of rather coarse pyrite, some of which are 8 inches in width, though most of them are only 1 to 1½ inches. Thirty feet south of the footwall a fracture nearly parallel in strike but dipping 69° N. contains 4 inches of gouge. The granite gneiss between the Gem vein and this fracture is all somewhat altered and contains pyrite sparingly disseminated through it. (See also p. 291.)

Vein *A* (fig. 56) is a 4-inch vein of quartz and pyrite which is frozen to the walls.

Vein *B* is an 18-inch zone of crushed pegmatite in which there has been a slight deposition of pyrite.

Vein *C* is a 2 to 4 inch quartz-pyrite vein parallel to the schistosity and frozen to both walls.

The Tropic vein ranges from 1½ to 6 feet in width (average about 2 feet). Next the hanging wall in most places there is from 2 to 4 inches of gouge, below which is altered silicified schist traversed by bands not more than 10 inches wide carrying dark sphalerite, galena, and

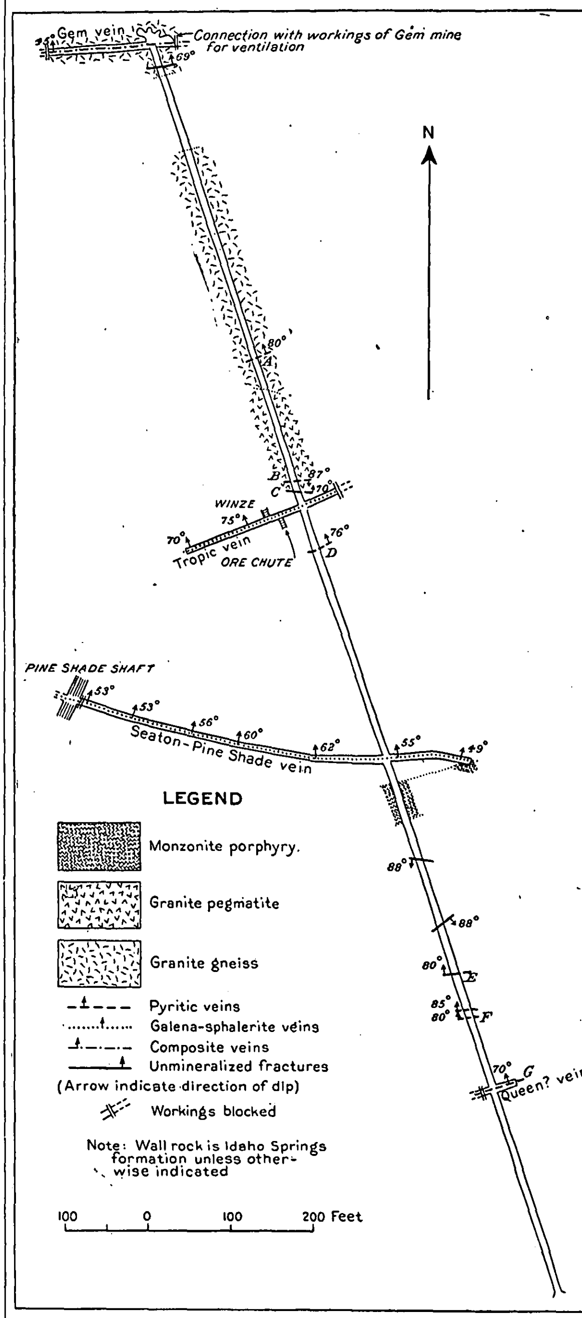


FIGURE 56.—Geologic plan of Tropic tunnel. Surveyed by hand compass and pacing.

more or less pyrite and chalcopyrite. In some of the ore here a small amount of gray copper is closely associated with galena and sphalerite. In the Tropic vein on the Argo tunnel level some rhodochrosite is found.

[1] Raymond, R. W., Statistics of mines and mining in the States and Territories west of the Rocky Mountains, 1871, p. 351, 1873.

Sampling-works assays of a few shipments of smelting ore from different parts of the Tropic vein give some idea of the metal content.

Sampling-works assays of ore from the Tropic vein.

	Gold.	Silver.	Copper (wet).	Lead.	Zinc.
	Ounces.	*Ounces.*	*Per cent.*	*Per cent.*	*Per ct.*
Argo level	0.23	29.70	....	18.00	20
Surface	.19	53.00	....	....	......
Seventh level	1.60	24.10	....	20.90	23
	1.24	117.80	....	13.50	23
Tropic tunnel level	.26	21.30	....	....	9
	.75	56.40	0.50	....	18
	.70	169.00	4.10	12.00	7

The tenor of the ore is so variable that it is difficult to give a satisfactory average. Sampling-works assays of 25 lots of smelting ore, aggregating 68 tons, shipped from 1908 to 1910, show gold 0.1 to 7 ounces and silver 0.5 to 118.5 ounces.

In general the gold content is less than 1 ounce and the silver less than 50 ounces, though some ore from the upper levels contained several hundred ounces of silver as a result of downward enrichment. Copper generally is below the smelter limit of 1.5 per cent. Lead averages about 10 per cent.

The gross production is said to be about $200,000.

Vein *D* is a 3-inch fracture in which the crushed schist contains a little disseminated pyrite.

The Seaton-Pine Shade vein, as exposed in the Tropic tunnel and in drifts on the vein which connect the tunnel with the Pine Shade shaft, ranges from 7 inches to 5 feet in width (average about 2½ feet). The vein consists of dark-gray quartz with galena, dark and light sphalerite, pyrite, and chalcopyrite. In some places the schist has been silicified and contains disseminated sulphides. At one place about midway between the Tropic tunnel and the Pine Shade shaft the ore has been brecciated and partly recemented and lies in a matrix of crushed wall rock and white quartz. For the value of the ore and a description of other development on this vein, see pages 294–297.

Vein *E* is a 2-foot zone of crushed altered schist, somewhat silicified, which contains disseminated pyrite. It is about parallel to the foliation of the schist and is separated from both walls by 1 inch of gouge.

Vein *F* comprises 10 feet of shattered and bleached schist. On the hanging wall and the footwall and near the center of this zone there are 12 to 14 inch bands of quartz and pyrite.

Vein *G* is about 5 feet wide. For 8 inches above the footwall the crushed schist is silicified and contains a little disseminated pyrite. The rest of the vein consists of fractured but unmineralized schist.

CRYSTAL TUNNEL.

The portal of the Crystal tunnel is on the east side of Virginia Canyon at an elevation of about

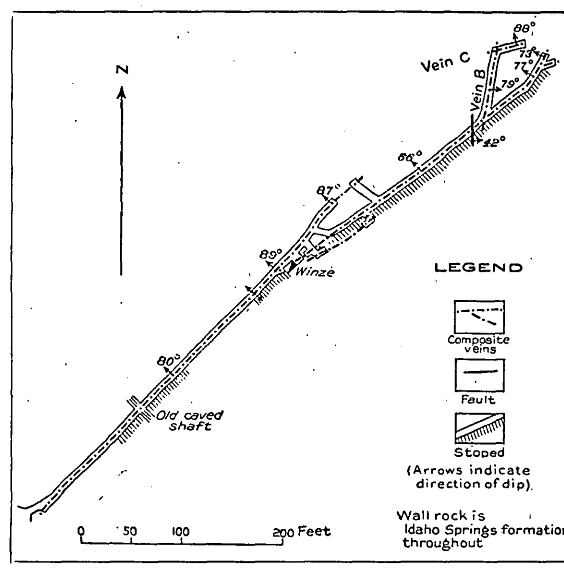


FIGURE 57.—Geologic plan of Crystal tunnel. Surveyed by hand compass and pacing.

8,250 feet. The vein is strong and without branches from the portal to the winze, shown in figure 57, and in this distance varies from 6 inches to 4 feet in width. An exposure 300 feet from the portal shows a tight slip plane next the footwall followed successively by 8 inches of silicified schist carrying disseminated pyrite, a 4-inch vein of quartz, pyrite, and sphalerite, 3 feet of silicified schist carrying disseminated pyrite, and a tight slip plane next the hanging wall. Near the winze the vein divides into three forks, and the principal development follows the middle fork. Specimens from near the face of the north fork show clearly that the mineralization is composite, coarse pyrite being traversed by veinlets of quartz, galena, and sphalerite.

About 600 feet from the portal the middle branch is cut without displacement by a fracture zone that parallels the schist foliation and shows 2 to 4 inches of gouge. About 10 feet farther on the vein is crossed by vein *B*, showing from 2 to 6 inches of fractured schist on the footwall and a 1 to 4 inch band of quartz, pyrite, galena, and sphalerite next the hanging wall. Vein *C*, at the end of the drift on vein *B*, is a 1 to 2 inch stringer of sphalerite frozen to both walls. At the face the schist for 4 inches below it is silicified and carries disseminated sulphides.

The metal content of the ore from the Crystal tunnel is variable. Sixteen lots of smelting ore, aggregating 35 tons, shipped from 1888 to 1910 inclusive, show, according to sampling-works assays: Gold, 0.15 to 3 (average, 0.76) ounces; silver, 5.5 to 95 (average, 37.4) ounces; copper (wet) in one lot 3, but usually less than 1.5 per cent; lead, 3 to 17 per cent; zinc, 6 to 16 per cent.

CASINO VEIN AND FOXHALL TUNNEL.

The portals of the Foxhall and Casino tunnels are near each other and at nearly the same elevation (about 8,450 feet) at the head of Seaton Gulch. (See fig. 55.)

The Foxhall tunnel cuts several minor veins, described below in order from portal to face and identified by letters in figure 55: A, a one-half to 2 inch vein of gray quartz carrying fine-grained pyrite; B, a tight but very vuggy quartz vein 1 to 3 inches wide, showing pyrite and some galena near and on the walls of vugs; C, a zone of fractured schist 4 inches to 1 foot in width carrying some disseminated pyrite; D, a one-half to 1 inch veinlet of gray quartz carrying pyrite; E, a fracture zone feebly mineralized with galena and sphalerite; F, a sharp-walled vein 1½ to 2½ inches wide consisting of coarse pyrite in a quartz gangue; G, a tight vein 1½ to 2½ inches wide, composed of galena, sphalerite and pyrite and probably an offshoot from the Seaton vein; H, a vein 1 to 2 inches wide, parallel to the foliation of the schist, consisting of pyrite and quartz. The schist for several inches on each side carries disseminated pyrite.

The Total Eclipse vein, as seen in drifts from the Foxhall tunnel, is not strongly mineralized. In places it is a barren fracture zone 2 inches to 2 feet across, but elsewhere it shows 1 foot of gray quartz and somewhat silicified schist carrying pyrite.

The Danube vein, as exposed in the Casino tunnel, is not heavily mineralized and no stoping has been done on it. In many places it is a barren fracture zone, 6 inches or so in width, about parallel to the foliation of the schist wall rock. In a few places small stringers of gray to brownish quartz carry fine galena, sphalerite, and pyrite.

The Casino vein is less regular than the other main veins cut by the Foxhall and Casino tunnels. It is composed of several branching fracture zones in the schist whose relations to each other are more or less irregular. The exact relations between the portions of the vein exposed in the Casino and Foxhall tunnel workings, respectively, are not clear; the relationship is evidently complicated by the presence of the Total Eclipse vein. The vein is not now being worked in the Casino workings, but at the time of survey it was being worked on a short level 150 feet below the Foxhall tunnel through a shaft starting underground in the Foxhall tunnel. On this level, 95 feet west of the shaft, the mineralization consists of three tight-walled veinlets one-half to 2 inches wide distributed through a width of 4 feet of schist and lying about parallel to its foliation. These veinlets consist of rather fine sphalerite, galena, and subordinate pyrite in a gangue of gray quartz and some pink calcite. The presence of gray copper in this portion of the vein is said to indicate good values.

The Casino vein has in the past yielded considerable amounts of rich telluride ore. The silver values in these ores were said to be small, and the valuable mineral was probably sylvanite. Only roasted specimens of this ore were seen by the writer, but some of these were exceedingly rich.

All the output is smelting ore, but its tenor is so uneven that it is impossible to give the average metal content. The following sampling-works assays show the high values occasionally found and the extreme irregularity in the gold-silver ratio. The first two probably represent ores enriched in silver; the third and probably the fourth are certainly of telluride ores; the last two more nearly represent the content of most of the ore.

Sampling-works assays of ore from Crystal tunnel.

Year.	Ore.	Gold.	Silver.
	Net pounds.	*Ounces.*	*Ounces.*
1888......	3,709	4.30	252.65
1888......	1,118	6.78	241.66
1893......	82	76.00	18.00
1894......	2,750	8.20	.25
1893......	3,674	1.58	8.34
1888......	3,414	2.25	3.00

EARLY BIRD TUNNEL.

The Early Bird tunnel, on the west side of Virginia Canyon opposite the mouth of Boomerang Gulch, is entirely on the vein and is said to be 640 feet long but could be entered for only 510 feet. At 310 feet from the mouth a winze, now full of water, has been sunk; and at 180 feet a 30-foot crosscut leads south. Schist of the Idaho Springs formation is exposed throughout the entire workings.

The vein strikes N. 55° E. and dips on an average 85° SE. It is usually from 12 to 18 inches wide. Branches into the footwall were noted just east of the winze and 80 feet from the mouth. A small parallel fracture with similar mineralization is exposed at the end of the crosscut.

The mineralization is entirely pyritic, small cubes of pyrite being disseminated in the crushed, bleached, and in places silicified schist along the fracture zone. At the winze the mineralized zone is at least 10 feet wide; nearer the mouth of the tunnel its maximum width is about 5 feet. In a few places lenses of white quartz with rather coarse pyrite are seen in the vein; in most places these are about 2 inches wide and are very short, but in one locality 6 inches of the material extends for about 20 feet along the drift.

Apparently little work has been done in this tunnel for years, and the water, which is considerable, is depositing limonite on the walls and floor. Near the winze the floor is covered with 2 to 3 inches of soft spongy limonite.

The Early Bird shaft, 300 feet southeast of the tunnel on the Old Proverb vein, is full of water. The dump indicates that this vein has the same constituents as the Early Bird vein.

BELL VEIN.

The Bell vein is developed by the Bell tunnel with portal in Seaton Gulch at an elevation of about 8,200 feet. The tunnel, which is about 650 feet in length, trends from east to N. 65° E., following a well-defined but lean fracture zone which only exceptionally shows small seams and lenses of pyrite. It is in general nearly vertical. In several places the fracture zone is 3 to 4 feet in width, but the widest pyrite stringer observed was only 1½ inches.

TREASURE VAULT MINE.

The Treasure Vault vein cuts across the nose of the ridge between Virginia Canyon and Buttermilk Gulch about three-quarters of a mile north of Idaho Springs, the main shaft and mouth of the tunnel being within 400 and 500 feet of the road between Central City and Idaho Springs. This vein has been worked through three shafts, the deepest of which has reached 130 feet below the surface. A drift tunnel 450 feet long, starting from the draw between Buttermilk and Seaton gulches, runs east to a point under the main shaft, with which it is connected by a 50-foot inclined raise. This shaft has levels at 76 and 126 feet and is equipped with a hand windlass. The lower level extends 135 feet east and 40 feet west of the shaft, the raise from the tunnel being at the extreme west end. The 76-foot level is 210 feet long, 50 feet of which is west of the shaft. Most of the stoping has been done between the first level and the surface, though some ore has been taken from greater depths.

Granite gneiss is the only rock seen underground. On the surface a very little monzonite porphyry is exposed just east of the tunnel mouth but was not noted in the tunnel.

The Treasure Vault vein strikes about N. 60° E. and dips 29°–58° N. It is accompanied by two subparallel veins. The first, a rather strongly marked, nearly vertical fissure averaging about 1 foot in width joins the Treasure Vault on the upper level about 90 feet east of the shaft and diverges from it westward. Thirty feet west of the shaft it is 15 feet south of the main vein, and it is probably identical with the southern 1 to 2 foot fracture in the tunnel level, where the veins are about 100 feet apart. Between the main vein and the first fissure a second fissure appears, about 50 feet from each in the tunnel and about equidistant n the upper level. It has a dip of 55°–70° S. Cross fractures connect the three main fissures, and the granite gneiss between them is more or less silicified and otherwise altered. The gently dipping Treasure Vault vein in particular tends to send off small very flat lying stringers which seem in some places to cut across the middle and vertical vein. These "flats," of which there are two and possibly three between the surface and the second level, seem to have some connection with the bonanza pockets. They are generally narrow and of short length along the vein, being rarely traceable for more than 30 feet.

In the tunnel the three fissures exposed were practically barren fracture zones containing a little disseminated pyrite. At one locality in the north or Treasure Vault drift a stope 100 feet long and 10 to 15 feet high shows two stringers of gray-blue cherty quartz with pyrite, each about 4 inches wide, separated by 4 feet of very slightly altered granite gneiss.

The ore is silicified granite gneiss cut by subparallel branching stringers of blue-gray cherty silica, commonly one-fourth to one-half inch wide but reaching 4 to 6 inches in a few localities, where they are apt to inclose a drusy central cavity. On the first level in the stope east of the shaft one of the "flats" crossing the drift shows successive depositions of a thin film of dark-gray cherty silica in small disconnected patches, a film of violet-colored fluorite, one-eighth inch in maximum thickness, and a coating over all of one-eighth to one-fourth inch of ferruginous calcite. That the fluorite and calcite were deposited in open cavities is shown by their drusy surfaces.

The gangue minerals are frozen to the granite gneiss, but there is in most places a tight parting between adjacent layers of the cherty silica near the walls. A very minor amount of fine pyrite accompanied the silica, but it is more abundantly disseminated in the adjacent wall rock than in the veins proper. The gold is largely native and in tellurides (found thus far only to a depth of 126 feet) and is largely confined to the stope at the shaft and the small flat stope in the east 76-foot level. The native gold occurs as irregular films on joint planes near the flat vein and as stringers up to one-fourth inch wide cutting brown-stained altered granite gneiss. The telluride is silver colored and is said to contain about equal amounts of gold and silver, being near sylvanite in composition. Tellurides are not nearly so abundant as native gold, but the two occur in the same manner and in close association with each other.

Only two localities show postmineral movement. On the 126-foot level, 115 feet east of the shaft, a nearly vertical fault striking northwest has displaced the vein bringing the east side down about 2 feet. What is probably the same fault is seen in the 76-foot level, but here it cuts the vertical vein, and neither the direction nor amount of displacement can be determined.

The ore, where rich enough to mine, is generally of bonanza grade, and the work is done entirely by hand in order to break only the good ground. The ore that has been shipped varies exceedingly in value. Some of it carried as high as 12 ounces gold per ton, though most of it seems to carry one-half to 1½ ounces. Small specimens run higher. The silver varies from one-half ounce to 50 ounces per ton. Some ore, low in gold, carries high silver, and the ore carrying the most gold had only 3 ounces of silver per ton. There seems to be no regular relation between the amounts of gold and silver present, ratio of gold to silver by weight ranging from 1:1½ to 1:16.

The total production of the mine is estimated to be at least $30,000.

IDAHO TUNNEL.

The Idaho tunnel, whose portal is in Boomerang Gulch at an elevation of approximately 8,250 feet, extends north-northeast under Seaton Mountain. The veins are shown in figure 58, to which the letters used below correspond.

A. A nearly vertical fracture zone 2 to 4 inches wide, lying about parallel to the foliation of the schist wall rock. In most places it is barren of mineral but in one place shows 1½ inches of light-gray quartz carrying pyrite.

B. A vein showing 1 to 3 inches of galena, sphalerite, and white quartz.

C. Several small veins carrying 1 to 2 inches of gray quartz and pyrite.

D. A tight veinlet, one-half to 3 inches wide, of galena, sphalerite, and subordinate pyrite.

E. Not a distinct vein; a few small stringers of galena and sphalerite traversing the monzonite porphyry.

F. A vein in one place about 10 inches wide, the upper 5 inches being nearly solid galena, sphalerite, and very subordinate pyrite, and the lower 5 inches silicified schist and pegmatite carrying some disseminated pyrite and a few very narrow pyrite stringers. In places the vein has a total width as great as 2 feet and includes several galena-sphalerite veinlets. It appears to be the westward continuation of the Seaton vein. It has been stoped to some extent.

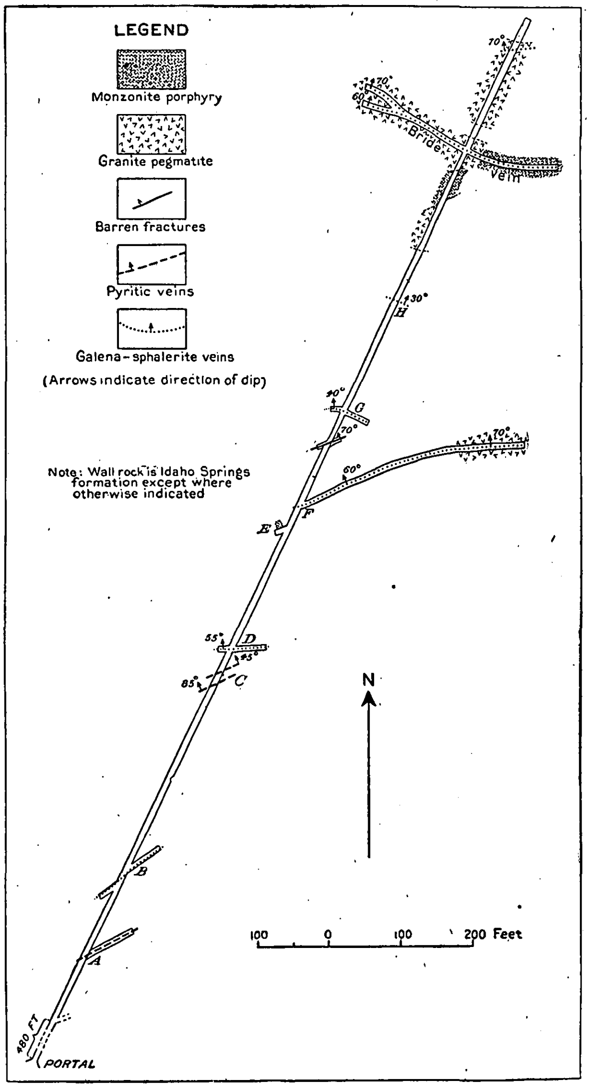


FIGURE 58.—Geologic plan of Idaho tunnel. Surveyed by hand compass and pacing.

G. About 4 inches of somewhat silicified schist, which carries disseminated pyrite and is traversed by several subparallel stringers of galena and sphalerite not more than one-half inch in width. It lies parallel to the foliation of the schist.

H. A ½-inch veinlet of galena, sphalerite, and pyrite, bordered on the hanging-wall side by 2 inches of gouge carrying some crushed sulphides.

The Bride vein is the principal vein cut by the tunnel. To the east of the tunnel its wall rock is monzonite porphyry and to the west granite-pegmatite; the vein is strong in both rocks. In a stope 25 feet above the drift and 130 feet east of the line of the tunnel the vein varied from 4 inches to 1½ feet in width and was made up of a number of narrow subparallel veinlets of galena, sphalerite, and pyrite cutting altered monzonite porphyry. One of the most heavily mineralized portions of the vein is exposed in a stope about 40 feet west of the line of the tunnel, where it is 2 feet in width and consists of a network of subparallel veinlets of solid galena, sphalerite, pyrite, and rarely a little chalcopyrite. Some of the sphalerite is resinous, though apparently original and contemporaneous with the more abundant darker variety. Minute fractures in the ore are coated by a varicolored film, probably of bornite, and by very minute crystals of chalcopyrite. These are plainly secondary depositions, probably from surface waters descending along the vein. In one place there is a width of 1 foot of solid sulphides, parts of which are coarsely crystallized with single crystals three-fourths to 1 inch in diameter.

On account of the high percentage of sphalerite present the ore from this vein is concentrated before shipment to the smelter, the ratio of concentration being about 1 to 3 or 4. The following sampling-works assays of different types of concentrates from shipments in 1911 give an idea of the metallic content:

Sampling-works assays of ore from the Bride vein in the Idaho tunnel.

	Gold.	Silver.	Copper (wet).	Lead.	Zinc.	Silica.	Iron.
	Ounce.	*Ounces.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Pyritic concentrate	0.31	11.90	....	3.00	8.50	21.10	....
	.59	23.70	2.60	6.10	9.50	51.00	....
Sphalerite concentrate	.49	25.10	2.35	6.70	21.50	16.00	....
	.47	24.50	2.70	8.20	23.75	18.00	....
	.42	23.00	2.40	7.40	23.10	16.00	....
Galena concentrate	.56	21.80	1.80	45.10	7.00	4.00	13
	.565	21.20	....	34.30	7.00	5.00	20

GOLDEN ROD MINE.

The Golden Rod mine, on the west side of Gilson Gulch at an elevation of about 8,250 feet, is developed by a drift tunnel about 430 feet long on a vein striking N. 60° W. and by the Bessie M. shaft, 160 feet deep, on a vein striking about N. 75° E. and dipping from vertical to 65° N. The two veins intersect in the tunnel, and short drifts have been driven from the tunnel on the shaft vein. The shaft and tunnel workings, however, do not connect.

The vein followed by the tunnel is in most exposures a tight fracture seam barren of sulphides, but it is said to have carried some high-grade silver ore locally. The shaft vein in two exposures showed 2 to 2½ inches of solid galena, sphalerite, and pyrite, bounded on each side by crushed wall rock and gouge.

ARGO TUNNEL AND VEINS CUT BY IT.

The Argo tunnel, formerly called the Newhouse, is the largest and most important mining work in the district covered by this report. It was begun in January, 1904. The work was delayed at several times by negotiations with mine owners whose veins it cut, but in spite of these delays the progress at certain times was rapid, the face being advanced 2,759½ feet in one year and 2,925 feet in another. Its cross section is 12 by 12 feet for the first 13,117 feet, beyond which it is 9½ by 6 feet, except for occasional widenings to provide passing tracks. Its total length is 21,968 feet, or about 4.16 miles.

The object in driving the tunnel was to intersect many of the largest veins of the district at depths considerably greater than the deepest shaft workings, thus decreasing the cost of deep mining, furnishing cheap and rapid transportation to the mills and railroad at Idaho Springs (see Pl. XVIII, *B*, p. 222), and affording natural drainage when the shaft workings were connected with the tunnel. In the case of the Old Town, Saratoga, and other veins where the shaft workings were some distance from the line of the tunnel, it was necessary to drive long laterals which are not completely shown in Plate XXI, *A* (in pocket).

The tunnel is double tracked in the 12-foot portion and single tracked with occasional sidings beyond. Haulage is in trains drawn by electric locomotives.

Developments from the Argo tunnel on veins that can be certainly correlated with veins on the surface are described in other parts of the report. The following descriptions include only veins and other geologic features not elsewhere treated.

No veins of importance are cut between the portal of the Argo tunnel and the Edgardine vein.

The Edgardine vein, as exposed in short drifts in the Argo tunnel, strikes nearly east and west. It is barren in places and elsewhere not heavily mineralized. A short distance west of the tunnel it shows 3 inches of brecciated schist cemented by rhodochrosite but without sulphides. About 80 feet east of the tunnel the sheared schist is traversed by a ¼-inch veinlet of galena and sphalerite. The outcrop of the Edgardine vein crosses Buttermilk Canyon at an elevation of about 8,150 feet, where it dips 60°–70° N. It is developed by a shaft which could not be entered. Sampling-works assays of 722 and 930 pounds of smelting ore shipped in 1897 and 1898 show, the one, gold 1.25 ounces and silver 4 ounces, and the other, gold 0.3 ounce, silver 13 ounces, lead 2 per cent, and zinc 7 per cent.

The so-called Queen vein is cut by the tunnel about 5,794 feet from the portal. It strikes slightly north of east and dips about 80° N. As exposed in drifts about 15 feet above the level of the Argo tunnel, it is not heavily mineralized. The wall rock is schist of the Idaho Springs formation throughout, and the vein is a sheared zone nearly parallel to the schist foliation. In places a little pyrite is disseminated through the schist, and in one place stringers one-half to 1 inch wide of quartz, pyrite, and a little galena were observed.

What is commonly called the Tropic vein on the Argo level is cut 6,545 feet from the portal. On the surface the Tropic vein lies about 360 feet north of the Seaton vein, but the Seaton, having the gentler dip, is supposed to have crossed the Tropic between the surface and the Argo tunnel level so that the relative positions are reversed. As exposed on the Argo level the Tropic vein is wholly in schist of the Idaho Springs formation. In most places it is a barren fracture zone 2 to 6 inches wide, but 35 to 40 feet west of the tunnel it opens, for a distance of about 5 feet, to a width of 2 feet, in which the lower 6 to 8 inches is somewhat fractured but barren schist, and the remainder is schist traversed by several sulphide veinlets 3 inches in maximum width, mainly of sphalerite and galena with a little chalcopyrite and pyrite. The strike and dip of this vein are fairly concordant with the Tropic vein as exposed in the Tropic tunnel.

The Seaton vein is cut 6,980 feet from the portal of the tunnel at about the point where it should be found if it maintains the average dip of 60° N. that it has in the upper workings. Its character in the Foxhall tunnel is described on pages 294–297.

The Gem system is cut between 7,790 and 7,900 feet from the portal. (See pp. 290–292.) The Gem shaft connects with the Argo workings 160 feet east of the tunnel, so that the lode has been certainly identified.

The so-called Belman vein is cut a little more than 8,500 feet from the portal and is developed by a drift extending east for about 490 feet. The average strike of the vein is about N. 75° E. and the dip is 55°–75° N. The wall rock is mainly schist of the Idaho Springs formation but in small part is granite gneiss. The vein varies from 6 inches to 1½ feet in width and consists of fractured and somewhat silicified wall rock, usually carrying some disseminated pyrite, locally traversed by small veinlets 2 inches and less in width of galena, sphalerite, and quartz. Some small veinlets of coarse pyrite are present, but their relations to the galena-sphalerite veinlets are nowhere shown. The surface workings on the Belman vein could not be entered. They consist of a drift tunnel more than 650 feet long and a shaft with 5 short levels.

A vein of fair size, though undeveloped, is cut about 8,925 feet from the portal of the Argo tunnel and 90 feet south of the Sun and Moon south vein. It shows 20 inches of quartz and coarse pyrite frozen to a monzonite porphyry footwall, above which is 18 inches of silicified schist carrying disseminated pyrite. On the west side of the tunnel a ⅛-inch veinlet of galena and sphalerite cuts across the coarse pyrite vein.

The Sun and Moon workings connected with the Argo tunnel have already been described. (See p. 289.)

A vein showing 10 inches to 2 feet of silicified gneiss carrying disseminated pyrite is cut about 9,384 feet from the portal. There is a tight slip on the hanging wall and gradation into granite gneiss on the footwall.

A vein 9,543 feet from the portal shows a tight slip next the hanging wall, below which is 2 inches of crushed barren granite gneiss, 2½ inches of similar material carrying some pyrite, and 5 inches of quartz, pyrite, and chalcopyrite.

A 10 to 18 inch vein of quartz at about 9,900 feet carries coarse pyrite.

A 1-foot zone of crushed schist carrying at one place a 4-inch wide lens of quartz, pyrite, and chalcopyrite is cut about 9,978 feet from the portal and 25 feet south of the Morning Star vein. It dips 55° N.

The Morning Star vein is cut at 10,003 feet and has been drifted on for 280 feet east of the tunnel. It is a narrow zone of crushed and somewhat silicified schist carrying a little disseminated pyrite.

A fractured zone 18 to 20 inches wide, in schist, carrying some disseminated pyrite, is cut at about 10,330 feet.

Two inches of crushed schist, carrying lenses of quartz, galena, and sphalerite, is cut at about 10,383 feet.

The Half and Half vein, controlled by the Bertha Mining Co., is cut 10,511 feet from the portal. The east drift, 120 feet long, is caved within a few feet of the tunnel and the west drift 150 feet west of the tunnel. As exposed in this 150 feet the vein is a sheared zone 8 inches to 1 foot wide, mainly in schist. This zone is locally silicified and carries disseminated pyrite. In general the mineralization is very weak.

The south vein of the Frontenac-Aduddell group is cut at 11,210 feet. (See fig. 59.) The Druid lateral, which extends northeastward from the Argo tunnel for over 1,300 feet, starts on the north vein, but was flooded 50 feet east of the tunnel and was inaccessible for study. In general, mineralization along the south vein is very meager, only a little disseminated pyrite appearing locally in crushed porphyry or gneiss. The north vein is more strongly mineralized, showing 30 feet from the southwest face, 1½ inches of sheared granite gneiss next the hanging wall, below which is a veinlet of coarse pyrite 2 to 4 inches wide, traversed near its center by a ½-inch to ¾-inch sharp-walled veinlet of sphalerite and galena. The vein on the north side of the drift

(A, fig. 59) is 3 inches to 1 foot in width, with sphalerite and galena predominant and some pyrite.

The Wellington No. 6 vein, of the King Bee Gold Mining Co., is cut 12,260 feet from the portal. It is developed by a lateral extending about 225 feet east of the tunnel and by another which extends over 700 feet west but which at the time of this survey was caved 330 feet from the tunnel. A winze has been sunk from this west drift and a considerable amount of stoping done above it. The vein was well exposed in a stope 200 feet above the west lateral, where mining was in progress at the time of this survey. There it is a tight vein 2 to 4 inches wide, between walls of granite gneiss, consisting of galena, sphalerite, and pyrite in a gangue of gray quartz and altered gneiss. Vugs lined with quartz and pyrite are numerous, and there are a few lenslike enlargements of the vein 1 foot in maximum width. The smelting ore from this stope is reported to carry 2 to 3 ounces in gold and 20 to 25 ounces in silver per ton. The fine-grained pyrite is reported richer than the coarse. As exposed in the east lateral the vein is in many places represented by a barren fracture and elsewhere is a tight sulphide vein not more than 2 inches wide.

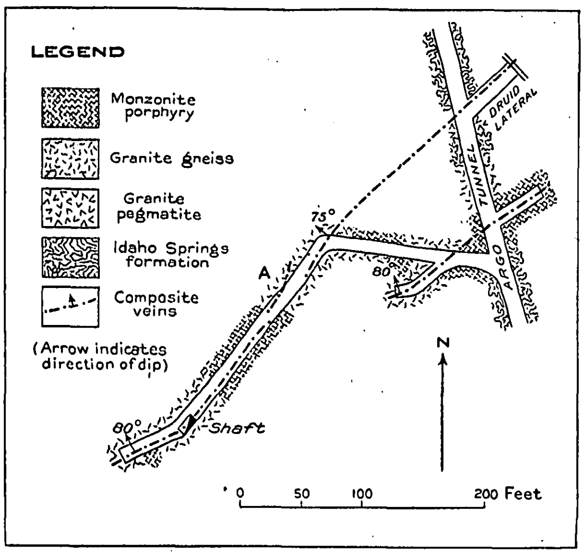


FIGURE 59.—Geologic plan of workings on Frontenac-Aduddell system of veins on Argo tunnel level. Surveyed by pacing and hand compass.

What is called the Compeer vein of the King Bee group is cut 12,710 feet from the portal. On the west wall of the tunnel it is a series of subparallel fractures without sulphides. On the east wall it shows 14 inches of quartz carrying fine galena and pyrite.

Four feet of crushed and somewhat silicified schist carrying disseminated pyrite is cut about 12,850 feet from the portal.

The Compensation vein of the King Bee group has been provisionally identified as one of two veins 20 feet apart which cut the schist 12,980 to 13,000 feet from the portal. The south vein consists of 18 inches of crushed schist carrying disseminated pyrite. The north vein is in places a tight barren fracture but elsewhere shows 6 inches of crushed and silicified schist carrying disseminated pyrite.

The Japan vein, cut 13,235 feet from the portal, shows a tight fracture on the hanging wall, below which is 14 inches of highly silicified schist carrying disseminated pyrite and 2½ feet of crushed schist only slightly silicified and carrying only a little pyrite.

The Saratoga vein is cut at 15,080 feet. (See pp. 267–268.)

A large vein at 15,350 feet shows a tight slip next the footwall, above which is 8 inches of soft altered gneiss cut by a network of small pyrite stringers, 1 inch of coarse pyrite and quartz, 14 inches of gneiss carrying disseminated pyrite, 4 feet of quartz with coarse pyrite, and 8 inches of quartz carrying some pyrite, frozen to the porphyry hanging wall.

A tight vein consisting of 2 feet of pyritiferous quartz is cut at about 16,336 feet.

The Calhoun lateral is reached about 16,506 feet from the portal, but was accessible for only 350 feet west, beyond which it was flooded. In the 350 feet examined it follows a fractured zone 2 to 2½ feet wide in granite gneiss weakly mineralized with minute veinlets of pyrite and some disseminated pyrite. The prevailing dip is about 80° N.

Three pyritic veins, none of which is heavily mineralized, are cut in the 150 feet north of the Calhoun lateral. One of these veins assayed gold 0.2 ounce and silver 1.2 ounces.

A 4-foot zone of silicified granite gneiss 16,780 feet from the portal is traversed by numerous subparallel tight fractures and by small stringers of quartz and pyrite. It carries more or less disseminated pyrite.

A zone 10 feet wide in granite gneiss is cut by numerous subparallel fractures at about 17,020 feet. The gneiss is silicified and carries disseminated pyrite. About 2 feet above the footwall is a 1-foot vein of quartz carrying abundant fine pyrite.

Three veins are cut between 17,160 and 17,230 feet. The southernmost vein is an 8-foot vertical zone of crushed and silicified gneiss carrying abundant disseminated pyrite; the middle vein dips 80°N. and shows 1 foot of crushed granite gneiss next the footwall, followed by 1½ feet of silicified gneiss carrying disseminated pyrite; the northern vein dips 85° N. and shows 1½ feet of pyritic quartz.

The Mammoth lateral leaves the Argo tunnel about 17,370 feet from the portal. It was studied to a point 1,350 feet east of the tunnel, beyond which flooding prevented further study. For the first 700 feet the lateral follows a sheared belt 6 inches to 1 foot in width, only slightly mineralized with disseminated pyrite. Beyond this the mineralization is slightly more pronounced and at about 825 feet is strengthened by a branch vein coming in from the south wall. Beyond 825 feet the vein shows commonly 1 to 2 feet of silicified schist carrying abundant disseminated pyrite. The mineralization is not at all comparable in strength with that of the Mammoth vein as exposed in higher workings, and no stoping of consequence has been done. A sample of heavy pyritic ore from the breast of this lateral assayed gold 0.06 ounce and silver 0.5 ounce. A width of 1 foot of the heaviest pyritic ore in the lateral assayed gold 0.16 ounce, silver 1.3 ounces.

The so-called Illinois vein is cut by the Argo tunnel 18,088 feet from the portal and has been drifted on for 30 feet east and 50 feet west.

What is probably the California vein is cut 18,362 feet from the portal. Its identification is based not only on its position but on its association with a dike of bostonite porphyry, a feature which charactérizes it in the shaft workings. (See p. 223.)

The Patch is traversed between 18,867 and 19,412 feet from the portal. (See p. 236.)

What is supposed to be the Dyke vein is cut at about 20,370 feet, where development was in progress at the time of this survey. The Dyke lateral extends west from the tunnel for about 800 feet, following a well-defined vein strongly mineralized for the first 700 feet but only weakly so in the last 100 feet. In most places it is 1 to 2 feet wide, in one place reaching 2½ feet. In some places it is merely a heavy dissemination of pyrite through a zone of fractured gneiss but elsewhere shows one or more sharp-walled veins of gray quartz and pyrite bordered by gneiss carrying disseminated pyrite. In one place it contains 8 to 10 inches of nearly solid pyrite. The prevailing wall rock is granite gneiss, but near the face, where the vein becomes leaner, there is some schist of the Idaho Springs formation.

A large number of assays of ore from along the Dyke lateral show a gold content of 0.3 ounce to 2 ounces (maximum of 9.8 ounces). The silver content is commonly between 3 and 15 ounces (maximum 36 ounces). The copper content is usually negligible.

Shipments in 1910 as shown by sampling-works assays were as follows:

Sampling-works assays of ore from Dyke vein, Argo tunnel.

Ore.	Gold.	Silver.
Net pounds.	*Ounce.*	*Ounces.*
5,306	0.62	4.30
13,020	.77	4.10
12,673	.56	3.02
14,760	.62	6.20
16,342	.275	9.72

The Dyke shaft is in the east part of Nevadaville, but little ore has been mined through it.

The Prize vein is cut about 20,980 feet from the portal and has been developed by short drifts. (See p. 221.)

The Gunnell South, Gunnell Middle, and Gunnell North, and Elizabeth veins are cut 21,296 to 21,563 feet from the portal. (See fig. 29, p. 216; also pp. 216–218.)

The Hattie vein, cut about 21,798 feet from the portal, is a 2 to 3 inch zone of crushed schist carrying disseminated pyrite.

FALL RIVER.

DOVER AND PHILADELPHIA TUNNELS.

The Dover and Philadelphia tunnels are near each other on the east side of Fall River near its junction with Clear Creek. Parts of the workings in both are on the same northwest-striking vein. (See fig. 60.)

The Dover tunnel is an adit about 840 feet long with short branch drifts and crosscuts. For about 600 feet from its mouth this adit follows a fracture zone which trends about N. 45° E. and dips 30°–50° NW. The vein is commonly barren, consisting only of crushed or silicified wall rock, though locally it carries pyrite disseminated through gouge or through gray quartz probably formed by silicification of the wall rock. The greatest width of pyrite and quartz observed was 16 inches.

The main vein is crossed with slight displacement 440 feet from the mouth of the adit by a vein striking about N. 40° W. and dipping about 60° NE., which shows 6 to 9 inches of white and gray quartz, probably formed by silicification of the wall rock along a fracture zone. It is barren of sulphides. About 100 feet of drifting has been done on this vein.

The main vein is cut 600 feet from the mouth of the adit by a fault striking about N. 60° W. and dipping 50° NE. The main adit turns and follows this fault but is caved a little beyond the turn. The fault where exposed shows 6 inches of gouge. It is the same fault (see fig. 60) on which extensive drifting has been done in the Philadelphia tunnel.

That portion of the Philadelphia tunnel which trends northeast follows several nearly parallel fractures comprising the Boston vein, along which for a width locally of several feet the granite gneiss has been much silicified and carries disseminated pyrite. Only a few distinct veinlets of pyrite are present, and all are small except in the stoped part of the vein, 300 to 380 feet from the portal, where in one place an 8-inch vein of pyrite and quartz was exposed. In other places galena-sphalerite veinlets one-half and 1 inch wide were noted. In one place the Boston vein forks and reunites (see fig. 60), and in another place it is offset into one wall of the drift by cross faults. The ore is of low grade and has been stoped at only the one place noted. A little drifting has been done on two barren fracture planes which cross this vein.

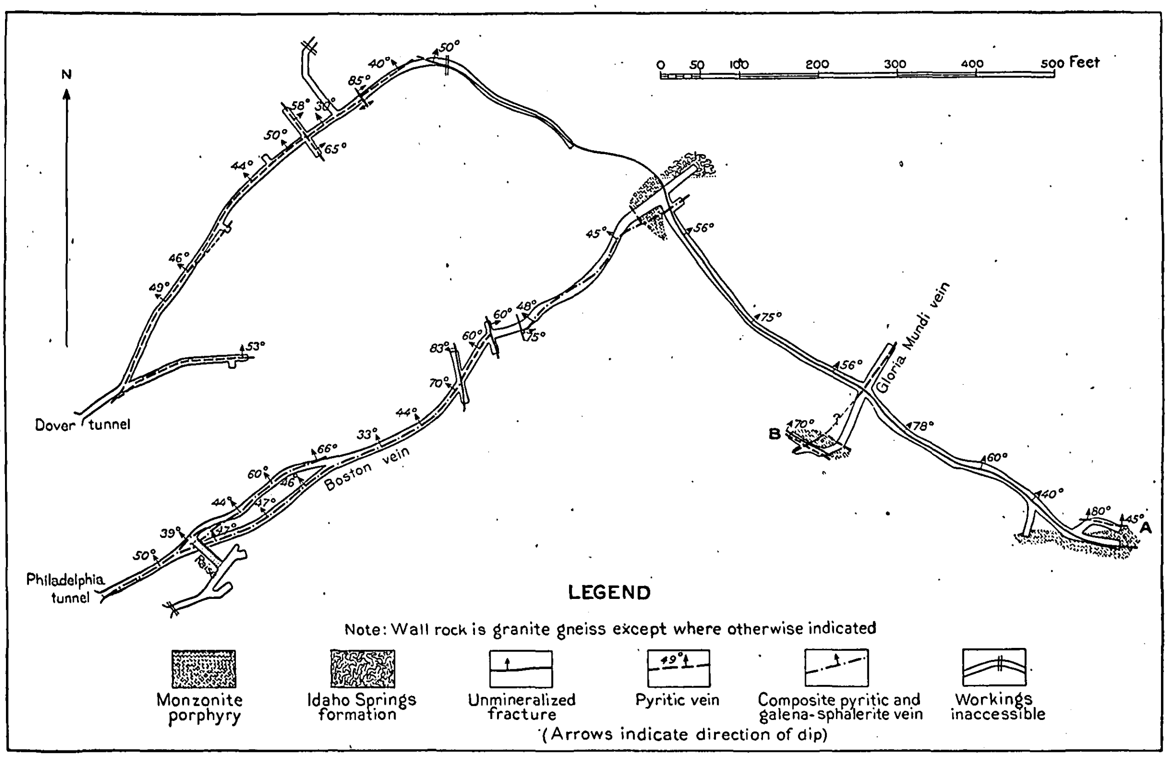


FIGURE 60.—Geologic plan of Dover and Philadelphia tunnels.

The part of the Philadelphia tunnel which trends northwest and southeast follows a fault plane which parallels the general course of a dike of monzonite porphyry. The fault plane is characterized by much breccia and gouge but is barren except for scattered grains of disseminated pyrite. No stoping has been done on it.

The Gloria Mundi vein shows a small amount of stoping. (See fig. 60.) In one place it carries, frozen to the hanging wall, a 2-inch band of quartz, pyrite, and chalcopyrite, below which for about 4 feet the granite gneiss is cut by small stringers of pyrite one-eighth inch to $1\frac{1}{2}$ inches wide. This vein is distinctly later than the monzonite porphyry dike. A vein (A, fig. 60) a short distance northeast of the main fault vein, which may be a spur from it, shows next the hanging wall 6 inches of crushed granite gneiss, below which the gneiss is traversed for a width of 2 inches by pyrite stringers 1 inch and less in width and carries disseminated pyrite.

A vein (B, fig. 60) about 100 feet below the main fault vein shows 4 feet of granite gneiss more or less silicified, containing pyrite in disseminated grains and as small stringers. Above it lies an open watercourse, along which much dark-gray cherty silica has been deposited.

UNITED GOLD TUNNEL.

The United Gold tunnel is on the east side of Fall River, about one-fourth mile north of its junction with South Clear Creek. A 10-stamp mill, known as the Ristedt mill, is in the creek bottom opposite the mouth of the tunnel, with which it is connected by a short trestle over the Fall River road. (See fig. 61.)

The main tunnel is a drift 450 feet long. A crosscut started about 150 feet from the mouth is 600 feet long and intersects six narrow fracture seams, which strike 16°–42° NW. The mineralization in all of them is weak, consisting generally of a small amount of disseminated pyrite in the walls very close to the fractures. Lenses of white or light-gray quartz with fairly coarse pyrite occur in places, particularly in the fourth fracture intersected by the crosscut.

The first fracture in the crosscut consists of 4 inches of barren crushed granite gneiss and is probably the extension of a fault encountered in the main drift. The second fracture consists of 1 foot of crushed granite gneiss with abundant disseminated pyrite separated from both walls by gouge; the wall rock for 4 feet on either side is impregnated with pyrite. The third fracture is tight and barren. The fourth fracture contains a vein filling of white quartz 2 to 10 inches in width, which carries locally a minor amount of coarse pyrite and is commonly frozen to the walls, though at one place it is separated from the hanging wall by 2 inches of gouge. The walls are everywhere slightly silicified, and near the face of the south drift some pyrite is disseminated in the footwall through a width of 20 inches. The fifth fracture is a 1-foot zone of slightly silicified granite gneiss containing a very minor amount of pyrite. The sixth and last fracture shows a 2 to 4 inch stringer of white quartz, which carries a few pyrite cubes and is usually frozen to the footwall and separated from the hanging wall by a slip plane.

From 40 to 300 feet from its mouth the main drift follows a flat vein 2 to 6 inches wide of light gray quartz with fairly abundant pyrite, separated from both walls by an inch or so of gouge. At 300 feet from the portal this flat vein is cut without displacement by a vertical barren fracture which the drift follows from that point. This fracture contains 4 to 6 inches of crushed granite gneiss, much of which approaches gouge in fineness. Near the face of the drift a lens of white quartz 6 inches wide by 5 feet long shows a minor amount of pyrite, as does also about 2 inches of the adjacent crushed wall rock.

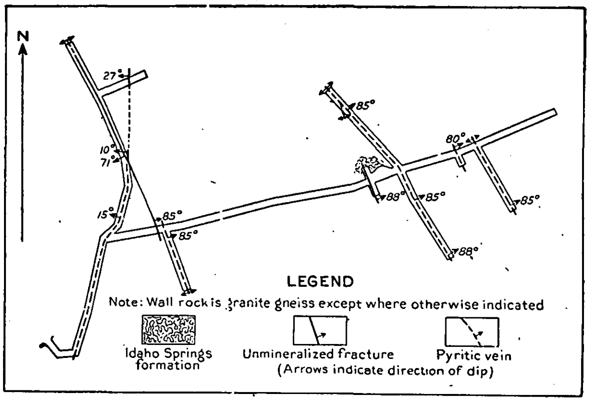


FIGURE 61.—Geologic plan of United Gold tunnel.

There has been no stoping on any of the veins exposed by this tunnel.

DUBUQUE MINE.

The Dubuque vein, on the west side of Fall River a short distance above its confluence with Clear Creek, is developed by two drift tunnels, the upper 120 feet long and the lower over 400 feet long. The vein strikes northwest, following the northeast side of a dike of monzonite porphyry. The workings could not be entered at the time of this survey. Ore on the dump showed pyrite and chalcopyrite.

LUCANIA TUNNEL.

The Lucania crosscut tunnel runs N. 40° E. for at least 6,240 feet from a point on the east side of Fall River about 1 mile north of South Clear Creek. The tunnel, which is one of the longest in this district, was designed to cut the veins of Russell Gulch and Quartz Hill at considerable depths and to reach the Patch about 14,800 feet from the portal at a depth of about 1,400 feet. In September, 1911, the face was under the head of Davenport Gulch.

The country rock throughout the tunnel is granite gneiss, which for the first 4,435 feet is more biotitic than it is near the face. The line of demarcation between the two facies is fairly sharp and is parallel to the gneissic structure.

In the tunnel the gneiss is cut by a succession of small, tight, nearly parallel fractures, which strike on the average N. 80° W. Most of them dip north at rather steep angles (75° being most common), but one or two dip 80°–85° S. Near the face an exceptionally large well-mineralized fracture, cut by the tunnel, strikes N. 50° W. and dips 70° NE. Accompanying this near the south wall is a 10-foot monzonite porphyry dike.

Except for the vein just mentioned the mineralization of the fractures is weak. In about 20 fractures noted in the entire length of the tunnel only very minor amounts of pyrite occurred, generally disseminated in the wall rock near the fissure but in places occurring as stringers of coarse pyrite and quartz in the fissure. In three fractures, about two-thirds of the way in from the mouth, some galena, sphalerite, and chalcopyrite associated with gray quartz occur in lenses, most of which are frozen to the walls above the pyritic veins.

The large vein near the face is supposed to be the John L. Emerson, opened higher on the hill by the Knickerbocker tunnel. In the Lucania tunnel it is 42 feet wide, with about 30 feet of the hanging wall slightly mineralized. The cross section of this vein is as follows:

Section of John L. Emerson vein (?) in Lucania tunnel.

	Feet.
Granite gneiss, dark colored, altered, carrying disseminated pyrite	10
Tight slip plane.	
Quartz, white, carrying a little pyrite	$1\frac{1}{2}$
Granite gneiss, crushed, with abundant disseminated pyrite	2
Granite gneiss, darker, much altered, cut by numerous stringers of white quartz and pyrite with a little chalcopyrite. These minerals also occur in small grains disseminated through the gneiss. Several slip planes traverse this part of the vein	15
Quartz, white, containing pyrite	1
Quartz, gray, carrying pyrite	$1\frac{1}{2}$
Monzonite porphyry, much altered, carrying disseminated pyrite and traversed by numerous very small stringers of dark quartz locally carrying galena and chalcopyrite	10
Tight slip plane against footwall.	

A little ore obtained in crosscutting the vein was largely galena and chalcopyrite but apparently came from a lens, for similar material was not seen along the walls. At the time of survey there had been no drifting on the vein.

The veins underground are numbered from the mouth of the tunnel. An aggregate of 1,040 feet of drifting has been done on Nos. 12, 13, 14, 15, and 17. The longest drifts are on No. 16 vein and extend 450 feet west of the tunnel and 220 feet east. In the west drift there has been some stoping, but a cave at the east end of the stopes has blocked them. A little ore shipped in 1908 and 1909, possibly from this stope, carried as high as 1 ounce of gold and 12 ounces of silver to the ton and 20 per cent of lead. The average content, however, was about 0.5 ounce gold and 6 ounces silver.

BERRY VEIN.

On the west side of Fall River 900 feet northwest of the mouth of the Lucania tunnel two tunnels on the Berry vein strike N. 50° E. and dip 45° NW. in granite gneiss. The upper tunnel is very short, but the lower one is 620 feet long with only the first 80 feet off the vein. The vein fracture is 1 to 6 inches wide and is gouge-filled for its entire length, the gouge in most places being slightly mineralized. In a few places narrow stringers of white quartz with pyrite are seen above the slip. The hanging wall is mineralized for 1 to 2 feet from the slip by a small amount of disseminated pyrite and by a few narrow stringers of coarse pyrite. There has been no stoping on the vein, and as far as known the property has had no production.

U. P. R. MINE.

The U. P. R. mine is on the east side of the valley of Fall River between Phillips and Lucania gulches. The development work comprises two short drift tunnels, only the lower of which is accessible. The country rock is granite gneiss with small lenses of granite pegmatite.

The general strike of the mineralized zone is about N. 70° E. and the dip 50°–60° N. The vein, as seen in the lower tunnel, consists in most places of 2 to 4 feet of wall rock penetrated by a network of small stringers of white quartz and pyrite, which in places unite to form a well-defined vein 1 foot in maximum width, bordered by gneiss carrying a little disseminated pyrite. Near the end of the tunnel the lode forks, forming two veins each 10 inches wide, which in 30 feet from their separation are 15 feet apart.

No stoping has been done, and no data are at hand regarding the value of the ore.

KINDA VEIN.

The Kinda vein, on the east side of Fall River valley about three-fourths of a mile north of the confluence of Clear Creek, is developed by three drift tunnels at elevations of 800, 940, and 1,000 feet above Fall River. The upper tunnel is connected with the surface by a 75-foot shaft and with the middle tunnel by winzes. Connection is planned between the middle and lower tunnels but has not as yet been completed. There is a total of a little over 2,000 feet of work on the property, the middle tunnel exposing 650 feet of the vein.

The country rock is granite gneiss and granite pegmatite, the latter rock occurring as narrow offshoots from a large mass whose western boundary passes between the portals of the upper and middle tunnels.

The vein strikes about N. 55° E. and dips on an average 50° NW., though dips as low as 39° and as high as 59° were noted. It is a zone from 1 to 3 feet wide of fractured pegmatite and granite gneiss, in which disseminated pyrite occurs, and in the more open portions of which quartz has been deposited. Lenses of coarsely crystallized quartz 8 inches in maximum width but not of great length were noted. The ore is all oxidized and in a few places shows small bunches of a light-yellowish earthy material which carries a little lead probably as an oxide. The pyrite was apparently coarse, but as the ore is largely oxidized only casts and small remnants of the original crystals usually remain. South of the main vein and about parallel to it are two relatively unimportant fractures, along which there has been a little mineralization. There has been slight postmineral movement along the main vein.

The first 250 feet of the vein in the middle tunnel has been stoped for about 30 feet both above and below the tunnel. Several smaller stopes are near the face of the drift.

Sampling-works assays of 45 lots of smelting ore aggregating 477 tons, shipped in 1908 and 1909, show gold 0.02 to 1.16 (average 0.5) ounces and silver 1 to 31 (average 9.5) ounces. Lead is not reported for most of the shipments and seldom runs over 10 per cent. One lot assayed gold 1.06 ounces, silver 31 ounces, and lead 23 per cent, showing higher values for the three metals than most of the other shipments.

The total gross production is said to be about $150,000.

BOURBON VEIN.

The Bourbon vein, on the south side of Phillips Gulch a little over one-fourth mile east of Fall River, is developed by a tunnel 760 feet long, of which the first 110 feet is a crosscut and the remainder a drift on the vein. The country rock throughout is granite gneiss. The vein strikes N. 80° W. and dips 25°-78° N. (average about 54°). The vein proper varies from knife-blade thinness to 6 inches and consists of white quartz with some coarse pyrite. In most places the bordering granite gneiss is altered and impregnated with pyrite for a few inches to 2 feet from the vein proper. This impregnation is usually in the footwall but is locally present in the hanging wall. Small stringers of quartz and pyrite branching from the main vein cut the pyrite-impregnated walls. Two small branches run into the hanging wall, one 120 feet from the face of the drift and the other 150 feet from its mouth. Near the end of the tunnel a few small stringers of dark-gray fine-grained quartz contain a very small quantity of galena and are apparently younger than the quartz-pyrite mineralization. A very slight amount of postmineral movement is indicated by one-fourth to three-fourths of an inch of gouge next the hanging wall. There has been no stoping on the vein, and the production if any has been very small.

MANDOLINA VEIN.

The Mandolina vein, on the south side of York Gulch just east of Fall River, is developed by a tunnel 660 feet long, of which the first 30 feet is crosscut and the remainder a drift on the vein, which strikes S. 85° E. and dips 50° N., cutting only granite gneiss. It is a well-marked fracture zone 1 to 4 feet wide which contains abundant disseminated pyrite in altered wall rock. In most places a stringer of coarse pyrite and quartz lying near the center ranges from 2 inches to 6 inches in width, the smaller size being the more usual. Postmineral gouge 1 to 12 inches wide is present on the hanging wall of the vein. A little molybdenite was noted in small flakes on joints in some ore from the dump.

So far as could be learned no stoping has been done.

HELEN TUNNEL.

The Helen tunnel starts on the north side of Phillips Gulch one-fourth mile east of Fall River opposite the Bourbon tunnel. It is a crosscut 530 feet long, which for the first 340 feet runs generally north and then gradually shifts to the right until in its last 20 feet it trends southeast. The country rock is granite gneiss. At 450 feet from the mouth a 2-inch quartz-pyrite stringer frozen to the walls and striking N. 21° W. cuts across the tunnel.

A winze 110 feet from the mouth is sunk to an undetermined depth on a mineralized zone striking N. 80° E. and dipping 59° N. This zone consists of about 2 feet of pyrite-impregnated granite gneiss cut by very small stringers of coarse pyrite; below this and separated from it by a tight slip plane is a streak of dark quartz one-half to 2 inches in width that carries galena and sphalerite. The galena-sphalerite vein is separated from the footwall by a thin film of gouge.

Eighty feet from the mouth a winze about 80 feet deep is sunk on a 4-foot zone of pyrite-impregnated granite gneiss cut by stringers of quartz and coarse pyrite one-fourth inch in maximum width. This zone strikes about parallel to the one last described but dips more steeply north.

So far as known there has been no production from this property.

KNICKERBOCKER TUNNEL.

The Knickerbocker tunnel is in the east fork of York Gulch, about three-fourths of a mile southwest of Russell Gulch. In the first 80 feet it bears N. 84° E., crosscutting through granite gneiss to the John L. Emerson vein. It then turns southeast on the vein, which strikes N. 46° W. and dips about 60° NW., and follows it to the Emerson shaft. The tunnel is caved 780 feet beyond the turn.

The vein, where exposed in the crosscut, shows 20 feet of crushed, sheared, granite gneiss which carries fine disseminated pyrite and is somewhat silicified. A central zone 3 feet wide contains disseminated quartz and pyrite in greater abundance and is cut by stringers of almost solid pyrite.

Postmineral movement along the hanging wall of the vein is shown about 310 feet from the turn of the tunnel by striæ that pitch 59° NW. and in several places by small seams of gouge that contain finely ground pyrite.

There has been much stoping along the vein, but the production is not known.

MAGDALENA VEIN.

The Magdalena vein is in the lower part of the middle fork of York Gulch, about half a mile south of Bald Mountain. It is developed by an inclined shaft said to be 265 feet deep, with short drifts on the 120 and 200 foot levels, and also by a 260-foot crosscut tunnel.

The vein, which strikes N. 40° E. and dips on an average 47° NW., cutting Idaho Springs formation, varies from one-half inch to 3½ feet in width, with an average of 10 inches in the tunnel and about 16 inches in the shaft. It is a zone of crushed and altered schist between gouge-filled slip planes. The schist is impregnated with pyrite and is locally cut by veinlets not more than one-half inch wide of pyrite with some chalcopyrite. Microscopic examination showed the presence of calcite in one of the pyritic veinlets but not in the bordering schist. The altered schist wall rock consists exclusively of quartz, sericite, and scattered grains of pyrite. The shapes of the quartz grains suggest recrystallization; the sericite probably in the main replaces feldspar; and the pyrite was also introduced by the vein solutions.

Very little ore has been taken from the mine. A small lot sent to the smelter is reported to have carried $36 gold and $3 silver per ton.

MILLIONAIRE VEIN.

The Millionaire vein, on the east side of York Gulch, lies about 500 feet south of the

Magdalena, is parallel to it, and has a similar flat northwest dip. It is developed by a short tunnel which does not reach a sufficient depth to expose unoxidized ore. A small amount of ore on the dump is iron-stained, pyrite-impregnated, silicified schist and in some places contains small stringers and lenses of quartz.

DENBIGH VEIN.

The Denbigh vein is at the head of the east fork of York Gulch about half a mile southwest of the town of Russell Gulch. The development consists of two drift tunnels and an incline shaft, but the lower tunnel and the shaft were not accessible. In the upper tunnel the walls are entirely Idaho Springs formation with a little granite pegmatite. A bostonite porphyry dike cuts the schist about 350 feet north of the shaft.

The vein in general strikes N. 47° E., dips about 75° NW., and is 2 to 6 inches in width. In most places it is frozen to one or both walls, but in a few localities a very thin clay parting separates it from wall rock. Several small branches entering the footwall dip 75°–80° SE.

The vein filling is white or light-gray sugary quartz, carrying pyrite and in places a little chalcopyrite. Locally, where the fracture is slightly wider, there is a suggestion of comb structure, quartz being frozen to the walls and bordered by a central band of coarsely crystalline pyrite. In some places the pyrite is coated with a thin film of chalcocite. In one place the schist footwall, somewhat silicified, contained disseminated pyrite for 1 foot from the fracture; in most places, however, the walls are unmineralized and only slightly altered. There is a little iron stain in the fracture, but the ore as a rule is only slightly oxidized.

The Denbigh vein is cut off, 400 feet from the mouth of the tunnel, by a fault that strikes N. 61° W. and dips 78°–80° SSW. The fault zone is marked by 6 inches to 3 feet of crushed schist between walls carrying three-fourths to 1 inch of gouge. There is a small amount of pyrite disseminated in this fault material and a few narrow stringers of coarse pyrite cut it in places. The material, however, is said to have almost no value. The displacement of the Denbigh vein along this fault has been about 12 feet, the north wall moving west with respect to the south wall.

North of the fault the vein is known as the Gold Rock and has been drifted on and stoped for a considerable distance beyond the Gold Rock shaft, but as the drifts were caved it could not be examined.

The Denbigh vein has been stoped from the surface to the lower tunnel to within 30 feet of the fault, and the remainder was being removed in 1911 by lessees. At this place the streak of smelting ore is slightly wider than usual and the wall rock for a foot from the vein is somewhat mineralized.

Sufficient data is not at hand for computing the average metallic content of the ore. Sampling-works assays of 13 lots of smelting ore shipped between 1888 and 1910 show gold 0.8 to 7.5 ounces, silver 2.96 to 16 ounces, copper (wet) 1.5 to 6.6 per cent.

PENNSYLVANIA TUNNEL.

The Pennsylvania tunnel has its mouth on the north side of Fall River about one-half mile above the mouth of York Gulch. It is a crosscut, the first 300 feet of which bear N. 41° E. and the remainder due north, the total length being 2,000 feet. The country rock throughout is Idaho Springs formation intruded by granite pegmatite.

Numerous veins are cut by the tunnel. At 1,890 feet from the mouth an unmineralized fracture zone 1 foot wide which strikes N. 85° E. and dips 80° N. has been followed east for 7 feet. At 1,700 feet a drift 240 feet long runs northeast on a barren fracture, striking N. 69° E. and dipping 70° NNW. The fracture is commonly about one-half inch wide and is filled with gouge, but in some places contains a foot of crushed schist. At 1,210 feet a fracture which strikes N. 50° E. and dips 50° NW. is followed by a 90-foot northeast drift, in which it contains about 1 foot of crushed barren schist above a half inch of gouge. At 500 feet a fracture striking N. 40° E. is exposed by a 70-foot drift running northeast from the tunnel. It is barren and consists of 4 to 12 inches of crushed schist and pegmatite. At 385 feet a fracture striking N. 45° E. and dipping 50°–70° NW. has been followed for 40 feet. It is a 2-inch zone of crushed wall rock above one-half inch of gouge. At 300 feet a well-mineralized vein which strikes east and dips 55° N. is developed by a long drift to the east which could be explored for only 140 feet on account of the rotten condition of the timbers. The vein is rather wide, consisting of a breccia of wall rock and pyrite cemented by dark-gray quartz and crushed rock and containing numerous small incompletely filled interstices, some of which are lined with yellowish-green barite. From this vein to the mouth the tunnel bears S. 41° W. At 200 feet the Pennsylvania vein strikes N. 86° E. and dips 40° N. A small amount of drifting shows that it is offset 50 feet east of the tunnel by a north-south fault which has shifted its continuation 30 feet to the north. The vein is on the average about a foot in width and consists largely of crushed wall rock, though in places it contains lenses of white quartz with pyrite and, more rarely, stringers of massive pyrite. At 150 feet from the mouth of the tunnel a 4-inch east-west vein of crushed schist and white quartz, carrying some pyrite and chalcopyrite, dips 60° N.

No figures showing the values of the ore were available. The output has apparently been small.

WASHINGTON TUNNEL.

The Washington tunnel begins on the north side of Fall River about 1¼ miles above the mouth of York Gulch, bears N. 40° E., and is 1,080 feet long, all in Idaho Springs formation. The first 400 feet follows a fracture zone which dips 70°–75° NW. and is tight and barren in most places. At 400 feet the fracture turns a little east and is followed for about 60 feet by a drift, in which there is a 6-inch wide lens of quartz carrying a little pyrite and chalcopyrite. A few small branches from the main fracture run into the east wall, and some of them show a little mineral. At 350 feet a fairly open cross fracture, striking N. 79° W. and dipping 60° N., contains a little local quartz with pyrite and chalcopyrite. At 950 feet two veins are exposed. One strikes N. 13° W. and dips 80° E., is about 6 inches wide, and consists of crushed schist with some disseminated pyrite. The other, a narrow unmineralized fracture, strikes N. 68° W. and dips 50° N.

MOHAWK VEIN.

The Mohawk vein is exposed by a 140-foot tunnel starting in the small draw just north of Comstock's house in Fall River. It strikes N. 75° E. and dips 70° N. Eighty feet from the mouth of the tunnel a branch coming in from the north wall is wider and more strongly mineralized than the main vein. The wall rock is Idaho Springs formation. The ore is all more or less oxidized but shows pyrite in a quartz gangue. At the junction of the two veins about 2 feet of crushed schist contains disseminated pyrite and is cut by strings of iron-stained quartz and pyrite.

LUCKY GROUP AND PHILIPS TUNNEL.

The Lucky Group of eight claims, on the south side of Fall River about 1¼ miles southeast of the mouth of Woodpecker Gulch, is developed by a few shallow pits and by the Philips tunnel, 435 feet long, starting 25 feet above the floor of the valley. The entire tunnel, which trends generally west, is contained in an irregular-shaped stock of monzonite porphyry, which intrudes the Idaho Springs formation and is exposed on both sides of Fall River. (See Pl. I, in pocket.) The porphyry stock is cut by a series of east-southeast joints, some of which are occupied by veinlets of dark quartz carrying pyrite and occasional chalcopyrite, from which stringers of quartz one-half inch in minimum width diverge in all directions. The porphyry along these quartz bands is bleached, altered, much softened, and generally contains a little disseminated pyrite. There is no regular vein but rather a fractured and mineralized zone of unknown width elongate in a direction a little north of west, as shown by the surface exposures.

The narrow siliceous and pyritic veinlets, together with a little of the near-by altered porphyry containing disseminated pyrite, constitute the ore, which is said to average about $5 a ton in gold. This material is treated in a water-driven 10-stamp mill at the mouth of the tunnel.

STANDARD TUNNEL.

The Standard tunnel, starting on the east side of Fall River about one-half mile southeast of the mouth of Woodpecker Gulch, runs northeast for its first 750 feet and due north for its last 500 feet. (See fig. 62.) The main tunnel and several drifts connecting with it traverse a stock of monzonite porphyry (see Pl. I, in pocket), and cut numerous dike offshoots from it. Some feldspar phenocrysts in this porphyry are 1 inch in length. The other wall rocks are pegmatite and schists of the Idaho Springs formation.

All of the veins cut by the tunnel belong to the pyritic type, except No. 11 vein, 1,180 feet from the mouth, which is of the galena-sphalerite type. It is noteworthy also that none of the work of small pyritic veinlets shortly after entering the main porphyry mass.

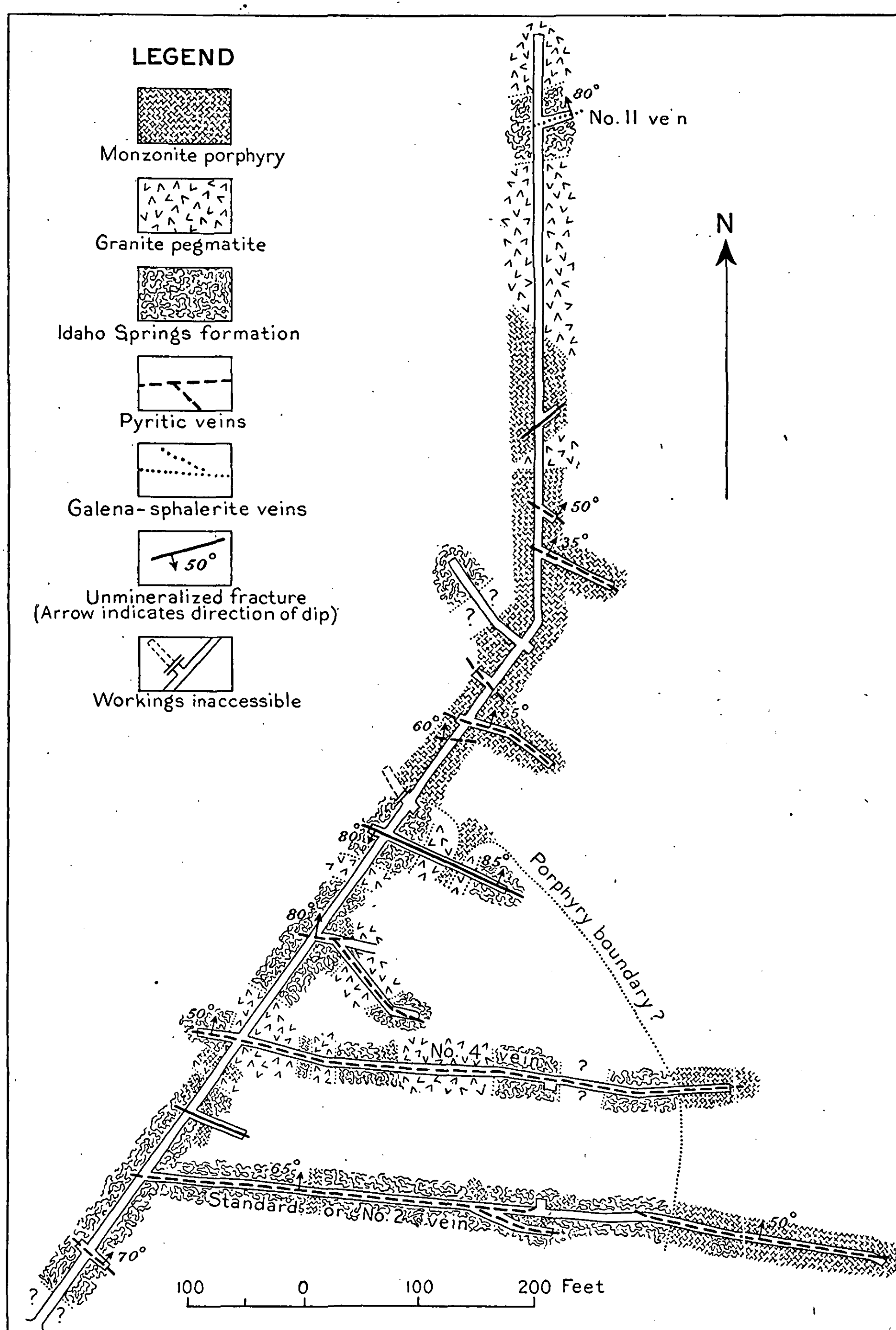


FIGURE 62.—Geologic plan of Standard tunnel

veins lying wholly in porphyry have proved of commercial importance, and that the two most extensively developed veins split up into a number of minute subparallel seams or a net-

The most important vein is the Standard or No. 2, intersected 160 feet from the portal, which has been drifted on for 650 feet and has been stoped in some of its wider portions. In general the mineralization consists of a dissemination of pyrite in small grains through the wall rocks near minute fractures, the boundaries of the vein being indefinite. Extensive development of silica has usually accompanied the more intense mineralization, and some of the more siliceous portions carry 20 to 50 per cent by volume of pyrite. In the wider parts of the vein in one of the stopes several ½-inch to ¾-inch veinlets of solid pyrite, some of which show a little galena and sphalerite in their wider portions, are exposed within the general mineralized zone. As already stated, the vein breaks up soon after entering the porphyry area into a network of small fractures, near which the minerals of the porphyry have been more or less replaced by quartz and pyrite. The ore in the porphyry is of low concentrating grade.

The vein cut 300 feet from the portal has been developed by a drift 470 feet in length. The mineralization consists for the most part of pyritization and accompanying silicification of the wall rocks near a series of small fracture planes, but a few small sharp-walled veinlets, half an inch to 2½ inches wide, of gray quartz and pink calcite carrying pyrite occur. No stoping has been done.

The veins cut between 300 and 1,180 feet are small and are mineralized similarly to the larger veins already described, except that chalcopyrite and tennantite were observed in some of them.

Vein No. 11, cut at 1,180 feet, is unlike all the other veins in the mine, being of the galena-sphalerite type. It is a tight vein half an inch to 2 inches wide, consisting of galena, sphalerite, and very minor amounts of pyrite. A specimen from the dump which probably came from this vein showed barite as a gangue mineral.

According to 14 sampling-works assays the ore from No. 2 and No. 4 veins is very similar in tenor and in mineral character. It contains gold 1.2 to 5.95 ounces, silver 1.75 to 21.4 ounces, and copper 5 per cent or less. Sufficient figures are not at hand to furnish a reliable average. The silver content is particularly variable, even when only the larger shipments are considered, and this is due probably to the local presence of galena and sphalerite formed during the second mineralization. Some small lots of particularly rich ore assayed as high as 25 ounces in gold and others as high as 53 ounces in silver. About half a ton of ore shipped from No. 11 vein in 1910 ran 0.08 ounce in gold and 100 ounces in silver. A single specimen from this vein assayed 400 ounces in silver.

There is no record of the gross production, but it has been small, in spite of the fact that ore was extracted from the property as early as 1865. A mill near the tunnel mouth, idle at the time of this survey, is equipped with 20 stamps, Wilfley tables, classifiers, etc.

GOLCONDA MINE.

The Golconda claims are on the ridge between Fall River and Spring Gulch east of south of the mouth of Woodpecker Gulch. The old workings, now inaccessible, are on the Spring Creek side of the ridge at an elevation of about 9,050 feet. A crosscut tunnel, whose mouth is near Fall River about half a mile southeast of Woodpecker Gulch, has been driven southwest 1,665 feet, intersecting the Golconda vein at a vertical depth of 835 feet. The tunnel runs S. 65° W. for 900 feet, S. 13° W. for 90 feet, and S. 36° W. for 675 feet to the face. Idaho Springs formation forms the wall rock for the entire length.

About 1,015 feet from the portal what is called the Virginia vein strikes N. 50° W. and dips about 75° NE. It varies from 4 to 8 inches in width and is largely composed of crushed schist, some white and gray quartz, and minor amounts of pyrite and chalcopyrite, these sulphides occurring disseminated in the filling and as small stringers.

The No. 4 vein, cut 1,190 feet from the portal, has drifts both west and east. The west drift is caved 70 feet from the crosscut; but the east drift can be traversed to the face, a distance of 250 feet. The first 60 feet east of the tunnel has been stoped to a height of about 60 feet. The vein strikes N. 68° W. and dips on an average 55° N. It varies from a very narrow slip plane west of the crosscut to a maximum width of 2 feet near the center of the east drift. The vein filling is crushed schist, which is mineralized for 100 feet east of the tunnel but which elsewhere contains practically no ore. The ore is crushed schist with white and gray quartz containing some pyrite and chalcopyrite, and is said to have been of fair grade and to have contained some small lenses of high-grade material.

The Golconda vein, cut 1,380 feet from the mouth of the tunnel, strikes N. 43° W., and in general dips 64°–65° NE. The east drift is caved 50 feet from the tunnel. The west drift is 475 feet long with a 40-foot winze 180 feet west of the tunnel, but shows little of the vein above the tunnel except near the end of the drift. In a stope 300 feet west the vein is 4 to 18 inches wide and consists largely of crushed schist, carrying disseminated pyrite, chalcopyrite, and some galena and sphalerite, the latter two usually occurring in small bunches rather than scattered through all the ore. The vein pinches about 20 feet west of this stope to 3 inches of unmineralized gouge and continues small to the end of the drift. In the winze the hanging wall is marked by 1 to 3 inches of postmineral gouge with horizontal striæ, below which is 10 to 14 inches of crushed schist with abundant white and gray quartz, pyrite, chalcopyrite, and some tennantite, galena, and sphalerite. This is rather hard ore, usually of smelting grade. The footwall is not well marked and contains, below the vein proper, irregular, usually very soft and somewhat porous masses of quartz and sulphides 3 to 4 feet across, which are said to carry about 1.16 ounces gold, 15 ounces silver, and 1 per cent copper per ton. Some small lenses of almost pure chalcopyrite in this mass are said to be of much higher value. In general this ore shoot pitches 75° NW. and extends about 250 feet along the vein at the tunnel level.

At 240 feet beyond the Golconda vein short drifts run east and west on a fracture that strikes N. 53° W. and dips 55° N. and is supposed to be the Logan vein. It is not mineralized where cut by the tunnel.

In 1909 some ore shipped from the Golconda ran as high as 11.78 ounces gold, 98.50 ounces silver, and 8.6 per cent copper, and some ran only 0.85 ounce gold, 10.3 ounces silver, and 1.3 per cent copper. It is not certain from which vein this came. The average content of 1.3 tons shipped during that year was 3.26 ounces gold, 31.2 ounces silver, and 2.31 per cent copper per ton. The average value of all the smelting ore shipped during 1910 was 1.25 ounces gold, 9 ounces silver, and 1.07 per cent copper per ton, which is probably nearer the average value of this class of ore for the mine.

The total production of the property is said to be about $4,000.

ALMADEN MINE.

The Almaden mine is on Fall River about one-half mile below the mouth of Woodpecker Gulch. The principal working is a nearly straight drift tunnel about 1,300 feet long trending slightly north of west. This tunnel for its whole length is on the Colorado No. 1 or Blazing Star vein. The workings are in schist of the Idaho Springs formation intruded by small amounts of granite pegmatite.

The Blazing Star vein consists of 3 inches to 3 feet of fractured and altered schist (in some places crushed to a clayey gouge), generally barren but in a few places traversed by small veinlets carrying fine-grained galena, sphalerite, and pyrite in a gray quartz and calcite matrix. The widest observed veinlet of this kind was 1½ inches. There is some disseminated pyrite in the schist. Some slipping and brecciation along the vein has taken place subsequent to the original mineralization. The richer ore was not seen in place, but numerous specimens saved in the mining show clearly its mode of deposition. Along irregular fractures in the galena-pyrite ore and the neighboring wall rock proustite (ruby silver), pearceite ($9Ag_2S.As_2S_3$), and secondary chalcopyrite have been deposited. The secondary chalcopyrite forms a characteristic aggregate of very minute grains. The pearceite seen did not exhibit crystal faces but occurred in massive forms intimately intergrown with the chalcopyrite. The proustite is usually well crystallized. Minute crystals of cerargyrite (horn silver) were observed in one specimen. Native silver in small wires was found in vugs in the upper part of the vein. One specimen seen came from a depth of 125 feet.

A polished specimen of rich silver ore from the Almaden mine was examined under the reflecting microscope. In the portions unaffected by downward enrichment the earliest sulphide (pyrite) is brecciated by later ore consisting of gray quartz, galena, sphalerite, and chalcopyrite. Fracturing subsequent to both these mineralizations was followed by the development of secondary sulphides as fillings of small fractures, as metasomatic replacements of galena and quartz, and as incrustations on the walls of vugs and open fractures. The secondary sulphides consist of chalcopyrite, pearceite, and a little galena. Replacement veins between quartz and galena (similar to those shown in figs. 14 and 15, p. 144) are common. In some of the secondary veinlets proustite or ruby silver is irregularly associated with the pearceite and chalcopyrite.

Some specimens from this mine are among the finest of their kind that the district has produced. One specimen showed 1 inch of pure ruby silver associated with a ¼ to ½ inch band of pearceite. A mass of ruby silver several inches across, now in the Idaho Springs public library, came from this mine. A specimen from 200 feet below the surface shows galena cut by a ¼-inch veinlet of pearceite.

The native silver, proustite, pearceite, cerargyrite, and fine-grained chalcopyrite are all shown by their mode of occurrence in fracture planes cutting the galena-pyrite ore to have been deposited later than the original mineralization. They form a striking example of the enrichment of a vein in silver by the action of atmospheric waters descending through the more or less porous vein material. These waters dissolved certain of the metallic minerals of the original vein, such as argentiferous galena and chalcopyrite, and redeposited some of their constituents in the form of the silver sulphides, chalcopyrite, etc., farther down. It is this process which is largely responsible for the richness of the vein, and without which the vein would not improbably have been too lean to work. It is improbable that the enrichment will continue for any great distance below the level of Fall River.

The output of the mine has been small though of high grade. The complete record of sampling-works assays on all shipments shows gold 0.04 to 0.3 ounce, silver 19.5 to 480.8 ounces, and lead not exceeding 17.5 per cent. Two lots of ore weighing 149 and 510 pounds, from a shallow winze below the tunnel level, showed respectively the following extraordinary values: Gold 0.38 ounce, silver 5,810.3 ounces, and gold 0.487 ounce, silver 4,084.92 ounces.

SEVEN-FORTY TUNNEL.

The Seven-Forty tunnel is on the south side of Fall River about 700 feet southeast of the mouth of Woodpecker Gulch. It bears west for 80 feet at which distance it intersects a group of minor slip planes which strike S. 60° E. and dip 50° SW. Some of these seams contain a little calcite and siderite and rarely a small amount of galena as a thin discontinuous crust between the carbonates and the wall rock.

POLAR STAR TUNNEL.

The Polar Star tunnel, on the north side of Fall River 700 feet below the mouth of Woodpecker Gulch, bears N. 68° E. for 240 feet and about N. 45° E. for 160 feet. The wall rock is schist of the Idaho Springs formation, except for the last 20 feet, which is granite gneiss. The tunnel follows the schistosity, which dips steeply northwest. Some movement has taken place along the foliation, producing a little gouge which has not been mineralized. Where the direction of the tunnel changes the schist is cut by a fracture plane striking N. 13° W. This zone shows about 10 inches of brecciated, crushed, and slightly silicified country rock, through which pyrite is sparsely disseminated. In some places a little quartz and carbonate gangue minerals contain sphalerite, galena, and pyrite.

IDA MAY TUNNEL.

The Ida May tunnel, on the spur just west of the mouth of Woodpecker Gulch, bears N. 28° E. in its first 110 feet along a vein which dips 65° NW. The ore is all oxidized but shows occasional remnants of galena and pyrite and is said to average about $22 per ton in silver. At 110 feet from the portal the tunnel leaves the vein and trends N. 7° E. for 130 feet, cutting at an acute angle through a bostonite porphyry dike for the greater part of that distance. Beyond the porphyry a 20-foot drift is driven on a vein that strikes N. 20° W. and dips 65° NE. This vein is fairly well mineralized, carrying considerable galena and some pyrite.

CLIFFORD VEIN.

The Clifford vein runs along the divide between Woodpecker and York gulches. About a mile south-southeast of Mount Pisgah it is opened by a shaft which could not be entered, but which is shown by mine maps to be an incline a little over 150 feet deep, with 300 feet of drifting on the 100-foot and about 400 feet on the 150-foot level.

The country rock belongs to the Idaho Springs formation, and biotite schist is the only rock seen on the dump. On the surface the vein is not well exposed but appears to strike N. 60° E. The drifts shown on the mine map strike about N. 59° E., and the vein dips steeply southeast. The ore in the bins consisted of white quartz cut by seams and stringers of dark quartz carrying galena, light and dark sphalerite, chalcopyrite, and some pyrite.

Most of the ore is siliceous, but some specimens carry barite, which is either embedded or implanted on the walls of vugs and which crystallized with the dark quartz and the lead and zinc minerals. Postmineral movement has crushed some of the ore, producing in some places a grayish gouge.

THOMAS TUNNEL.

The Thomas tunnel, on the north side of Fall River about 250 feet west of the mouth of Hamlin Gulch, trends generally north for 515 feet and connects near the face with a 210-foot drift that bears N. 75° W. The country rock throughout is schist of the Idaho Springs formation. The first 215 feet of the tunnel cuts the schistosity at acute angles, and the following 300 feet trends parallel to the structure (about N. 15° E.). This part of the tunnel discloses a zone of somewhat silicified schist, which dips 65°–70° W. Sphalerite, galena, and pyrite are sparingly disseminated through the schist of this 8-inch to 3-foot zone and are locally concentrated in veinlets with a quartz gangue. The drift near the face of the tunnel is on a vertical barren fracture which has not displaced the ore zone shown in the tunnel.

BOSS TUNNEL.

The Boss tunnel, on the north side of Fall River half a mile west of Hamlin Gulch, at an elevation of 8,575 feet, is a crosscut 240 feet long, the first 90 feet of which penetrate schist and the remainder heavily pegmatized schist except for a 30-foot bostonite dike 20 feet north of the schist and pegmatite contact. Forty feet from the face of the tunnel a small fracture striking N. 75° E. shows in places a very slight galena-pyrite mineralization.

MANHATTAN TUNNEL.

The Manhattan crosscut tunnel starts near the head of the west fork of Hamlin Gulch at an elevation of 10,150 feet and runs N. 50° W. to pass under Yankee Hill. It has been driven 600 feet, all through granite gneiss. A little galena-sphalerite ore seen on the dump was said to have come from a northeastward-trending stringer. Some pyrite and chalcopyrite are associated with the galena and sphalerite. The gangue minerals are white quartz and siderite.

WYOMED TUNNEL.

The Wyomed tunnel is on the north side of Fall River a little over a mile above the mouth of Hamlin Gulch. (See fig. 63.) The wall rock throughout is Idaho Springs formation. The workings expose several barren fractures and one mineral-bearing fracture (A, fig. 63), which shows a central 4-inch band of oxidized sulphides bordered on each side by about 4 inches of altered schist. In the drifts farther west this vein shows little mineral on the tunnel level, but in a level 115 higher it shows in one place about 6 inches of more or less silicified schist next the hanging wall, below which there is a 3-inch vein of quartz and sulphides. The ore carries chalcopyrite, sphalerite, siderite, quartz, and subordinate galena.

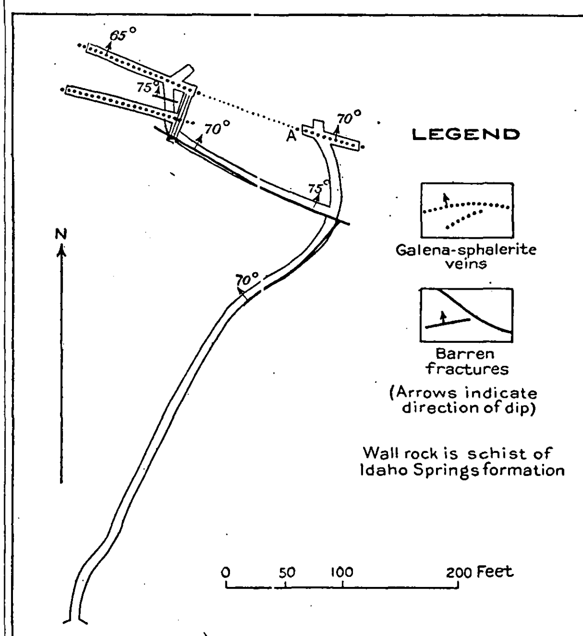


FIGURE 63.—Geologic plan of Wyomed tunnel. Surveyed by hand compass and pacing.

SEAMAN TUNNEL.

The Seaman tunnel, on the north side of Fall River at an elevation of about 9,100 feet, trends about N. 38° W., is 3,636 feet in length, and was driven to drain at depth the veins at the head of Cumberland Gulch and at Yankee. At the time of this survey bad air prevented its being traversed for more than 1,400 feet, and in this distance only barren fracture planes were seen.

BONNIE BRIAR MINE.

The Bonnie Briar mine is on the south valley wall of Fall River nearly opposite the mouth of Cumberland Gulch, at an elevation of about

9,650 feet. The principal development is a tunnel about 400 feet in length, which exposes three fracture zones, none of which show any important mineralization. A porphyry dike is intersected near the face. A second tunnel, about 75 feet lower than the first, is short and was not accessible.

MERRY MONARCH TUNNEL.

The Merry Monarch claims are on the ridge south of Fall River opposite the mouth of Silver Creek. A crosscut tunnel 380 feet long trends S. 15° W. from a point just west of where the Alice-Dumont road crosses Fall River. The first 350 feet of the tunnel is driven through granite gneiss, which shows only two small fractures, both unmineralized, which strike about N. 70° W. and dip very steeply south. The last 30 feet of the crosscut is in schist, which is cut by a fault zone striking N. 70° W. and dipping 80° S. This zone has been followed westward for more than 75 feet to where it is caved. There is apparently very little mineralization along this fracture, certainly none of any importance in the part that can be seen.

ALICE, YANKEE, AND VICINITY.

The ores of Alice and Yankee are mainly of the pyritic type with the exception of a few, such as those of the Stonewall vein in the Ninety-Four mine, and the Cumberland and the Lombard veins. The pyritic ores, whose predominant value is in gold, were rich in the surface oxidized portions, but the unaltered sulphide lower down was generally below workable grade. As a consequence few of the pyritic deposits are now being mined, except where oxidized ore remains. The surface portions of the great pyritic stockwork of the Alice mine were first worked in the early eighties by hydraulic methods and were fairly rich, but the unaltered ores below had not to the time of this survey been successfully exploited.

The few galena-sphalerite veins of the region carry important amounts of silver as well as of gold.

AURA VERDE VEIN.

The Aura Verde mine, at the head of Silver Creek at an elevation of about 10,200 feet, lies about 1½ miles north of the town of Alice. The development work consists of a crosscut tunnel driven generally northwest. The only important vein is the Aura Verde, 70 feet from the portal, which strikes N. 80° E. and dips steeply, and upon which considerable drifting has been done. Where the conditions of the workings permitted examination, the vein was found to be in places a barren fracture and elsewhere to contain 4 inches of ore. On account of the slight depths attained in this tunnel, most of the ore has been oxidized and shows alternate bands of siderite, quartz, and hematite. From certain specimens on the dump it is judged that the unaltered ore was of the pyritic type.

The mine was idle in 1911 and so far as known its production has been small. No data as to the value of the ore were obtained.

LITTLE BLANCHE TUNNEL.

The Little Blanche tunnel, on the northwest side of St. Marys Lake, is 460 feet long and follows a tight fracture striking S. 87° W. that cuts what is probably a dark variety of Silver Plume granite, which is exposed on the surface in this vicinity. At a few places the fracture opens to a maximum width of 2 inches. One lens of ore 2 inches wide and 10 feet long consists of white quartz, carrying a small amount of galena, sphalerite, and chalcopyrite. The values are said to be largely in gold but no important production is recorded.

METEOR VEIN.

The Meteor vein is exposed on the cliffs on the southwest side of St. Marys Lake and is developed by 2 tunnels about 10 feet and 260 feet above the high-water mark of the lake. A shallow shaft is sunk from a point above the upper tunnel. The lower tunnel is 440 feet long, the first 90 feet being a crosscut and the last 350 feet a drift on the vein. The upper tunnel consists of 190 feet of crosscut and 60 feet of drifting on the vein. The country rock is a dark, slightly porphyritic granite, probably a variety of the Silver Plume granite.

The lode strikes about N. 40° E. and dips 70°–75° SE. In the upper tunnel it varies from 8 inches to 4 feet in width, but in the lower tunnel it is uniformly about 5 feet wide. The filling is brecciated wall rock in a matrix of cherty-looking silica or very finely crystallized gray quartz with some siderite. The siderite is more common in the upper tunnel, but narrow stringers of it occur along more or less open fractures in the lower tunnel. Pyrite and chalcopyrite are sparsely disseminated throughout the vein, both in the fragments and in the matrix of the breccia. The mineralization has been stronger where the brecciation was greatest. In the lower tunnel, where the fragments are small and few and the vein filling is almost entirely quartz, there is less pyrite and almost no chalcopyrite.

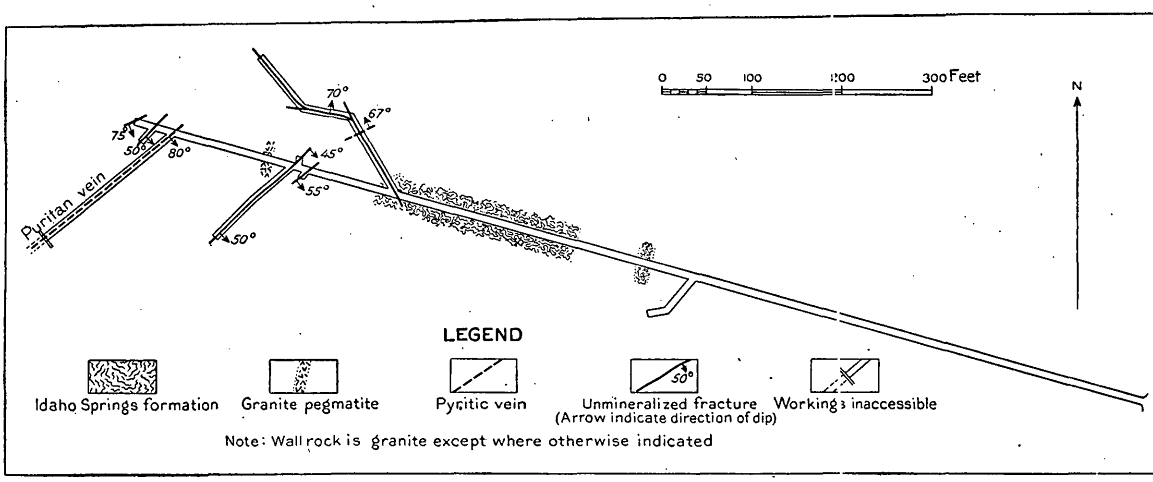


FIGURE 64.—Geologic plan of Mayflower tunnel. Surveyed by hand compass and pacing.

No stoping has been done in either of the tunnels, but 90 tons of oxidized material from the shaft is said to have carried about $20 per ton in gold. This gold was not free but was carried in the pyritic concentrates.

PURITAN VEIN.

The Puritan vein is on the north side of the ridge between Anchor Gulch and St. Marys Lake, about half a mile south of the lake. It is developed by two drift tunnels and an old shaft near the crest of the ridge and at greater depth by the Mayflower tunnel (see fig. 64), which starts in Silver Creek valley about one-fourth mile southwest of Silver Lake.

The vein could be studied only in the Mayflower tunnel, where it cuts coarse-grained biotite granite with a little associated pegmatite. It strikes N. 45° E. and dips very steeply southeast or stands vertical. It is a zone varying from a few inches to several feet in width, in which numerous small subparallel fractures have been formed. The granite in this zone is altered, bleached, and much softened and contains a little disseminated pyrite; it is traversed by small stringers of dark-gray or white quartz and nearly white siderite carrying pyrite and chalcopyrite.

One of the widest portions of the vein is exposed in a stope 15 feet above the Mayflower tunnel level and about 110 feet southwest of the line of the tunnel. The general fracture zone in this place is about 5 feet wide and shows the following section from southeast to northwest:

Section of Puritan vein.

	Ft.	in.
Granite, cut by many subparallel slickensided fractures trending parallel to the course of the vein and by several trending across it	3	0
Granite, bleached, cut by 2 to 3½ inch veinlets of quartz and siderite carrying pyrite	1	0
Veinlet, of white and gray quartz carrying pyrite and chalcopyrite; said to carry most of the metal.		1½
Strong slickensided fracture parallel to the trend of the vein.		
Granite, altered, grading into unaltered granite		6

Some postmineral movement has taken place along the vein, which is crossed by numerous minor slip planes.

Some surface ore from one of the upper tunnels is said to have assayed 7 ounces in gold, 27 ounces in silver, and 6 per cent copper. Five shipments in 1910, aggregating a little over 6 tons, show, according to sampling-works assays, gold, 1.12 to 2.6 (average 1.56) ounces; silver, 1.5 to 6 (average 2.27) ounces; and copper, 2 per cent or less.

The total production from the Puritan vein is said to have been about $4,000.

GOLD ANCHOR MINE.

The Gold Anchor mine is about one-half mile northwest of the village of Alice, at an elevation of about 10,000 feet. The vein, which trends northeast-southwest, is developed by a shaft 200 feet deep. It could, however, be studied only at one point, where it strikes N. 60° E., dips 80° SE., and is 3 feet in width. It consists of more or less altered granite gneiss, traversed by veinlets 4 inches or less in width of white quartz and pyrite (or iron oxide formed by alteration of pyrite). Ore on the dump showed bands of quartz and pyrite alternating with bands of nearly pure pyrite. Most of the ore is somewhat oxidized, and the free-milling surface ore appears to have been rich in gold, which fell off in amount as depth was gained and the less altered ore reached. A 10-stamp mill is at the mine.

The gross production is said to have been between $4,000 and $5,000.

CHESAPEAKE TUNNEL.

The Chesapeake tunnel starts on the west side of Silver Creek about one-half mile southwest of Silver Lake, about 250 feet above the bottom of the valley. The tunnel, which trends west under the ridge between Anchor Gulch and St. Marys Lake, is said to be 1,500 feet long. The first 260 feet is crosscut and intersects the crossing of two veins at a point about 100 feet from the portal. Beyond 260 feet the tunnel follows an east-west vein for at least 280 feet, beyond which it was inaccessible because of bad air.

The two veins cut 100 feet from the mouth of the tunnel are known as the Champion Nos. 1 and 2. The No. 1 vein strikes N. 70° E. and dips 80° SSE. There is a 15-foot drift on it on each side of the tunnel. The vein is a zone of fracturing in granite along which the rock is somewhat silicified and in which there are three narrow stringers of white drusy quartz containing some pyrite and locally a little chalcopyrite. The No. 2 vein strikes N. 85° E. and dips 80°-85° S. A 25-foot west drift on this vein shows it to be a shear zone 2 to 4 feet wide, in which the granite is crushed and somewhat silicified. One persistent stringer of white quartz with pyrite and chalcopyrite occurs in some places near the center of the zone but elsewhere shifts to the hanging wall. A smal stope 15 feet above the tunnel exposes a dark phase of the granite, which has been sheared along the vein and contains disseminated pyrite cut by minute pyrite stringers for about 5 inches next the footwall.

The America vein, which is cut by the tunnel at 260 feet and is followed by it for some distance beyond, strikes N. 85° W. and stands nearly vertical. It traverses granite containing lenses of magnetite-bearing pegmatite. The vein varies from a barren gouge-filled slip plane one-half inch in width to a zone of crushed granite 8 inches wide. In the wider portion of the zone the crushed granite between the walls is somewhat silicified and is cut by a central veinlet of white quartz carrying a little pyrite and exceptionally chalcopyrite.

All the ore in these three veins was considerably oxidized. It is said to average about $20 a ton in gold, 95 per cent of which is in free gold that can be saved by amalgamation. It carries no notable amount of any other metal.

NINETY-FOUR TUNNEL.

The Ninety-Four tunnel is about three-fourths of a mile northeast of the village of Alice at an elevation of 10,512 feet. (See fig. 64.) It cuts several veins, one of which, the Stonewall, is also developed by a shaft 300 feet deep, now inaccessible.

The Yankee Centennial vein, which strikes nearly east and west, is the first vein intersected. This vein, as exposed, varies from a barren fracture an inch or so wide to a band of white quartz 10 inches wide which carries pyrite, scattered or in irregular bands. At one place the vein is 8 inches wide, including 3 inches of alternating bands of white quartz and pyrite and 5 inches of fractured and altered wall rock.

The Enterprise vein is best exposed in a short drift from the main tunnel 360 feet from the portal, in which it shows at one place two veinlets of quartz and pyrite (in part copper stained) 1½ and 2 inches wide, inclosing 8 inches of altered wall rock.

The Stonewall vein, on which the greatest amount of stoping has been done, shows in its narrower portions 1½ inches of barren crushed wall rock but in other portions as much as 10 inches of white quartz traversed by a number of irregularly bounded sulphide stringers of sphalerite, galena, and pyrite, with subordinate chalcopyrite. Vugs 1½ inches or less across, lined with white quartz, calcite, and pyrite are common. At one place, where the vein is over 2 feet wide, it shows a slip plane next the footwall, followed above by about 1 foot of fractured and altered wall rock and by 14 inches of similar altered rock traversed by a number of veinlets 2 to 3 inches wide of white quartz carrying scattered specks of sulphides. The Stonewall vein is cut off (A, fig. 65) by a barren fault. The vein B–C beyond the fault is apparently not a continuation of the Stonewall, for its mineralization appears to be wholly pyritic. This vein in turn is cut off by a fault plane (C, fig. 65).

The Last Chance vein, so far as observed, is pyritic. It is commonly narrow and shows in one place, next the hanging wall, 1 inch of gouge followed by 1 inch of gray quartz carrying some fine pyrite. At this point it has been more or less fractured through a width of 3 feet.

The Hidden Treasure vein is only feebly mineralized. At one exposure it shows, next the hanging wall, 1 inch of gouge followed by 8 inches of brecciated and silicified wall rock stained in streaks by iron oxide and carrying some disseminated pyrite and a few irregular masses of pyrite 1 inch across. A narrow open crevice is lined with quartz.

All of the veins except the Stonewall carry gold almost exclusively. According to statements of the foreman the smelting ore from the Yankee Centennial vein, of which about 50 tons have been shipped, averaged about 3 ounces in gold with very little silver. The vein B–C (fig. 65) and the Hidden Treasure vein are said to average $4 to $5 per ton, almost wholly in gold.

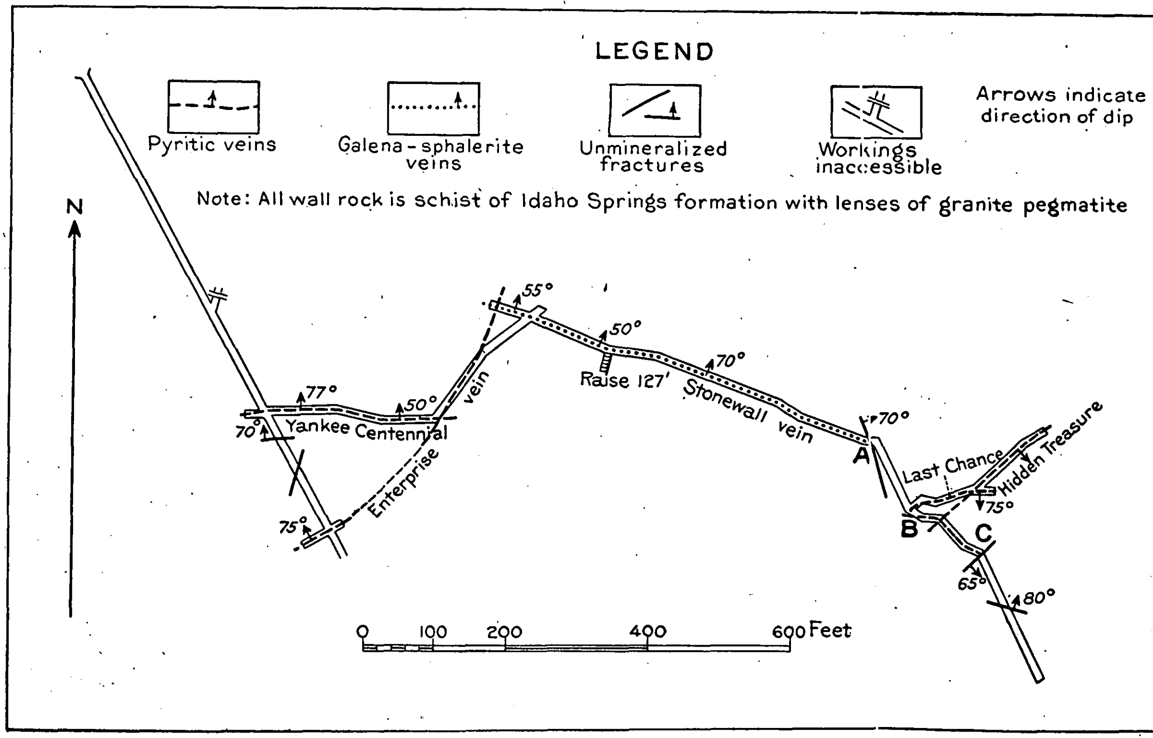


FIGURE 65.—Geologic plan of Ninety-Four tunnel. Surveyed by hand compass and pacing.

The ore from the Stonewall vein is said to average about 1 ounce in gold and 10 to 12 ounces in silver. Most of this ore has been treated in the company's mill near the mouth of the tunnel. This mill, however, made only experimental runs, using a dry process of concentration. Smelting ore is hauled by team 12 miles to sampling works at Idaho Springs.

LALLA VEIN.

The Lalla vein, on the east side of Silver Creek, one-eighth mile north of the Alice-Central City road, is developed by two tunnels. The lower, on a level with the road, is 355 feet long; and the upper, about 100 feet higher up the hill slope, is shorter. The country rock is schist of the Idaho Springs formation except for the first 100 feet in the lower tunnel, in which it is porphyritic granite.

The vein is a strong well-mineralized fracture which strikes N. 60° E. on the average and dips 70° SSE. It ranges from 1 to 3 feet in width and is mainly filled with crushed pyrite-impregnated schist, in most places carrying 2 to 4 inches of white quartz and coarse pyrite near the walls. In the narrow portions of the vein these quartz-pyrite bands come together to form the entire filling of 1 foot or less. In both tunnels there has been much stoping. The ore is much oxidized and in 1911 was treated at the mouth of the lower tunnel in a 2-stamp mill, which was saving $14 per ton on the plates. Concentrates from a Gilpin County bumper were said to carry about $7.25 in gold. The average metal content of 5.18 tons of oxidized smelting ore shipped in 1910 was, according to sampling-works assays, gold 1.7 ounces and silver 0.88 ounce per ton.

The Little Mary vein lies 15 feet north of the Lalla near the mouth of the lower tunnel, with which it is connected by two short crosscuts. The vein is almost parallel in strike to the Lalla but dips 55° SSE. It varies from 6 inches to 1 foot in width but is not strongly mineralized. Some pyrite is disseminated in crushed wall rock and a few short stringers of quartz and pyrite were seen.

PRINCESS ALICE VEIN.

The Princess Alice vein, on the east side of Silver Creek northeast of Silver Lake, is opened by a crosscut tunnel 250 feet long with a 670-foot drift on the vein. The crosscut continues eastward beyond the vein for 520 feet but cuts no other lodes. A second crosscut 100 feet lower down the slope has been driven 140 feet but has not intersected the Princess Alice vein. The country rock exposed in all of the workings is Idaho Springs formation.

Ninety feet from the mouth of the crosscut a vertical vein striking N. 56° E. has been drifted on for 50 feet either way. It is from 4 to 6 inches wide, and the filling is white quartz, locally carrying coarse pyrite crystals.

The Princess Alice vein strikes N. 48° E. and dips 70°–80° SE. It is a strong, well-mineralized fracture of white quartz and coarse pyrite 6 inches to 2 feet wide (average 4 to 10 inches). Part of the vein filling in the wider portions is crushed chloritized schist carrying some disseminated pyrite and cut by small stringers of quartz and pyrite. At 590 feet from the crosscut the vein receives a 4-inch stringer of quartz and pyrite from the footwall. Where first cut by the tunnel the Princess Alice vein is 18 inches wide and is entirely quartz and pyrite. At this point 1½-inch crusts of coarse pyrite on each side of the vein border a 2-inch central cavity lined with quartz crystals and a few very large pyrite crystals. This lens continues southwest along the vein with an average width of 12 inches for 170 feet and is repeated for 150 feet northeast of the crosscut. In all places the vein quartz is separated from the wall rock by a thin parting. Some stoping has been done in this drift. At 395 feet from the crosscut a raise 15 feet high has been driven, and between 210 and 240 feet from the crosscut a stope is carried at least 30 feet above the floor of the drift. Northeast of the crosscut some stoping has been done, and a winze southwest of the crosscut, now full of water, is said to be 20 feet deep all in ore.

The ore is said by the company to assay from 0.18 to 3.2 ounces gold and 0.5 to 9.3 ounces silver per ton with an average content of about 1 ounce of gold and 3.7 ounces silver. Some smelting ore shipped in 1910 averaged 1.14 ounces gold and 4 ounces silver per ton. A very minor amount of lead and copper is said to occur in some places, but none was noted either in the vein or on the dump. In milling 50 per cent of the gold and silver are said to be saved by amalgamation. The production as yet has been small.

ALICE MINE.

The Alice mine is about three-fourths mile west-southwest of Alice post office at an elevation of about 10,300 feet. The deposit is not of the vein type but constitutes a large irregular body of more or less mineralized rock which has been developed by an open pit and by irregular underground workings. (See fig. 66.) The rocks in the vicinity of the mine are Idaho Springs formation and intrusive porphyry, the latter forming the wall rock in all the mine workings.

The porphyry is of two varieties. The coarser and more abundant variety is a typical quartz monzonite porphyry, so crowded with feldspar phenocrysts as to appear granitic in texture to the naked eye. When viewed under the microscope, however, it is found to be truly porphyritic, phenocrysts being crowded in unusual abundance through a much finer grained groundmass. The rock is gray with locally a pink cast. It shows some variation in coarseness, but in its coarsest phases most of the feldspar, hornblende, and biotite phenocrysts are under 3 millimeters in greatest dimension. Among the phenocrysts plagioclase feldspar (andesine) is most abundant, brown biotite is next, and green hornblende last. The groundmass shows a granular texture and consists mainly of orthoclase and quartz, with subordinate amounts of plagioclase, hornblende, biotite, titanite, magnetite, and apatite. No sulphides were observed in the fresh rock.

The gray quartz monzonite porphyry is intruded by dikes of a light-gray to nearly white porphyry, very poor in iron-bearing minerals, which shows a sparse scattering of quartz phenocrysts in an aphanitic groundmass. All the specimens collected show a large amount of metasomatic alteration similar in character to that in the quartz monzonite porphyry. The groundmass has a microgranular texture, and probably consisted originally of quartz and feldspar, though the latter mineral has been largely replaced by sericite. A few areas having the shape of feldspar crystals are made up of minute sericite flakes forming an aggregate with low double refraction. These areas are probably replaced plagioclase phenocrysts, and other and more irregular areas of larger sericite plates may also have started as replacements of feldspar phenocrysts. Aside from sericitization metasomatic alteration shows itself in the development of nodular masses of pyrite, few of which exceed 5 millimeters in diameter and which, by their distribution, suggest that some of them, in nucleus at least, were replacements of feldspar phenocrysts. In some of the aggregates two or all of the minerals, quartz, sericite, and pyrite, and exceptionally apatite, are present in irregular association. The rock in some places presents a blotched appearance, owing to the uneven development of sericite. In the absence of perfectly fresh specimens it is not possible to apply a precise name to this rock, but it may provisionally be called an alaskite porphyry, the term alaskite signifying merely the absence of iron-bearing minerals. It is probable that it came from the same general magmatic source as the associated monzonite

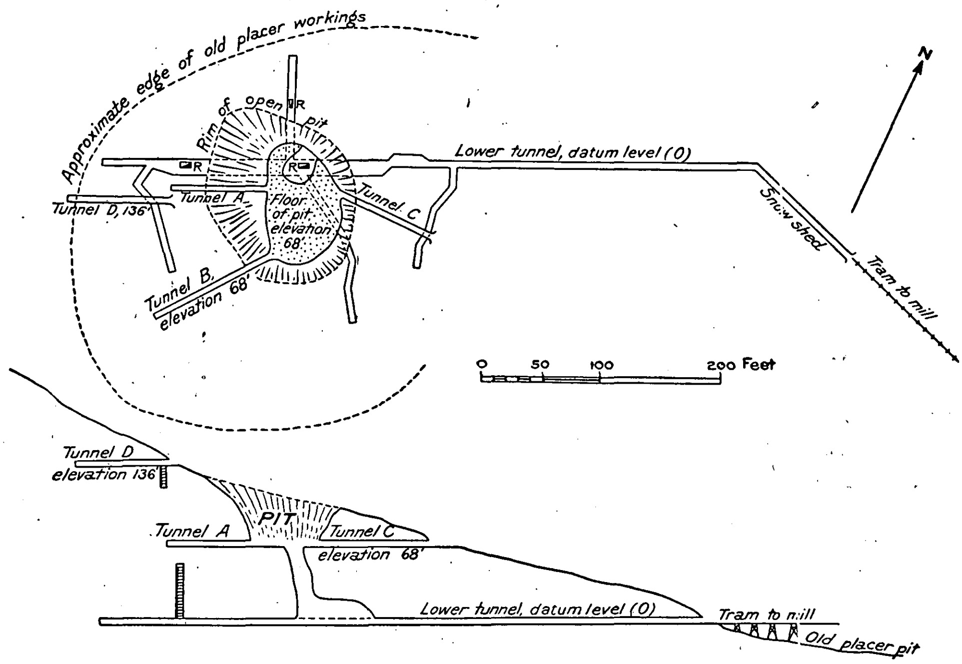


FIGURE 66.—Plan and section of workings of Alice mine. From surveys made for the owners.

porphyry but at a slightly later time. The larger alaskite porphyry dikes send off narrower branches into the quartz monzonite, and the two are usually in welded contact.

Typical fissure-vein mineralization, so common in this vicinity, is represented in the Alice mine only on a small scale by a few straight and persistent pyrite veinlets, none of them over one-half inch in width and none of them commercially important. The important mineralization has been accomplished through the removal in solution of certain constituents of the porphyries and the deposition in their places of metallic sulphides, or, technically speaking, by metasomatic replacement which was initiated along a network of irregular fractures. Both porphyries are mineralized, the quartz monzonite more extensively than the alaskite, probably because its coarser texture was more favorable to metasomatic replacement and possibly also because of its more extensive fracturing. Mineral-bearing solutions similar in character to those which deposited the typical pyritic veins of the Alice district and probably coming from the same source were the mineralizing agents, but instead of penetrating along straight and open channels they worked their way through a network of minute crevices formed by the irregular fracturing of a large body of porphyry. The cause of this fracturing is unknown, but it is not unique in this general district, similar fracturing being observed in the Commercial Union mine near-by and on a more extensive scale in the Patch, near Nevadaville. The alteration of the porphyry is most intense along the crevices which formed the main channels of circulation and decreases gradually away from these channels, so that a rock composed wholly of sulphides and secondary silicate minerals grades gradually into little-altered porphyry. The maximum alteration took place where two or more fractures intersected, in which places "nests" of ore minerals 3 inches or less across were developed. Less often cavities occur at such intersections and are partly filled with ore minerals. Some such cavities or vugs are a foot in diameter. Most of them were probably formed by the solvent action of solutions, but others may represent open spaces formed by movement between the porphyry fragments and only partly filled with ore. Figure 7 (p. 98) illustrates the general relation between the mineralization and fractures, and Plate XIV, *A* (p. 97), shows the progressive alteration of the ore, as exhibited in a hand specimen. The nature of this alteration has already been described in detail on pages 108–109.

The metallic constituents of the nests and vugs of ore are predominant pyrite and subordinate chalcopyrite. Quartz and brown siderite are the principal gangue minerals. Intimately associated with the chalcopyrite in some places is a sulphide of bismuth which is very rich in silver.

Pyrite and subordinate chalcopyrite. Gangue quartz siderite

The form of the mineralized area is not determinable from present exposures, but the open pit and all of the underground workings west of the first crosscut on the lower tunnel level are in mineralized porphyry for most of their length. The scattered character of the mineralization will probably necessitate the mining of all the mineralized porphyry without much selection, the limit of profitable extension of the workings being determined by assay as in other low-grade disseminated deposits. The amount of ore available is undoubtedly very large and has been estimated by different engineers whose reports are accessible to those especially interested. By driving a tunnel one-half mile in length from the valley of Fall River the deposit could be cut at a depth of 400 to 500 feet below the present workings. The ore may reasonably be expected to persist with little if any decrease in value for several hundred feet below the present workings, though not to indefinite depths, but an increase in copper content with depth, as is postulated in some private reports, is not to be expected. The somewhat similar mineralization of the Patch near Nevadaville becomes negligible on the Argo tunnel level.

The Alice property was first worked as a placer with the aid of hydraulic giants, and $60,000 is said to have been recovered by these methods. Later an old-fashioned stamp mill was erected, and a portion of the free gold in the oxidized ore saved by amalgamation, concentration not being attempted. The mill operated at a profit for three seasons until the relatively free-milling oxidized ore was exhausted. Since that time several attempts to treat the unoxidized ore by concentration have met with indifferent success. The ratio of concentration in the earlier attempts at milling vary from 12 to 1 to 17 to 1. In experimental runs concentration ratios of from 6.4 into 1 to 13.5 into 1 were obtained. The concentrates shipped do not appear to have exceeded $10,000 in total value.

The average value of the ore has been accurately determined by a number of careful samplings and by experimental runs. Automatic head samples of crude ore from five lots taken from various parts of the mine and aggregating 587 tons gave an average metallic content of gold, 0.167 ounce; silver, 0.82 ounce; and copper, 0.38 per cent. Gold assays on 57 samples taken by Mr. E. E. Chase from various parts of the mine ranged up to 0.98 ounce, with an average of 0.225 ounce. Silver determinations on 39 of these samples showed values ranging up to 10.3 ounces, with an average of 1.21 ounces.

A large mill building in good repair, but containing only five stamps and a little other machinery for testing, is connected with the lower tunnel by a trestle. A pipe line from Fall River with a head of 350 feet furnishes about 100 horsepower.

Whether the property can be profitably worked on a large scale after the manner of low-grade gold ores elsewhere is a question involving the tonnage available and the cost of mining and treatment, all of which are matters to be carefully estimated by engineers. Concentrates and supplies must be hauled 10 miles to and from the railroad at the mouth of Fall River.

COMMERCIAL UNION TUNNEL.

The Commercial Union tunnel is about one-half mile southwest of Alice at an elevation of nearly 10,500 feet. It is a straight crosscut trending N. 12° W. for about 470 feet, with several short crosscuts. The workings expose no true veins but develop an irregular ore body of considerable size. The wall rock is Idaho Springs formation locally highly quartzitic. Throughout much of the workings minute seams of pyrite traverse this rock in all directions, but locally the mineralization is strong, and irregular "bunches" of coarse pyrite 12 by 18 inches in maximum dimensions are developed. In these heavily mineralized portions the wall rocks become highly altered and nearly white in color through the development of quartz and sericite, and locally the alteration has proceeded so far that the rock has been wholly converted into a soft aggregate of these two minerals.

In general the mineralization at this mine is similar in character to that at the Alice mine except that the wall rock is schist of the Idaho Springs formation instead of porphyry. It represents mineralization throughout an area of irregular fracturing rather than along a linear fracture or vein. The ore values are said to be very similar to those of the Alice mine.

GOLD RESERVE GROUP.

The Gold Reserve group, which is apparently similar in character to the Commercial Union deposit, lies east of Alice on the northeast slope of Bull Hill west of Washoe Gulch. Over a large area the schist and pegmatite have been fractured and traversed by a network of irregular stringers of specular hematite and have also been somewhat silicified. The deposit is exposed only in surface pits, and as the oxidized zone is passed and depth attained will unquestionably become pyritic.

LOMBARD MINE.

The Lombard mine is in the upper part of Cumberland Gulch. The vein, which trends generally N. 55°–60° E. and dips 50°–75° NW., has been developed for about 2,000 feet by a shaft 150 feet deep and four drift tunnels.

The lower or No. 4 tunnel begins near the Lombard mill, trends about N. 45° E., and was about 780 feet long at the time of this survey. The wall rock is entirely schist of the Idaho Springs formation. The vein, which is reached 350 feet from the portal, branches in numerous places and in general is not strongly mineralized. A dike of bostonite porphyry 20 feet wide is cut 70 feet from the portal.

The No. 3 tunnel, next above the No. 4, is about 1,440 feet in length and follows the Lombard vein for 1,130 feet of this distance. It cuts a 20-foot dike of bostonite porphyry at about 750 feet, and both vein and tunnel follow a dike of porphyry from 1,110 to 1,360 feet. This porphyry is too altered for certain determination but is probably bostonite. A raise to the surface is about 940 feet from the portal. In general the Lombard vein as exposed in this tunnel is well defined and varies from a tight crevice to about 2 feet in width.

It is barren in places but elsewhere shows one or more narrow seams of galena, sphalerite, chalcopyrite, and pyrite.

Tunnel No. 2, about 250 feet higher than No. 3, connects through a raise with the Lombard shaft. The wall rock is Idaho Springs formation with some pegmatite. The vein is reached at about 230 feet and is followed for the remaining 950 feet of the tunnel. For about 250 feet beyond where it is first met the vein parallels a 4-foot dike of porphyry, than which it is distinctly later. The vein as exposed in this tunnel varies from 2 inches to 2 feet in width and shows the usual alternation of barren and mineralized stretches. At one of the widest portions it shows 2 inches of gouge next the hanging wall, succeeded by 10 inches mostly white and gray quartz in subparallel veinlets 2 inches in maximum width. Quartz predominates in these veinlets, but locally they carry sphalerite, galena, chalcopyrite, and pyrite.

The highest or No. 1 tunnel is about 75 feet above No. 2 and is about 800 feet long, all on the vein. Most of the ground between No. 1 and No. 2 tunnels has been stoped.

In general the ore from the Lombard vein consists in order of abundance of white quartz, sphalerite, galena, chalcopyrite, and pyrite, with light-colored siderite in certain places. These minerals are usually irregularly associated and all belong to the same period of mineralization. In some places comb quartz and pyrite were the first minerals deposited next the walls, but even these are not interpreted as belonging to an earlier period of mineralization. As in most veins of this type fine pyrite is commonly disseminated through the schist bordering the sulphide veinlets.

The metasomatic alterations in porphyry bordering the Lombard vein consist in some places in the development of sericite in the feldspar phenocrysts and the development of calcite in great abundance in the groundmass. Original magnetite grains have been partly converted to hematite. In other places, where alteration has progressed still farther, the porphyry has been almost completely sericitized and consists of large flakes of secondary muscovite embedded in a matrix made up mainly of minute sericite flakes. Quartz is fairly abundant in irregular grains and carbonate less so. Pyrite and sphalerite are scattered through the rock in irregular grains, and minute amounts of galena are locally present.

A 15-stamp mill for the treatment of ore from the Lombard vein, recently installed near the mouth of the No. 4 tunnel, is operated electrically by power furnished by a 720-horsepower hydroelectric plant in the valley of Fall River near the mouth of the Seaman tunnel.

According to Mr. H. I. Seaman smelting ore from the Lombard mine averages about $65 per ton and milling ore about $13.

CUMBERLAND MINE.

The Cumberland mine is in Cumberland Gulch near Yankee, about one-fourth mile northwest of the Lombard shaft, at an elevation of about 10,650 feet. The mine was being unwatered at the time of this survey but could not be entered. The shaft is 150 feet deep with about 150 feet of drifts. The vein strikes about N. 45°–50° E., nearly parallel to the Lombard vein, and dips northwest. The ore on the dump was practically identical in character with that of the Lombard vein. Some pieces showed 3 inches of solid coarse galena.

The mine was located in 1897 and has been worked intermittently.

GOLD BAND VEIN.

The Gold Band vein extends east from the summit of Yankee Hill to the head of Miners Gulch. It has been developed by a tunnel 750 feet long, for the first 210 feet of which the walls are granite gneiss and for the remainder Idaho Springs formation. The contact of these two formations strikes about north and south and dips at medium angles to the east.

The vein strikes N. 80° E. and dips 55° N. It is commonly about 6 to 8 inches wide and consists of crushed wall rock containing disseminated pyrite. Fairly continuous narrow stringers of white quartz and pyrite are seen either on the walls or near the center of the vein. From 550 to 650 feet from the mouth of the tunnel a stope has been carried up about 30 feet on an 18-inch wide portion of the vein. The ore here is crushed and bleached schist, which carries abundant disseminated pyrite and is cut near the center of the vein by a 2-inch quartz-pyrite veinlet. This ore is said to average about $17 per ton in gold and silver. Postmineral movement is shown by thin gouge on one or both walls.

OHIO VEIN.

A 640-foot drift tunnel on the Ohio vein has its mouth about 600 feet northeast of the Gold Band tunnel. (See p. 327.) The vein strikes a few degrees south of west and traverses granite gneiss. The tunnel could not be entered, but ore on the dump showed a 2 to 4 inch vein of quartz carrying pyrite, some chalcopyrite, and rarely a little fine galena. It also showed pyrite disseminated in granite gneiss, some of which was crushed and had evidently formed part of the vein. Druses were lined with crystals of pyrite, quartz, and siderite, of which the siderite appeared to have been the last deposited.

MINERAL POINT VEIN.

The Mineral Point vein, 300 feet south of the Gold Band tunnel, is opened by a tunnel 180 feet long, the first 100 feet of which is crosscut. The vein strikes N. 55° E. and stands nearly vertical. It is from 1 to 6 inches wide (average about 2 inches). The ore is largely oxidized but at the face of the drift shows remnants of pyrite and minor amounts of galena. Post-mineral slickensided fractures show striæ pitching 80° SE.

SURPRISE VEIN.

The Surprise vein is in the head of Peck Gulch south of the Alice-Central City road and about three-fourths mile southeast of Yankee Hill.

It is developed by two shafts, an old one on the vein, and a relatively new one 50 feet north of the vein outcrop. Little work has been done on the vein for several years, and the workings are inaccessible. The country rock at the mine is granite gneiss but farther west is Idaho Springs formation.

The vein strikes N. 60° E. and apparently dips steeply north. The ore on the dump consisted of altered, pyrite-impregnated granite gneiss cut by numerous small stringers of white quartz, coarsely crystalline pyrite, and some chalcopyrite. This vein is said to be a continuation of the Cumberland vein, opened by a shaft about three-fourths of a mile southwest.

FAUST MINE.

The Faust mine, in Yankee, was idle and inaccessible at the time of this survey. The development consists of a shaft 200 feet deep without important drifts. The shaft was sunk in 1901, and no work has been done on the property since that year. Nothing could be seen of the trend of the vein or the character of the ore.

OTHER MINES NEAR YANKEE.

On the southwest slope of Yankee Hill north and northeast of the now abandoned camp of Yankee several veins are opened by shallow shafts and tunnels, none of which are now accessible. The veins all cut Idaho Springs formation and with one exception strike northeast and southwest across the schistose structure. They are fairly strong fractures from several inches to 2 feet in width and are apparently very uniformly mineralized. The ore on the dumps was iron-stained quartz with minor amounts of siderite, some remnants of pyrite, and abundant impressions of former pyrite crystals. Some of the sulphide ore carried very small quantities of chalcopyrite, but none of the oxidized ore showed copper carbonates.

The Texas vein, which strikes N. 70° W., is opened by a shaft 500 feet northeast of Yankee. The ore on the dump indicated that the vein is at least 10 inches wide and consists of crushed, pyrite-impregnated schist containing some lenses not over 5 inches wide of quartz and coarse pyrite with very minor amounts of chalcopyrite. It is said that a little galena was occasionally found in the ore. The oxidized surface material is said to carry about $50 in gold and silver per ton, but the unoxidized sulphide ore is of low grade.

The Mary Murphy shaft is about 800 feet east of the Texas on the south side of the Alice-Central City road. The shaft is over 40 feet deep and has about 120 feet of drifting on the 40-foot level. The vein strikes N. 60° E. and apparently dips steeply north. The ore in the bins was similar to that at the Texas shaft. A shipment of 12 tons of surface ore from this property is said to have had a gross value of $42 per ton.

The Jennie Jones vein, 500 feet north of the Mary Murphy, strikes about N. 65° E. and dips 30° to 50° N. It is opened by several shallow shafts, now full of water. The vein filling, which is apparently about 30 inches wide, is largely crushed bleached schist with some disseminated pyrite and is cut by small pyrite-quartz stringers. In one pit an 8-inch streak of white quartz with some coarse pyrite was seen on the hanging wall. The surface ore is said to average about $15 per ton, mainly in gold.

The Ophir vein, bearing N. 45° E., was opened by a tunnel, now caved, and by several pits and shallow shafts. The tunnel mouth is about 600 feet north of the Texas shaft house. The ore in the bins was entirely iron-stained quartz with a little siderite carrying, it is said, some free gold.

The Little Clara and Cap-the-Climax are two parallel veins about 150 feet apart, the southernmost being one-fourth mile north of Yankee. They are opened by shallow shafts and pits, now largely caved. The Little Clara, the southern vein, is 8 to 10 inches wide, and the Cap-the-Climax appears to be at least 1 foot wide. The ore is entirely oxidized and similar to that in the Ophir bins.

The Barbara vein, one-half mile north of Yankee, strikes about N. 70° E. and stands nearly vertical. It is opened by a shaft, said to be 80 feet deep with 40 feet of drifting 55 feet below the collar, and by several near-by shallow pits on the vein northeast of the shaft. The ore is oxidized to a depth of 40 feet, below which the vein consists of from 6 inches to 1 foot of white quartz and pyrite with no chalcopyrite. The sulphide ore is said to be very low grade, but some of the surface material was rich enough to pay.

Three hundred feet south of the Barbara a parallel vein of small size and similar mineralization is opened by a few shallow pits.

NORTH STAR-MANN VEIN.

The North Star-Mann vein crosses the divide between Peck and Miners gulches about a mile east of Yankee Hill on the Central City and Alice wagon road.

The original work on this vein is west of the divide on the Mann ground. It consists of about 500 feet of shallow surface trenching and an abandoned shaft said to be over 100 feet deep. The North Star shaft is at the head of Peck Gulch. It is reported to be 300 feet deep with levels at 50, 115, 200, and 300 feet, all short except the 115-foot, which is a drift tunnel that intersects the shaft about 430 feet from the mouth and continues westward beyond it for at least 640 feet. There is little stoping on the tunnel level. The 50-foot level extends 200 feet west of the shaft and has been stoped for 170 feet.

The vein cuts Idaho Springs formation west of the divide, a large lens of pegmatite at or near the divide, and granite gneiss east of the divide near the North Star shaft. Underground, the 50-foot level and all but the west 200 feet of the 115-foot level, which is in schist, are in granite gneiss and pegmatite. The contact between the schist and gneiss dips moderately west. The vein strikes N. 65° W. and stands vertical or dips steeply south. It has no branches and though strong in all formations is somewhat wider in the granite gneiss than in the schist. It varies in width from a few inches to a maximum of 5 feet with an average of about 2 feet.

The vein consists of crushed silicified wall rock which contains more or less disseminated pyrite and is cut by stringers, 4 inches in maximum width, of white quartz, pyrite, and chalcopyrite, or wholly of massive pyrite. Siderite occurs locally, particularly in druses. Three rather well defined ore shoots have been found. The easternmost extends from the tunnel mouth for 230 feet west along the vein and consists of oxidized ore containing remnants of pyrite in iron-stained quartz. The second extends westward from the shaft for about 200 feet. The third is seen in the schist in the last 80 feet of the 115-foot level. All apparently pitch steeply west.

A barren fault zone striking N. 60° E. and dipping 54° W. cuts the North Star vein without notably displacing it. It is seen on the 50-foot level 190 feet west of the shaft and on the 115-foot level about 250 feet west. A second cross fault, also unmineralized, is seen 500 feet west of the shaft on the 115-foot level. It strikes N. 20 E. and is vertical. Movement along the North Star vein has taken place subsequent to the formation of this fault. The unoxidized ore from the North Star vein is said to average $8 to $10 a ton in gold, but very rich oxidized ore was taken from the Mann shaft and surface trenches in the early days. The ore was treated in a 10-stamp amalgamation and concentration mill near the mouth of the tunnel.

The present owners report that their production is about $16,000 and that the production of the mine before they acquired it was about $100,000.

LITTLE ELDA VEIN.

The Little Elda is a north-south vein that crops out near the head of Peck Gulch, about 1½ miles east of Yankee Hill. It cuts across the ridge which divides the two parts of Peck Creek and is largely in the Idaho Springs formation just west of a contact with granite gneiss. There are two tunnels and a whim shaft apparently on this vein, but the size of the dumps indicates that the workings, now caved, were not extensive. The total width of the vein is not known but is at least 8 inches in places. Most of the ore on the dump consisted of banded siderite, quartz, pyrite, and a little chalcopyrite; specimens from next the walls show a thin layer of quartz, a band of sulphides with some quartz, and a center of siderite. The center of the vein is not everywhere completely filled, and the druses are lined with crystals of siderite one-fourth inch in maximum size.

LEIDENGER TUNNEL.

The portal of the Leidenger tunnel is about 1 mile southwest of Pecks Flat. The tunnel consists of a 100-foot crosscut and a drift over 1,160 feet long on a vein which strikes N. 60°–68° W. and dips steeply north or stands nearly vertical. The crosscut portion traverses Idaho Springs formation, but the vein drift is entirely in granite gneiss. The vein varies from a narrow slip to 4 feet in width (average, 8 to 10 inches). It consists largely of crushed granite gneiss somewhat silicified and containing a little disseminated pyrite. Numerous small lenses of quartz 2 to 3 inches wide (maximum, 2 feet) contain pyrite. All the ore is oxidized but shows pyrite casts or remnants of that mineral.

GOLD STANDARD VEIN.

The Gold Standard vein is an east-west fracture outcropping on the ridge between the two forks at the head of Peck Gulch. So far as could be learned the development consists of a drift tunnel, now caved, starting near the junction of the two forks about half a mile west of Pecks Flat. The vein, which cuts granite gneiss, shows a quartz-siderite gangue carrying dark sphalerite, galena, chalcopyrite, and pyrite. Some specimens from the dump show a little banding, carrying white quartz with pyrite next the wall and a central filling of siderite, a little quartz, sphalerite, galena, and chalcopyrite. Secondary chalcopyrite has been deposited along joints as disconnected patches of small brass-yellow crystals.

LAWSON AND EMPIRE STATION.

A number of mines near Lawson and Empire station, notably those of Red Elephant Hill and Silver Creek, have in the past been among the largest silver producers of the region. The Joe Reynolds vein appears to have been located as early as 1865 but was not actively developed until 1877. According to Fossett[1] the history of active mining in this part of the region dates from the discovery about 1876 of the Free America vein on Red Elephant Hill by a prospector named D. E. Dulaney. Reports of his discovery brought numerous prospectors from Georgetown and Central City and resulted in the discovery of other veins and in the building of the town of Lawson. The extension of the railroad from Floyd Hill to Georgetown in 1877 further stimulated the development of this locality.

MAUD S. VEIN.

The Maud S. vein, which crops out on the nose of Douglas Mountain, a little over one-half mile southwest of Empire station, strikes about N. 60° E. and dips 65°–80° NW. It is developed at an elevation of about 8,250 feet by a tunnel which is a crosscut for the first 250 feet or so and beyond that follows the vein. It was accessible for study for about 400 feet on the vein. The walls for the first 300 feet are schist of the Idaho Springs formation but beyond that are granite gneiss and some granite.

The vein varies in width from 4 inches to 5 feet. Where 5 feet wide it consists of granite gneiss traversed by three veinlets, 2 to 4 inches in width, which are about half quartz and siderite and about half sulphides. Where narrower the vein shows similar characters but fewer sulphide veinlets. The study of polished specimens of ores under the reflecting microscope shows that they belong to the composite type, pyrite of the first mineralization having been brecciated and the fractures filled with sphalerite, galena, chalcopyrite, quartz, and siderite. Subsequent to both mineralizations the ore in the upper parts of the vein was again fractured and was penetrated by solutions which deposited secondary chalcopyrite, pearceite, and quartz. Veinlets of one or more of these secondary minerals traverse primary

[1] Fossett, Frank, Colorado, its gold and silver mines, p. 382, 1879.

chalcopyrite, pyrite, sphalerite, and quartz. Pearceite also in places metasomatically replaces primary quartz.

No records of the value of the ore or of the production are available.

MARSHALL & RUSSELL TUNNEL.

The portal of the Marshall & Russell tunnel is on the north side of Clear Creek at Empire station, at an elevation of about 8,250 feet. The tunnel, which was about 6,000 feet in length at the time of this survey, trends about N. 23° W. and is designed to develop at depth the veins of the north Empire Creek district. Up to the time of this survey no important veins had been intersected and no ore shipped. The principal veins may be briefly described as follows, the letters used corresponding to those on figure 67:

Vein A. About 2 inches of light-gray quartz carrying a small amount of pyrite and chalcopyrite. It is older than vein B, which intersects it without displacement.

Vein B. A vein a few inches in width mineralized with siderite, sphalerite, chalcopyrite, and some pyrite and galena. It appears to belong to the Lawson type of silver veins.

Vein C. A small streak of disseminated pyrite and chalcopyrite through altered granite. The ore is said to assay $12 per ton in gold and copper.

Vein D. A fracture along which silicification and local development of pyrite has taken place through a width of 1 to 2 inches. The granite for 1 to 1½ feet on either side is more or less altered.

Five dikes cut by the tunnel between 2,000 and 2,640 feet from the portal are all similar and may be classed as bostonite. They are finely crystalline rocks, not notably porphyritic, and under the microscope are seen to be composed almost wholly of anorthoclase laths in more or less fluidal arrangement. A little original quartz is present, and sericite quartz and pyrite are secondarily developed, the latter being most abundant along seams traversing the rocks.

About 2,700 feet from the portal a single dike of unusual appearance shows gray feldspar laths one-fourth inch in maximum length in an aphanitic dark-gray groundmass. Pyrite is very abundantly developed in the groundmass in irregular masses three-sixteenths

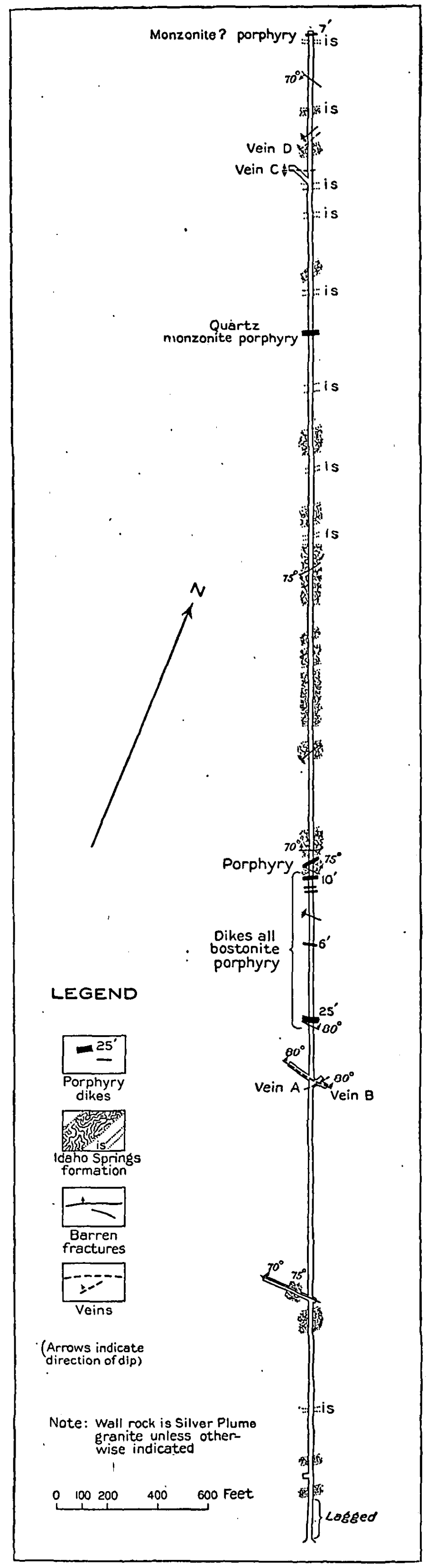


FIGURE 67.—Geologic plan of Marshall & Russell tunnel. Surveyed by hand compass and pacing.

inch or less across and also along minute seams. The rock is too much altered for its character to be certainly determined. The dark color of the groundmass is due to abundant secondary biotite in exceedingly small flakes and to magnetite.

A porphyry dike cut about 4,800 feet from the portal shows abundant phenocrysts of quartz one-fourth inch in maximum diameter, many of which show very perfect crystal forms. Less abundant are phenocrysts of pink feldspar one-fourth inch or less across. The microscope shows the rock to be much altered. Both plagioclase and unstriated feldspar are present, so that the rock is a quartz monzonite porphyry.

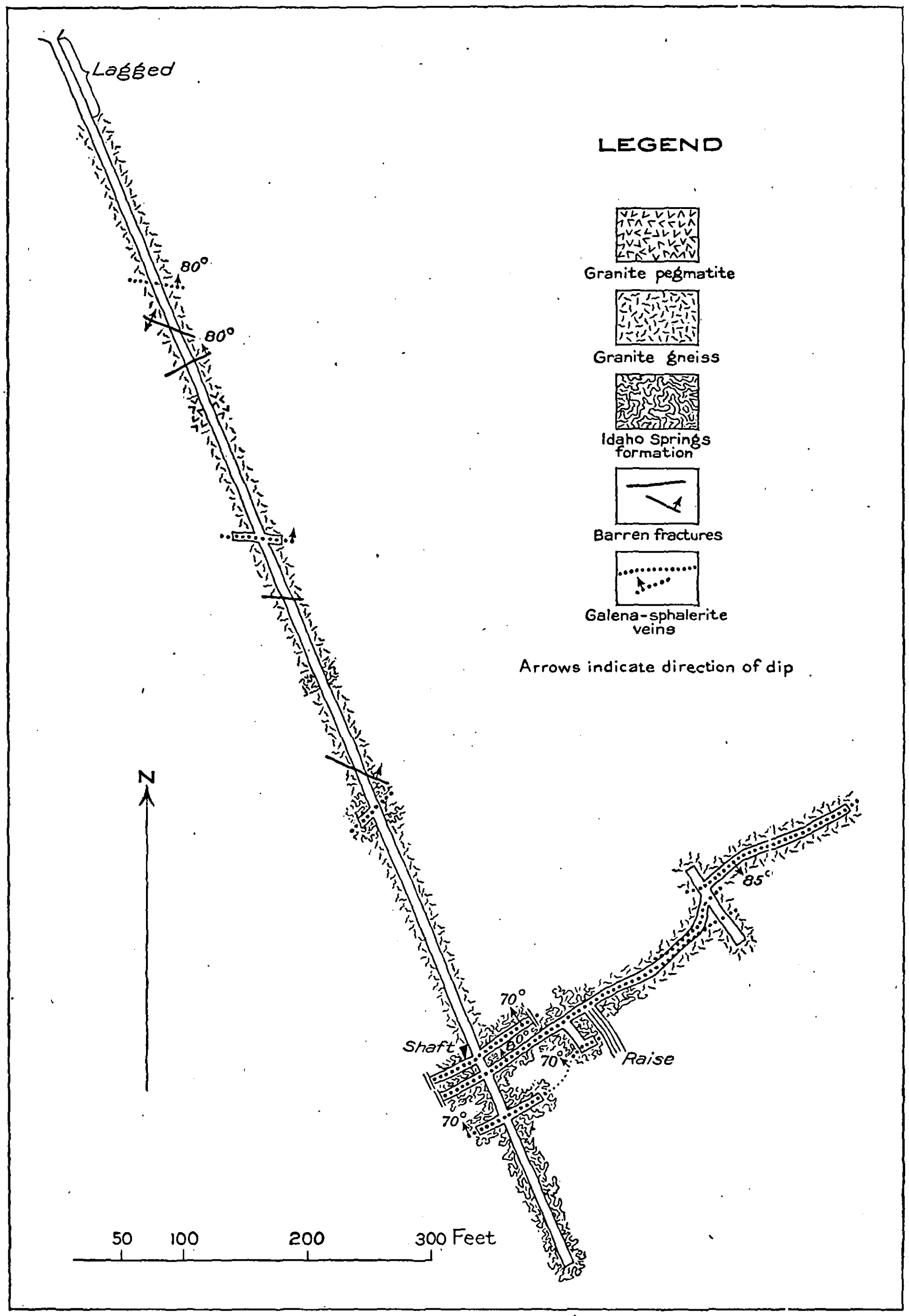


FIGURE 68.—Geologic plan of Bellevue-Hudson or Rochester tunnel. Surveyed by hand compass and pacing.

The 7-foot porphyry dike cut near the face of the tunnel is gray in color and contains abundant magnetite. It is doubtfully classed as monzonite.

BELLEVUE-HUDSON AND ANAMOOSA LODE.

The Bellevue-Hudson and Anamoosa lode apexes on the steep mountain slope forming the south wall of Clear Creek valley just southeast of Empire station. The first claim of this group, the Bellevue, was located in 1886 and for 10 years after that the mine was actively worked. From 1896 until 1907 the property remained practically idle but since 1907 has been worked on a small scale by lessees. The lode is developed by an upper tunnel (from which a shaft has been sunk), by an intermediate tunnel known as the Anamoosa, and by a lower tunnel known as the Bellevue-Hudson or Rochester, which starts near the level of the main road from Lawson to Georgetown. Together these workings develop the lode through a vertical distance of over 1,000 feet.

The Bellevue-Hudson tunnel begins on the south side of Clear Creek near Empire station and extends S. 24° E. for about 1,080 feet into the mountain. (See fig. 68.) At 225 feet from the portal it cuts two veinlets of quartz and calcite 1 to 1½ inches wide carrying fine galena, separated by 1½ inches of crushed granite gneiss; at 440 feet it cuts a tight vein 1½ inches wide which shows a little galena and sphalerite; and at 675 feet from the portal it cuts a ½-inch pyrite stringer.

Between 885 and 945 feet it cuts the main lode, which here consists of three nearly parallel veins, all of which have been developed to some extent by drifts. The southernmost vein is about 2½ feet in width with 2 inches of galena and sphalerite next the hanging wall and a slip plane next the footwall, the remainder of the vein consisting of crushed schist. This vein has been stoped to a height of about 30 feet. The northernmost vein, intersected just south of the shaft (fig. 68), is 1 to 2 inches in width and shows a little galena and sphalerite. The middle vein is followed by a drift for about 200 feet east of the shaft but shows little mineralization, consisting in most places of 3 to 14 inches of crushed and decomposed schist. About 155 feet east of the tunnel another vein showing 3 to 4 inches of gouge comes in from the north or hanging wall and is followed by the drift for about 70 feet. About 230 feet east of the tunnel the drift turns north and cuts another and more heavily mineralized vein, which varies from a few inches to 14 inches in width and consists of crushed and altered granite gneiss traversed by one or two veinlets of galena, sphalerite, and pyrite 1 to 3 inches wide.

The Bellevue tunnel workings are connected by a raise with higher and more extensive workings on the vein extending nearly to the crest of the hill. The upper portions of the vein were worked through an upper tunnel and a shaft heading underground also through the Anamoosa tunnel, the total vertical extent of the workings being about 1,000 feet. The great bulk of the ore mined has come from depths of less than 500 feet.

The Bellevue-Hudson vein system belongs to the type of silver veins represented by the Senator and Millington and the mines of Red Elephant Hill and like them appears to owe its high silver content mainly to downward sulphide enrichment. Few data could be obtained in regard to the distribution of ore values in depth, but the extensiveness of the upper workings as compared with those at greater depths indicates that the richest ore came from depths of less than 500 feet. The following sampling-works assays, selected at random from the records of shipments of smelting ore for 1890 and 1891, give an idea of metal range in the upper portions of the lode.

Sampling-works assays of ore from upper portions of the Bellevue-Hudson vein system.

Ore.	Gold.	Silver.	Lead.
Net pounds.	*Ounces.*	*Ounces.*	*Per cent.*
6,010	....	83.00	11.00
5,506	....	193.00	15.00
670	....	565.00	44.00
1,204	....	315.00	37.00
7,075	....	244.00	18.00
11,861	Trace.	268.00	20.45
1,880	....	431.00	52.00
26,698	....	202.85	16.50
21,621	....	164.50	13.25
14,826	0.08	25.85	1.00
25,596	....	338.00	22.50
33,026	Trace.	208.48	15.90
23,695	Trace.	161.65	10.60

In contrast to these high silver values 10 lots of smelting ore shipped by lessees in 1908, presumably from the lower levels of the mine, showed gold, 0.03 to 0.2 ounce; silver, 12.6 to 54.2 ounces; lead, 4 to 31.6 per cent; zinc, 3 to 14 per cent.

COMMODORE TUNNEL AND RED ELEPHANT GROUP OF MINES.

The Commodore tunnel, which starts at the village of Lawson and extends about N. 40° W.

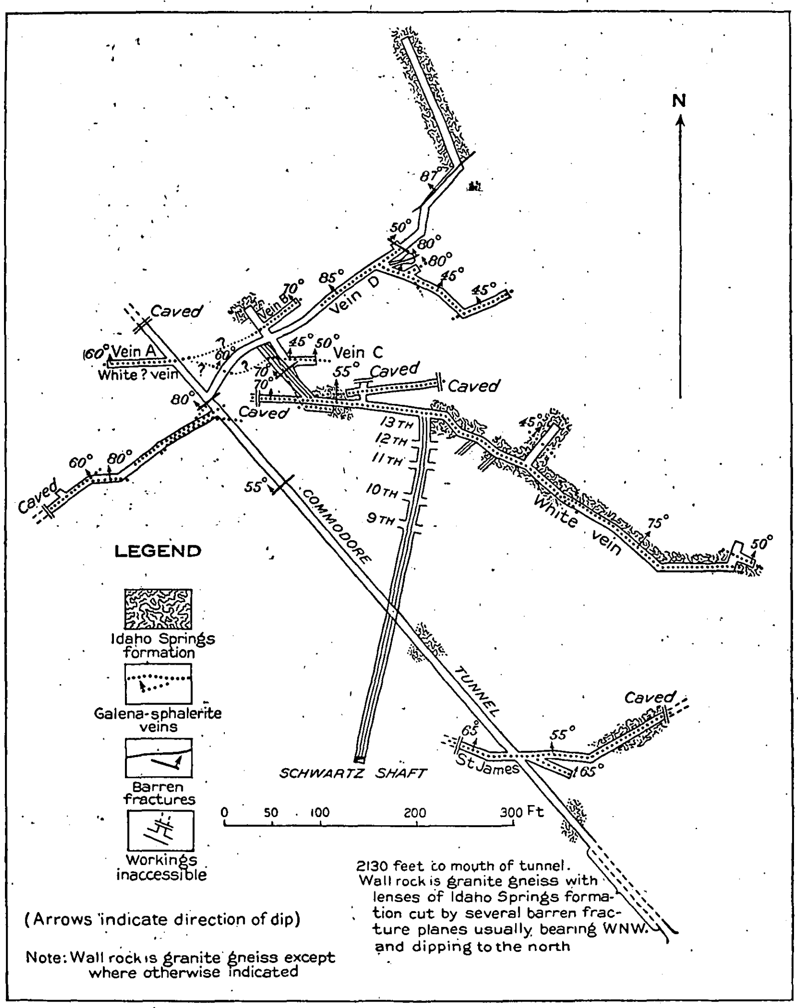


FIGURE 69.—Geologic plan of portion of Commodore tunnel and connecting workings. Surveyed by hand compass and pacing.

under Red Elephant Hill (Pl. XXII), is a straight crosscut 3,460 feet in length (in 1911). It was started in 1900 for the purpose of developing at depth the veins of the Tabor, White, Free America, Boulder Nest, and St. James mines on Red Elephant Hill. These mines had been actively worked and had yielded rich silver ores through their shaft workings from the time of their discovery until 1889, but have since been idle and at present are largely in a ruined and inaccessible condition and have been stripped of shaft houses and machinery. The gross production of the group is estimated at $1,500,000.

COMMODORE TUNNEL.

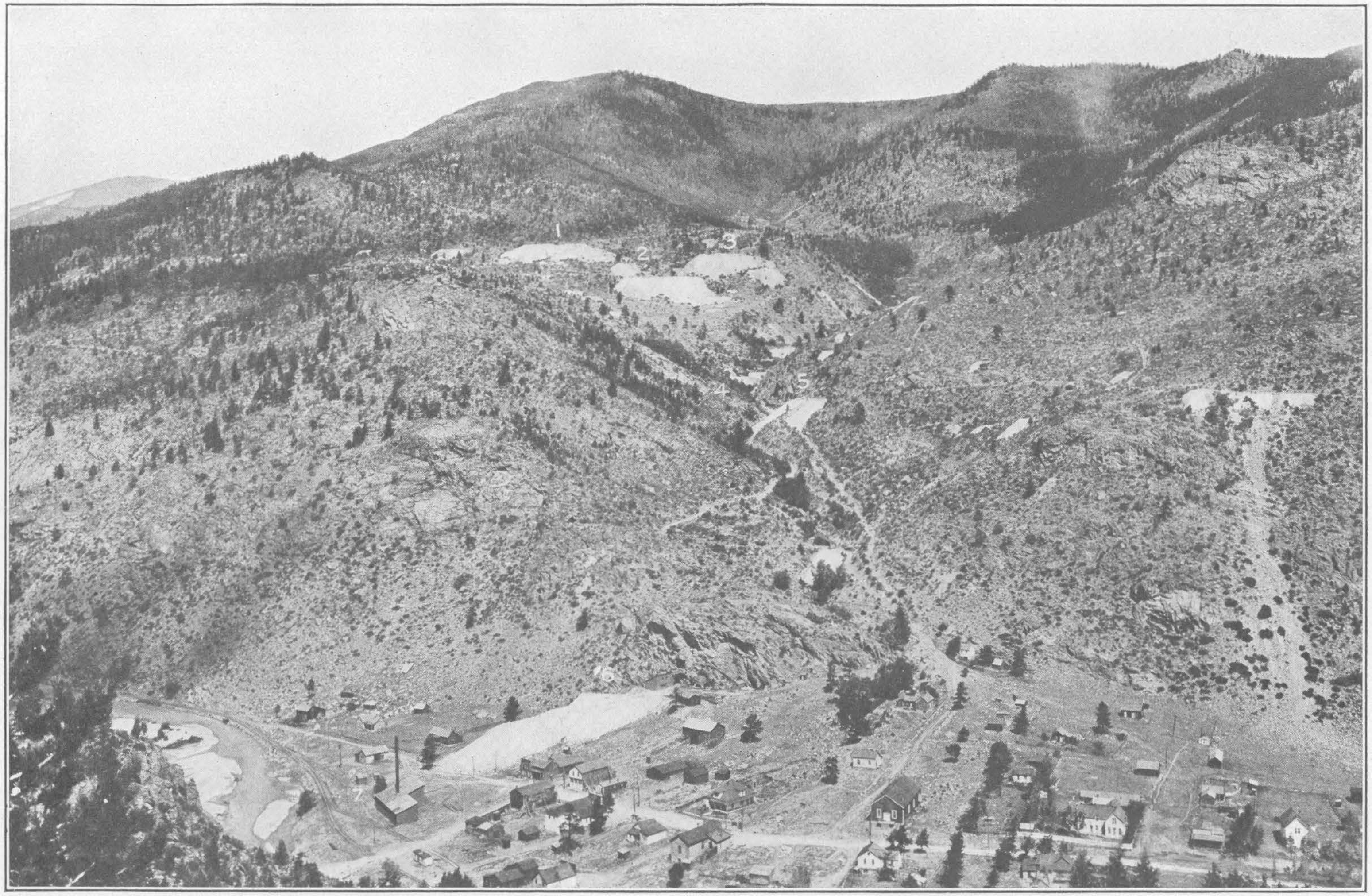
The detailed geology of the Commodore tunnel and its connecting drifts beyond a point 2,130 feet from the portal is shown in figure 69. Between the portal and the 2,130-foot point the tunnel cuts at 1,725 feet an unmineralized fracture striking about N. 60° E. and dipping 40° NW., along which the biotite granite gneiss is bleached for 2 feet, the biotite being altered to chlorite; and at 1,910 feet a fracture striking east and dipping 25° N., which carries no metallic minerals but shows some calcite and along which the biotite granite gneiss is chloritized.

At 2,250 feet the tunnel cuts the St. James vein, whose surface portion is developed by a drift tunnel about 400 feet in length, now inaccessible. The drifts from the Commodore tunnel are caved 60 feet west and 165 feet east of the tunnel. Forty feet east of the tunnel the north fork of the vein consists of a ¼-inch veinlet of quartz and galena, below which is a ½-inch veinlet of siderite. The remaining 2 feet of the vein material is crushed and altered granite gneiss without sulphides. Elsewhere the vein as exposed in these drifts is practically barren. No stoping has been done.

The following lettering of veins refers to figure 69:

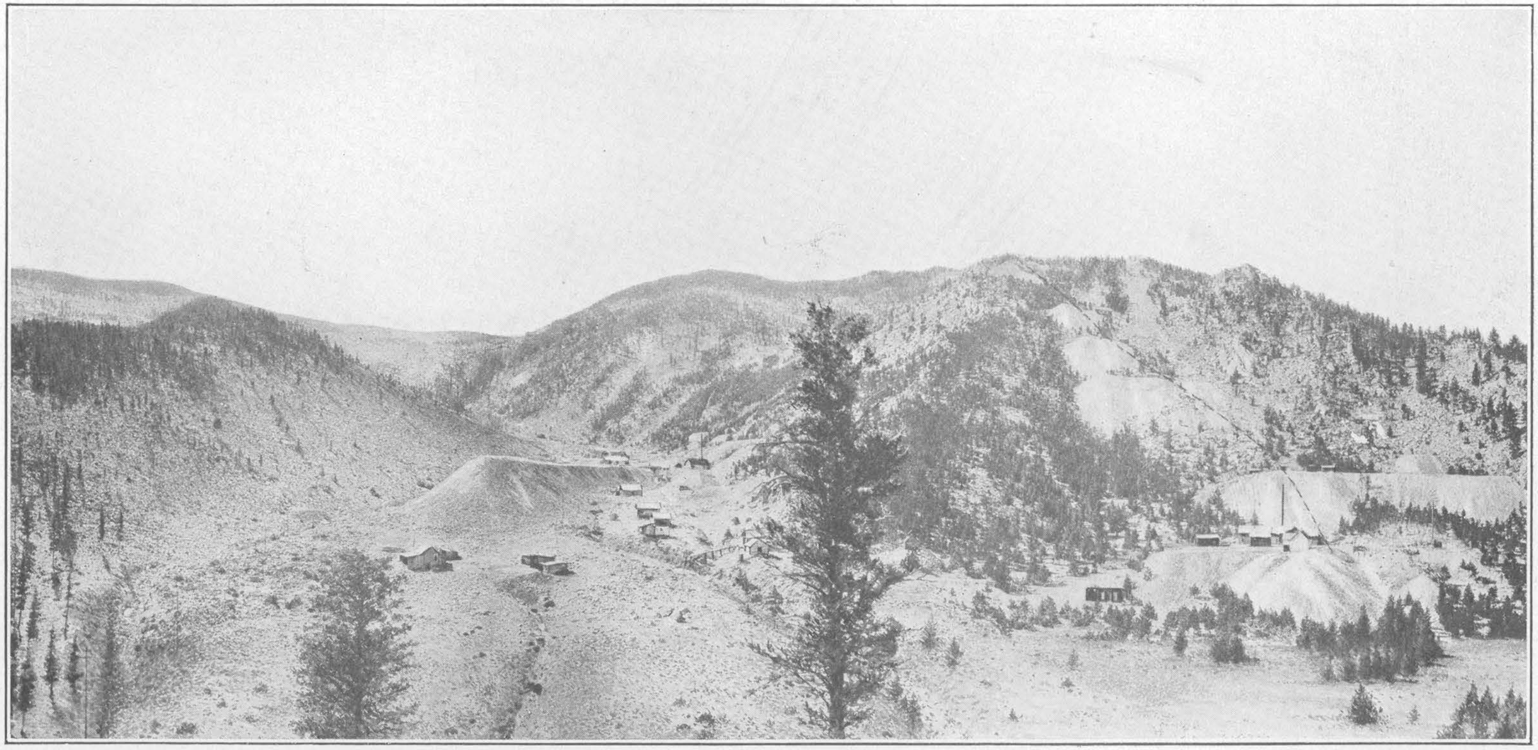
Vein A. A fracture zone along which the granite gneiss has been somewhat altered without mineralization.

Vein B. A vein which at one place shows 3 to 4 inches of somewhat crushed and altered granite gneiss next the hanging wall, succeeded,



LAWSON AND THE MINES OF RED ELEPHANT HILL FROM SOUTH SIDE OF CLEAR CREEK VALLEY NEAR LAWSON.

Boulder Nest shaft; 2, White shaft; 3, Free American shaft; 4, St. James shaft; 5, Tabor shaft; 6, Commodore tunnel; 7, Commodore power plant.
Photograph by R. B. Morton, 1907.



VIEW LOOKING UP SILVER CREEK NEAR LAWSON.

Dumps on right mark tunnels and shaft on American Sisters vein, whose outcrop is indicated approximately by the broken line. Large dump to left of center is from Jo Reynolds tunnel. Photograph by R. B. Morton.

below, by 10 to 11 inches of gray quartz and buff-colored siderite carrying galena, pyrite, and some sphalerite. In general this vein is not heavily mineralized.

Vein C. Two inches of gouge and no sulphides.

Vein D. A vein that in places shows merely 1 to 2 inches of crushed granite gneiss but that elsewhere broadens to 1 foot and shows stringers carrying quartz, siderite, galena, and pyrite.

A west drift from the tunnel at 2,730 feet exposes veins of fine-grained siderite and cherty silica through which pyrite is disseminated in small grains.

BOULDER NEST–FREE AMERICA VEIN.

The few details available in regard to the shaft workings in the Boulder Nest–Free America vein are summarized below.

Workings in Boulder Nest–Free America vein.

	Vertical depth of shaft.	Number of levels.
Boulder Nest	500	8
Free America	550	8
Free America Extension	350	4

A number of other shafts on the lode extend to depths of 200 feet or less. The levels range from 100 to 1,000 feet in length. There are no accurate maps of the workings.

According to Fossett[1] the Free America yielded ore to the value of $100,000 in 1877 and $80,000 in 1878. Between the spring of 1877, when shipments began, and the end of the year the Boulder Nest mine is said to have produced ore to the gross value of nearly $110,000. Of this ore, 391 tons are said to have averaged 37½ ounces of silver. The output in 1878 is reported to have exceeded $230,000, the silver in the ore mined ranging from 30 to 250 ounces. Several lots of smelting ore shipped from the Boulder Nest mine in the early nineties showed the following metal content, according to sampling-works assays:

Sampling-works assays of ore from Boulder Nest mine.

Ore.	Gold.	Silver.
Net pounds.	*Ounce.*	*Ounces.*
3,704		38.00
273		73.00
171	0.60	101.00
198		150.00
4,380		130.50
2,376		72.00

[1] Frank Fossett, Colorado, its gold and silver mines, p. 383, 1879.

TABOR VEIN.

The Tabor vein, on Red Elephant Hill, about 1,300 feet southeast of the Schwartz shaft, is developed by a shaft about 230 feet deep, with three levels, and by a tunnel which drains the mine slightly below the third level of the shaft. The vein strikes a little south of east, dips north, and shows mineralogic characters similar to those of the other veins of the Red Elephant group. The gross production of this mine is said to be about $70,000.

WHITE VEIN.

The White vein, which strikes nearly east, dips 50°–75° N., is developed by the Schwartz shaft with 13 levels, the lowest of which is connected by a raise with the Commodore tunnel workings. What appears to be the White vein (vein A, fig. 69) is cut by the Commodore tunnel about 2,800 feet from the portal near its junction with a northeast-trending lode which may represent the Boulder Nest–Free America. Near their junction the two veins show numerous branches, and the exact relation of any one of them to the veins developed in the higher workings is uncertain. The characteristics of the White vein are best exhibited in the thirteenth level of the Schwartz shaft workings, which may be reached through a 135-foot raise from the Commodore tunnel level. The vein there is a fracture zone varying from 3 inches to 4 feet in width, which, for much of its exposure on the level, follows a contact between schist and granite gneiss. In places the vein consists wholly of crushed wall rock, but elsewhere it shows galena, pyrite, and some chalcopyrite and sphalerite in a gangue of quartz, siderite, and barite. The sulphides and their gangue form in places sharp-walled veinlets but elsewhere grade gradually into altered wall rock. Small amounts of gray copper intergrown with galena as an original mineral are reported from this vein. Some bornite is reported from the thirteenth level.

Although the ore from this level on the White vein is in general very fresh in appearance it is interesting to record the occurrence of crystals of secondary chalcopyrite and of a black brittle sulphide, which is probably pearceite.[2] The mode of occurrence of these minerals in vugs indicates that they are prob-

[2] Similar to polybasite but with arsenic instead of antimony. The specimens reacted strongly for silver and arsenic and gave a clear copper reaction, but did not react for antimony.

ably secondary. It appears, therefore, that downward enrichment in silver extends to at least the thirteenth level in the Schwartz shaft workings—a vertical depth of about 700 feet.

The following sampling-works assays are of ore from the thirteenth level. The high silver content of many of the shipments is attributed to downward enrichment.

Sampling-works assays of ore from thirteenth level of the White vein.

Ore.	Gold.	Silver.	Lead.	Zinc.
Net lbs.	*Ounce.*	*Ounces.*	*Per cent.*	*Per cent.*
10,850	0.04	195.00	20.00	12
38,900	.03	111.50	18.40	12
28,100	Trace.	64.00	11.70	7
21,780	.02	202.00	25.00	8
18,800	....	188.10	14.00	9
27,880	.05	73.70	22.30	8
24,960	.05	49.50	24.00	10
15,000	.02	108.20	24.80	11
2,850	.04	178.00	30.00	6
5,750	.04	126.50	10.50	4

LITTLE GIANT VEIN.

The Little Giant mine is at an altitude of about 8,800 feet on the east side of the gulch leading north from Lawson. It lies across the gulch from the Red Elephant Hill group, which it resembles in mineral characters. The mine was in operation at the time of this survey, the development consisting of a shaft 270 feet deep with four levels. Only the two upper levels, at 80 and 140 feet, were accessible, the lower ones being water filled. Very little drifting, however, has been done on the lower levels. A short tunnel is being driven eastward on the vein on a level with the shaft collar.

The Little Giant vein strikes from N. 70° E. to N. 80° W., and dips about 60° N. As exposed on the 140-foot level for about 500 feet east of the shaft it consists in most places of sericitized granite gneiss cut by veinlets of quartz and siderite, which in some places form an intricate network through 2 feet of gneiss. The largest of these, 1 inch or so in width, locally carry some sulphides.

At one place in the tunnel a 1-inch veinlet of galena was bordered by a wall carrying disseminated galena. Specimens of ore from the ore bins showed galena and some sphalerite in a gangue of quartz and siderite and local barite. The galena of some vugs showed evidence of etching. Oxidation was observed to a depth of about 65 feet near the shaft, but was not observed on the 140-foot level.

Although no secondary silver minerals were seen, it is entirely probable that they occur, and that downward enrichment in silver has been of much importance.

PANAMA TUNNEL.

The Panama tunnel is a little over one-half mile northeast of Lawson, at an elevation of about 8,800 feet. The geologic features are shown in figure 70, to which the vein lettering below refers. All of the veins are of the silver type common near Lawson.

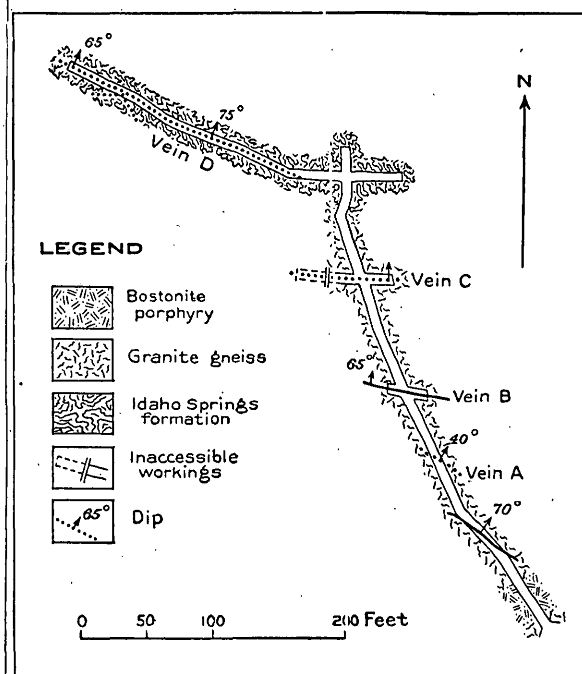


FIGURE 70.—Geologic plan of Panama tunnel. Surveyed by hand compass and pacing.

Vein A. A small vein showing 1½ inches of sulphides. One assay of ore from it gives 12 ounces of silver and 40 per cent of lead.

Vein B. A fracture zone showing only gouge with no sulphides.

Vein C. A vein that has been stoped west of the tunnel to heights as great as 48 feet. The portions of the vein exposed show little mineral. The value of the ore is said to be mainly in silver, which occurs native and in polybasite. Ore on the dump, said to come from this vein, showed galena, sphalerite, and chalcopyrite in a quartz-siderite gouge. Several assays average about 120 ounces silver.

Vein D. A vein that shows at the west face three subparallel stringers 1 inch or less in width of white quartz carrying some siderite and a few bunches of galena. The whole vein is about 1 foot wide, and the mineralization not particularly strong.

The Panama tunnel is being driven to reach a vein known as the No. 2, which has given surface assays of $12 to $52 per ton.

PLATTS VEIN AND PRINCESS OF INDIA TUNNEL.

The Princess of India tunnel, on the south side of South Clear Creek about one-fourth mile southwest of Lawson, is in part drift and in part crosscut. (See fig. 71.) The general country rock is granite gneiss, in which there are several lenses of schist of the Idaho Springs formation. Both formations are cut by porphyry dikes. Near the mouth of the tunnel an east-west dike of pyroxene monzonite porphyry contains large altered feldspar crystals. Bostonite porphyry is exposed in two places in the crosscut and also near the end of the Platts drift.

The veins cut by the tunnel are all of the galena-sphalerite type. Those in the crosscut south of the Platts vein are small, and where exposed are not heavily mineralized. The one on which the most drifting has been done (see fig. 71) has an average width of about 4 inches and shows a few fair-sized lenses of galena-sphalerite ore with quartz and barite as gangue minerals.

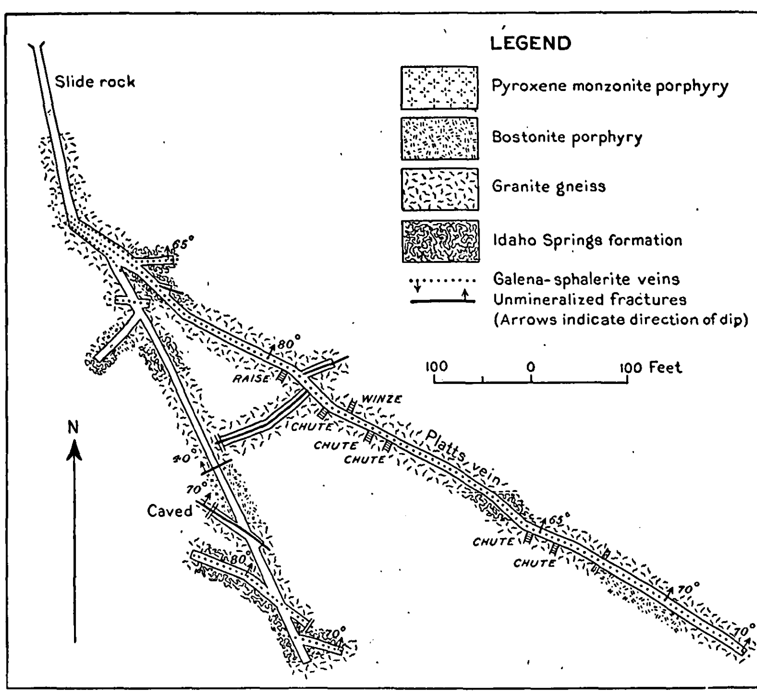


FIGURE 71.—Geologic plan of Princess of India tunnel, developing the Platts vein. Surveyed by hand compass and pacing.

The Platts vein strikes N. 60° W. and dips on an average 70° NE. It varies from a tight fracture to 14 inches in width. Near the crosscut it splits into three branches distributed through a width of about 12 feet of altered and somewhat mineralized country rock. The vein sends two feeders into the hanging wall, but neither of them is strong nor well mineralized. The Platts vein consists of crushed altered country rock, in places barren but elsewhere carrying disseminated sulphides and cut by veinlets of dark-gray quartz and barite in which there are elongate masses of sulphides up to 2 inches in width. Galena and sphalerite are the most abundant primary sulphides, though pyrite is present in all the ore and occasionally a little chalcopyrite is seen.

Downward enrichment in silver has played an important rôle in this mine, as is shown by the occurrence in vugs and small fractures in the primary ore of chalcopyrite as a coating of very small crystals and of pearceite in black metallic crystals. The chalcopyrite is in part later than the pearceite, coating it locally. The occurrence of pearceite as a metasomatic replacement of quartz and galena has already been described. (See pp. 144–145 and figs. 3, 14, and 15.)

In the Platts drift there are three stopes on lenses of ore separated by practically barren stretches. The longest extends 95 feet along the vein and the shortest 30 feet. A drift on the Platts vein has also been run from the 170-foot level of the Murray mine, but this could not be entered.

Sericitization is the principal wall-rock alteration near the vein.

A second tunnel, several hundred feet above the Princess of India tunnel, is crosscut for 60 feet and follows the Platts vein for 270 feet. The vein, which, as exposed in this tunnel, strikes about N. 55° W. and dips 65° NE., is in most places only sparsely mineralized, but locally shows sulphide lenses. At the face is a lens 6 inches wide of very fine "steel" galena associated with some cherty gray quartz. The bordering granite gneiss is somewhat altered but practically unmineralized. No secondary silver minerals were observed. The ore when sorted is said to average about $53 a ton.

Few data are available in regard to ore values or total production from the Princess of India tunnel. The gold content was low, the principal value being in silver, and, as in most of the veins of this region, the richest ore was apparently at slight depths and owed its high silver content to downward enrichment.

MURRAY VEIN.

The Murray vein, on the south side of South Clear Creek opposite Lawson, was inaccessible and most of the following information was obtained from a report by Mr. H. G. Chase.

The vein is developed by an old shaft said to be 90 feet deep and by a 275-foot shaft with levels at 80, 170, and 265 feet, respectively, 580, 550, and 257 feet long.

A pyroxene monzonite porphyry dike runs about parallel to the vein and is reported to form the south wall in most of the workings.

The vein strikes a few degrees north of east and at the surface stands vertical though below the surface it dips slightly to the north. The oxidized surface ore consists of iron-stained honeycomb quartz and crushed and altered wall rock, in which a few remnants of original galena and pyrite are preserved. The secondary minerals are limonite, copper carbonates, cerusite, and exceptionally polybasite. The ore from the upper workings was richest, and that from the 265-foot level is reported to be low grade. The principal values are in silver and are evidently the result of downward sulphide enrichment. The silver values above the 80-foot level ranged from 40 to 285 ounces. About 108 tons shipped by lessees between 1883 and 1888 showed an average metal content of about 0.35 ounce gold and 55 ounces silver; and 150 tons shipped in 1885–86 an average of about 0.44 ounce gold and 52 ounces silver. Lead in some shipments ran 45 per cent, and copper (wet) in some as high as 7 per cent. The total production of the property is not known.

CYMRIC TUNNEL.

The Cymric crosscut tunnel, in the valley of Silver Creek about three-fourths of a mile south-southeast of Lawson at an elevation of 8,690 feet, is about 1,265 feet long and runs S. 11° E. through granite gneiss and schist. Near the face a 45-foot dike of porphyry, probably bostonite, nearly free from dark-colored minerals, strikes a few degrees north of east and dips 55° N. Near the central part of the tunnel three unmineralized fracture zones strike east-northeast.

The Cymric vein, cut 1,155 feet from the portal, is an east-west fracture that dips 35°–60° N., and that has been drifted on west of the tunnel for 495 feet. In most places it is about 4 to 6 inches wide and consists of crushed schist wall rock which is very little mineralized. Stopes on two small lenses of ore are each 30 feet long and are barren at the backs at heights of 21 and 60 feet above the drift. The ore from these stopes is crushed wall rock and gray-brown cherty silica containing irregular stringers and bunches of fine-grained galena with a little dark sphalerite. Barite occurs exceptionally in the gangue. In some of the ore secondary chalcopyrite has been deposited along minute fractures.

The Big Horn fracture, which joins the Cymric 395 feet west of the main tunnel, strikes N. 53° W. and dips 40° NE. It has been drifted on for 130 feet, of which the first 125 feet is barren, and the last 5 feet contains vein filling to a maximum width of 1 foot. Next the hanging wall at the face there is a tight slip plane, below which is 6 inches of soft altered schist and pegmatite, 2 inches of brownish-gray cherty silica, another slip plane, 3 inches of fine-grained galena with some cherty silica, and 2 inches of cherty silica.

The ore from the small stopes on the Cymric vein is said to have been very rich, its value being largely in silver and lead. It is probable that the rich silver ore has been affected by downward enrichment, but no secondary silver minerals were observed. The production of the mine has been small.

MILLINGTON MINE.

The Millington mine is about three-fourths of a mile southwest of Lawson on a steep mountain slope overlooking the valley of South Clear Creek. The workings consist of four drift tunnels whose portals have elevations of approximately 9,225, 9,468, 9,584, and 9,668 feet. Observations were confined to the two lower tunnels, the upper tunnels being inaccessible at the time of survey. The lowest tunnel will be referred to as No. 1 and the one next above as No. 2.

The average strike of the Millington vein is about N. 45° E. and the dip is nearly vertical. No. 1 tunnel is in granite gneiss for about 570 feet from the point where it first meets the vein, and No. 2 tunnel is in the same rock for its first 340 feet. Beyond these distances the vein in both tunnels runs nearly parallel to a 2 to 10 foot porphyry dike, which is probably much altered bostonite porphyry. Though in some places forming a single strong fracture the lode elsewhere shows a marked tendency to fork, especially where associated with the porphyry dike. The vein is distinctly later than the porphyry and cuts across it at numerous points. Where represented by a single fracture zone the width of the vein ranges from 5 inches to as much as 4 feet. Where it splits into several fractures the width may be considerably more. A typical exposure shows 1 inch of iron-stained gouge next the hanging wall, followed below by 7 inches of soft crushed and mineralized granite gneiss and by a slip plane on the footwall.

In addition to the development on the Millington vein some mining has been done on a cross vein known as the Silver Treasure, which strikes about N. 70° W. and dips at 60°–70° NE. This vein is cut in No. 2 tunnel about 190 feet from the portal and has been drifted on for about 450 feet. Its material is more or less oxidized on the No. 2 tunnel level, but shows remnants of original quartz and fine-grained galena at several points. Oxidized ore from this vein has yielded a large content of native silver and horn silver.

Very little ore was seen in place in the workings on the Millington vein, but specimens from the dump and ore bins showed remnants of galena, sphalerite, and pyrite in a matrix of limonite, some azurite, and other oxidation products. The richer ore, which is reported to occur principally in bunches or pockets, undoubtedly owes its high silver content to downward enrichment.

The following assays selected from a large number of sampling-works returns give some idea of the range in the metal content of the smelting ore:

Year.	Ore.	Gold.	Silver.	Lead.	Remarks.
	Net lbs.	*Oz.*	*Oz.*	*P. ct.*	
1893..	25, 430	0. 07	39. 60	3. 50	Lowest return.
1893..	5, 652	. 75	195. 25	12. 70	Unusually high in gold.
1896..	53, 656	. 09	277. 00	7. 50	Large shipment.
1899..	164	. 28	1, 266. 70	12. 00	Particularly high grade.
1899..	312	. 17	658. 25	14. 40	High in silver.
1902..	3, 980	. 10	45. 40	17. 20	High in lead.

In general the gold content of the ore is below 0.1 ounce, even in lots carrying several hundred ounces of silver.

The gross production of the property is said to have been about $50,000.

AMERICAN SISTERS VEIN.

The American Sisters vein outcrops about three-fourths of a mile south of Lawson, where its position is marked by conspicuous dumps on the hill west of the settlement of Silver Creek. (See Pl. XXIII.) The vein is developed by a succession of drift tunnels along the slope of the mountain and by a shaft at the base. Plans of the workings were not available, and the development can not be described in detail, but it is known to be very extensive. The only portion of the workings that could be entered was the tunnel just above the lower shaft, which was studied for about 740 feet, the vein being stoped out for practically all of this distance.

The vein as shown in this tunnel strikes N. 50°–75° E. and dips 65°–70° NW. The roof of this tunnel is timbered except in a few places where the vein appears practically barren and no ore was seen in place.

Specimens from different dumps showed original galena, sphalerite, chalcopyrite, pyrite, quartz, and siderite. Many small vugs lined with crystals, mostly of clear quartz, less commonly of siderite, and exceptionally of galena and sphalerite were noted. Little of the galena seen was coarse, and much of it was exceptionally fine grained. Some of the sphalerite was of the resin variety. One specimen found shows banding formed by an alteration of narrow layers of siderite and wider layers of galena, but such a mode of occurrence appears rare in this mine, as well as in the district as a whole. Some small veinlets are mainly siderite with a little galena and a few are wholly siderite.

Many specimens of disseminated ore are very rich in sulphides, and this type of ore is said to have formed an important part of the output of the mine. One specimen of this type shows granite gneiss traversed by a network of narrow stringers of galena, chalcopyrite, pyrite, quartz, and siderite, the rock between the stringers containing abundant disseminated grains of sulphides. Under the microscope the rock between the sulphide veinlets is seen to be granite gneiss, in which the feldspars are crowded with sericite flakes and in which a carbonate, probably siderite, is abundant in irregular granular aggregates. Pyrite is abundant in irregular grains most of which are partly rimmed and in some cases wholly inclosed by sphalerite. Little of the latter mineral is present except in association with pyrite, but it is uncertain whether it has replaced the pyrite or been deposited around it. Galena is sparsely scattered through the rock in minute grains but is much subordinate to both pyrite and sphalerite.

Downward sulphide enrichment has been an important factor in this vein and to it is probably due the bonanzas. Specimens found on the dumps show small secondary crystals of proustite and pearceite developed on fractures and in vugs in the primary ore. A specimen belonging to Mr. P. R. Stanhope shows granite gneiss carrying abundant primary disseminated galena and chalcopyrite and cut by fractures along which secondary pearceite (?) and chalcopyrite have been deposited. Another specimen from a private collection shows a vug lined with large quartz crystals, on which some pearceite (?) had later been deposited and had in turn been coated in places by an irregular intergrowth of pearceite and chalcopyrite. Phenomena of replacement in the silver enrichment of this vein have already been described on page 146.

In order to determine the probable source of the silver in the secondary silver minerals two samples of fresh primary ore were collected and were assayed with the results given below. No. 1 was almost wholly fine-grained galena; No. 2 was mainly sphalerite with a little galena. Although no sweeping conclusions can be drawn from only two analyses these results suggest that primary sphalerite may be very important as a silver carrier.

Assays of primary ore from American Sisters vein.

No.	Gold.	Silver.	Copper (wet).	Lead.	Zinc.
		Ounces.	*Per cent.*	*Per cent.*	*Per cent.*
1.......	Trace.	6.24	0.35	61	2.10
2.......	Trace.	79.20	.25	9	46.60

Sampling-works records of 18 lots of smelting ore from the American Sisters mine, shipped from 1893 to 1898, inclusive, show gold 0.08 to 0.4 ounce, silver 33.5 to 367.2 ounces, lead 2 to 14.50 per cent, zinc 6 to 13 per cent

JO REYNOLDS VEIN.

The Jo Reynolds vein, which outcrops on the west side of Silver Creek a short distance south of the American Sisters vein, is developed by two tunnels, by a shaft which connects the two tunnel levels but does not extend to the surface, and by two shallow shafts. None of the workings, however, were accessible at the time of this survey.

The upper or Daily tunnel has its portal in the upper part of the settlement of Silver Creek at an elevation of about 9,000 feet. The lower or Elida tunnel, driven in 1900 to 1903, has its portal on the west side of Silver Creek at an elevation of about 8,500 feet and is connected by a tramway 3,500 feet long with a 40-ton mill on Clear Creek. Most of the ore has been obtained from nine levels, ranging from 200 to 1,500 feet in length, between the two tunnels. Three veins have been worked on the upper levels but only one below the fourth level. The average strike of the main vein is N. 65° E. and the dip 70° NW.

The Jo Reynolds claim was located in 1865, but it was not until the completion of the railroad in 1877 that any important amount of mining was done. From 1877 to 1907 the property was worked almost continuously.

The vein is similar in mineral characters to the neighboring American Sisters vein. The primary metallic minerals are galena, sphalerite, pyrite, chalcopyrite, and gray copper; and the secondary minerals polybasite, pearceite, proustite, argentite (original ?), native silver, chalcopyrite, and galena.

Scattered flakes of native silver in talclike material are reported to occur as low as the ninth level.

Like the other veins of the Lawson silver district the Jo Reynolds vein appears to owe its richness mainly to downward enrichment, the ore values showing a gradual decrease in depth. The records of the ore shipped are unusually complete. There are no records of any very rich ore between the surface and a depth of 50 feet. The gold content is everywhere low and fairly constant, being generally between 0.05 and 0.15 ounce, rarely as much as 0.25 ounce. The silver content in all shipments, classified according to source in the mine, is as follows:

Silver content of ore from the Jo Reynolds veins.

	Ounces.
Daily tunnel level	Some shipments as low as 20, but few less than 50 and one as high as 1,208 ounces.
First level	75 to 310
Second level	42 to 262
Third level	36 to 245
Third and fourth levels	34. 50 to 311
Fourth level west of shaft	52 to 171
Fifth level	30 to 241
Sixth level	31 to 153
Seventh level	28 to 357
Eighth level	28 to 279

In general, the silver content slightly decreases with depth, the highest being found above the third level. A single small block of ore in this part of the mine yielded $80,000 in ore running 800 to 1,000 ounces in silver. The average content of the ores below the third level is said to be about gold 0.1 ounce, silver 100 ounces, lead 10 per cent, zinc 12 per cent.

As compared with these high silver values, which are due to enrichment, the precious-metal content of the primary ore appears to be very low. A sample of "steel" galena from the Elida tunnel level, which appeared to carry no secondary minerals, showed, according to Mr. R. B. Morton, 73 per cent of lead and 14 ounces of silver.

Previous to 1904 the ore extracted was sent direct to the smelter, but from 1904 to 1907 the company operated a mill on Clear Creek, between Dumont and Lawson, which concentrated the lower grade material. In 1907, 267 tons of smelting ore and 414 tons of concentrates were shipped.

The total gross production of the property is placed at about $1,462,500.

TURKEY GULCH.

ROCKFORD TUNNEL.

The Rockford tunnel starts in Turkey Gulch, on the south side of Clear Creek, a short distance west of its junction with Fall River, and extends S. 30° E. under Trail Creek and into the hill beyond, its total length being about 2,000 feet. The tunnel is mainly in the Idaho Springs formation, but the last 120 feet are in granite gneiss. It cuts a 2-foot dike of porphyry at 70 feet from the portal and a 20-foot one at 1,220 feet. Both are bostonite, and the larger dike is probably identical with the one shown on the map near the crest of the ridge separating Turkey Gulch from Trail Creek.

The tunnel cuts two unimportant and undeveloped veins at 180 and 1,390 feet. At 950 feet it intersects the Megalona vein and at 1,830 feet the Donaldson-Champion Dirt vein, both of which have been developed by extensive workings.

The apex of the Megalona vein is on the south slope of the ridge between Trail Creek and Turkey Gulch. It strikes about N. 60° E., at about right angles to the trend of the tunnel, and dips 15° to 45° NW. (average about 30°). On the Rockford tunnel level it has not been developed to the east of the tunnel, but to the west has been drifted on for over 2,400 feet, throughout which distance the wall rocks are schists of the Idaho Springs formation and some pegmatite. At 250 feet west of the tunnel the vein cuts sharply through a dike of porphyry (probably bostonite), and is therefore the younger. In general the vein lies about parallel to the foliation of the schist, is strongly defined, and in places is heavily mineralized. In some portions it shows only 3 to 4 inches of sheared and somewhat silicified schist carrying scattered small grains of pyrite, but in other portions it shows a foot of coarse pyrite; in one place it shows 3 feet of light-gray quartz and very coarse pyrite mingled in nearly equal amounts, some of the pyrite crystals being 2 inches in diameter. The heavily mineralized portions of the vein form an ore shoot about 600 feet long, whose center is about 1,450 feet west of the tunnel, at a point where a raise and a winze have been excavated. This ore shoot has been stoped for most of its length, and is the only portion of the vein which has been worked. At the end of the drift the vein is cut off by a fault zone striking nearly north and south.

The ore consists almost wholly of pyrite, with only small amounts of chalcopyrite. Sampling-works assays of two fairly representative shipments, weighing 11.39 and 9.52 tons, show, respectively, gold 1.8 and silver 6.24 ounces, and gold 0.34 ounce and silver 1.16 ounces; both assays show a trace of copper.

The average content of over 2,000 tons shipped in 1910 was gold 0.427 ounce, silver 0.769 ounce, copper practically negligible (in no shipment exceeding 0.4 per cent).

Drifts on the Donaldson-Champion Dirt vein and its branches extend about 140 feet east and over 2,000 feet west of the Rockford tunnel. The vein, which in general is nearly parallel to the Megalona, dips 25°–35° N. (average about 30°). The strike is very variable, shifting from nearly east-west to about N. 50° E. From a point 850 feet west of the Rockford tunnel the drift is largely in granite gneiss for 650 feet and in schist of the Idaho Springs formation and pegmatite for 500 feet more (to the face). It cuts a dike of much-altered porphyry, probably bostonite, at about 1,450 feet from the tunnel.

As exposed near the tunnel the vein consists of 5 inches of nearly solid pyrite between tight, sharp walls carrying some disseminated pyrite. Near the raise leading to the upper or shaft workings the vein is 2 feet wide between pegmatite walls. Next the hanging wall is a 5-inch band of gray quartz and pyrite in about equal amounts, and next the footwall a 3-inch band of nearly solid pyrite; cross stringers connect the two. The wall rock contains very little disseminated pyrite. About 1,100 feet west of the tunnel short branch drifts on which some stoping has been done follow branches of the vein, which, like the main vein, dip 25°–35° N. Beyond a point 1,500 feet from the tunnel the mineralization is weak, and the last 150 feet of the drift appears to be off the vein. Most of the stoping has been done between the branch drifts mentioned above and the raise leading to the upper workings; that is, between 675 and 1,100 feet west of the tunnel.

The Centurion shaft has been connected with the Rockford tunnel workings on the Donaldson vein, and a raise from the Centurion tunnel connects with the Champion Dirt tunnel.

The upper workings in the Donaldson-Champion Dirt vein have been fully described by Spurr.[1] According to him the 50-foot level below the Centurion tunnel yielded a small pocket of ore, mainly galena and chalcopyrite, with subordinate pyrite, "gray copper," and an iron-bearing carbonate. Throughout most of the vein, however, the ore is almost exclusively pyrite with a quartz gangue.

Sampling-works assays of 12 shipments of smelting ore, obtained from this vein through the Rockford tunnel, show gold, 0.32 to 3.16 ounces; silver, 0.69 to 12.4 ounces; copper (wet), a trace to 2.92 per cent.

The average value of the ore shipped from the Donaldson vein through the Rockford tunnel in 1910 and 1911 was as follows:

Average value of ore shipped from Donaldson vein, 1910–11.

	Ore.	Gold.	Silver.	Copper (wet).
	Net tons.	*Ounces.*	*Ounces.*	*Per cent.*
1910		0.6180	1.567	0.335
1911	1,000	1.1096	3.200	1.189

The highest percentage of copper in the 1910 shipments was 0.646 per cent and in the 1911 shipments 3.858 per cent.

SPRING GULCH.

SILVER KING VEIN.

The Silver King vein, exposed on the west side of Spring Gulch about a mile north of its junction with South Clear Creek, is developed by two drift tunnels, the lower of which (see fig. 72) is accessible to 960 feet, where it is blocked by a cave. From this tunnel a 1,750-foot raise on the vein connects with the upper tunnel, which is short and was not visited. The wall rocks are Idaho Springs formation injected by varying amounts of granite pegmatite.

The vein strikes N. 75° E. on the average and dips 40°–70° N., the average for the first 700 feet being 65° N. and for the remainder of the tunnel about 43° N. It varies from 1 to 4 feet in width with an average of about 2 feet, and has two prominent branches running into the foot or south wall.

[1] Economic geology of the Georgetown quadrangle, Colo.: U. S. Geol. Survey Prof. Paper 63, pp. 336-340, 1908.

The vein consists of crushed altered wall rock and gray quartz containing abundant galena and sphalerite and some chalcopyrite and pyrite; galena is very much in excess of sphalerite. In most places ore of this sort is cut by numerous stringers of solid sulphides up to 8 inches in width.

Postmineral movement along the general course of the vein has produced a fine breccia of wall rock, quartz, and ore, only partly cemented by buff cherty silica and siderite, and may have produced a rough banding noted exceptionally in the sulphide seams. Near the center of the tunnel the vein is displaced by an unmineralized fault that strikes N. 16° E. and dips 68° W. A second north-south fracture about 900 feet from the mouth is mineralized in the same manner as the main vein. Postmineral fracturing has taken place along this vein but has not offset the main vein.

The sorted ore, consisting of massive galena and chalcopyrite, such as is seen in the bins, is said to carry from 35 to 100 ounces of silver, 12 to 35 per cent lead, and 5 to 10 per cent copper per ton. The high silver content of some of the ore is probably the result of downward enrichment, although no secondary silver minerals were visible at the time of this survey.

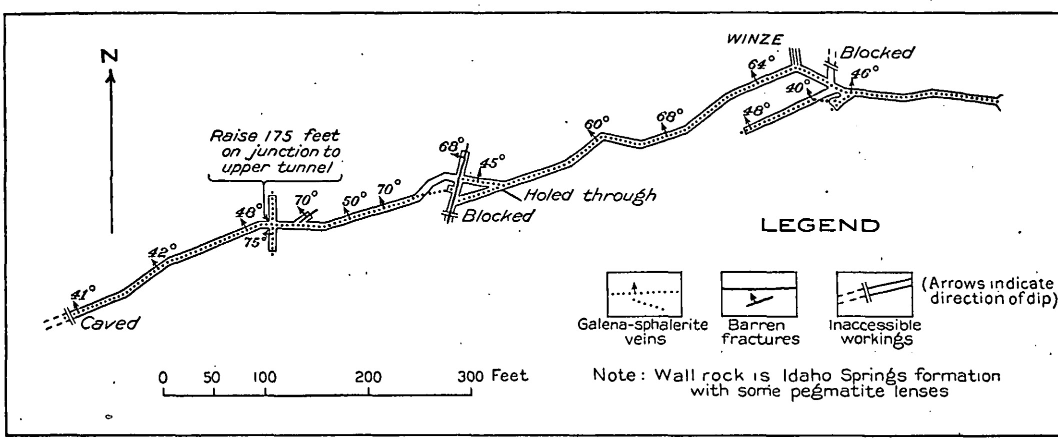


FIGURE 72.—Geologic plan of Silver King tunnel, in Spring Gulch. Surveyed by hand compass and pacing.

FIREMEN AND CONDUCTORS TUNNEL.

The Firemen and Conductors tunnel is at an elevation of 8,500 feet on the north side of Spring Gulch about 1½ miles northwest of its junction with South Clear Creek. A small stamp mill is near by. The tunnel is a crosscut bearing N. 17° E., which has been driven for over 510 feet, at which distance it is blocked by a cave. The country rock is schist of the Idaho Springs formation intruded by granite pegmatite.

The veins cut in the part of the tunnel open for inspection are only feebly mineralized. A minor fracture, 230 feet from the portal, strikes N. 75° W. and dips 45° N. and shows 5 inches of unmineralized crushed schist below an inch of gouge. A second fracture, 290 feet from the portal, strikes N. 42° W. and dips 60° NE. and shows 2 feet of crushed pegmatite that carries a little disseminated pyrite. A fracture zone at 390 feet strikes N. 83° W. and dips 50° N. and has been drifted in for 50 feet east of the tunnel and beyond a cave for 90 feet west. A winze, now full of water, is sunk from the west drift. This fracture zone, which is about 1 foot wide and has gouge on both walls, carries a little disseminated pyrite both in the crushed rock which fills the fracture zone and in the walls for short distances from it. Some very small seams of quartz with pyrite were noted in the hanging wall of the west drift cutting across the schistosity.

PIONEER TUNNEL.

The Pioneer tunnel, a little over a mile north of Dumont on the divide between Spring Gulch and Mill Creek, was idle and inaccessible at the time of this survey, but is said to be about 1,000 feet in length. A winze extending 170 feet below the tunnel and several raises to the surface develop the vein. The ore was hauled for treatment to a 30-stamp mill at Dumont owned by the company.

ALMIRA TUNNEL.

The Almira tunnel, $1\frac{1}{2}$ miles north-northwest of Dumont on the divide between Spring Gulch and Mill Creek, was inaccessible at the time of this survey. It trends nearly south and is about 350 feet long, with several short branch drifts.

GOLD CHEST TUNNEL.

The Gold Chest group of claims, on the ridge between Fall River and the head of Spring Gulch, is opened by several shallow pits on a series of nearly parallel fissures that strike north-northeast and dip vertical or steeply west. The ore in all these pits is iron-stained quartz. A crosscut tunnel to intersect these veins has been started from the south wall of Fall River valley, about half a mile west of Hamlin Gulch at an elevation of 8,500 feet. The tunnel was not entered, but the dump indicates that it can not be of great length. It cuts only schist of the Idaho Springs formation. A small amount of ore on the dump has a quartz-calcite-siderite gangue and carries galena and sphalerite with some pyrite and chalcopyrite.

DUMONT AND VICINITY.

BLUE RIDGE AND SENATOR MINE.

The Blue Ridge and Senator mine is about 1 mile southwest of Dumont on the nose of a ridge overlooking Clear Creek, at an elevation of approximately 9,000 feet. The workings accessible at the time of this survey (see fig. 73) develop two veins, a northeastward-trending vein known as the Senator and a smaller northwestward-trending branching lode, known as the Blue Ridge. No large amount of stoping has been done on the Blue Ridge vein from the Middle West tunnel level, but stopes from the Upper West tunnel, locally $4\frac{1}{2}$ feet in width, extend for about 100 feet on either side of the raise. The Senator vein has been extensively stoped for much of its length.

In the Middle West tunnel the Blue Ridge vein is first exposed about 270 feet from the portal, and it forks about 565 feet from the portal. None of the exposures show heavy mineralization and in most places the vein is practically barren. Near where it is first cut it shows merely a slip plane, with 3 inches of gouge next the hanging wall, and 2 feet of somewhat silicified granite gneiss. At another place it consists of 15 inches of gray flinty-looking quartz apparently barren of sulphides. In a stope about 400 feet from the portal the vein is $1\frac{1}{2}$ feet wide, the lower half being gouge and the upper half decomposed granite gneiss traversed by a 1-inch stringer of white quartz and by a few narrow veinlets of galena and sphalerite.

The Senator is the principal vein of the mine. On the middle tunnel level it cuts through the Blue Ridge vein, and the latter has not been found beyond this crossing. For the northern 700 feet or so of its exposure in the mine workings, the Senator vein is nearly parallel to a wide dike of bostonite porphyry. The vein is later than the dike, follows either or both dike walls and finally leaves it entirely. North of the place where it crosses the Blue Ridge vein the Senator vein so far as explored is in the porphyry dike and is practically barren.

A smaller dike 1 to 5 feet wide of nonporphyritic bostonite runs nearly parallel to the larger porphyritic dike and is exposed at five points in the mine workings. This dike has been traced on the surface for over a mile east of this mine. (See Pl. I, in pocket.) At a point in the lower east tunnel 140 feet southwest of the main shaft it is intrusive in the bostonite porphyry. The nonporphyritic bostonite is mineralized locally and at one place is cut through by the Senator vein. The vein formation is therefore later than both bostonite and bostonite porphyry.

In general abundant gouge gives evidence at many points of extensive movement along the Senator vein and makes heavy timbering necessary. The most heavily mineralized portion is in the southwest part of the mine from 350 to 1,200 feet southwest of the main shaft. On account of the softness of the vein and the heavy timbering used the ore can be studied at only a few points, the best exposures being near the new raise about 675 feet southwest of the main shaft. This raise, which at the time of survey was up 115 feet, is being driven in the hope of reaching an ore shoot that on the higher levels carried rich ores. At this raise on the tunnel level the vein is 18 to 20 inches wide, with gouge-covered slip planes on each wall, bounding crushed granite gneiss traversed by a single sulphide lens 2 inches in maximum width and extending 4 feet horizontally. At the top of the raise the vein consists of 4 to 8 feet of more or less fractured granite gneiss traversed by several slickensided slip planes and by sulphide veinlets which have been more or less crushed. Sulphides occur not only in the regular veinlets but in irregular masses (probably metasomatic replacements), which are wholly quartz and sulphides in the center but which grade gradually into the granite gneiss.

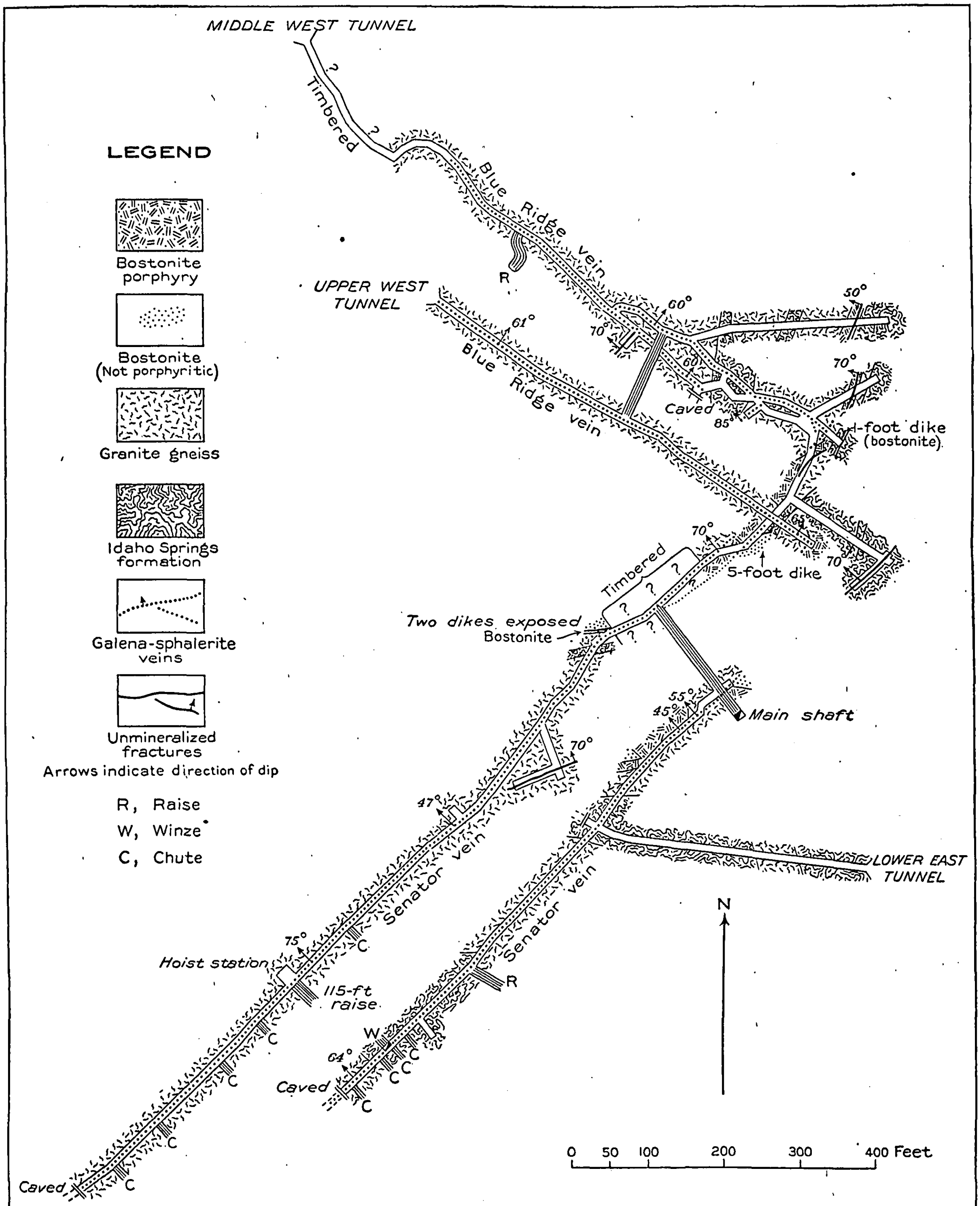


FIGURE 73.—Geologic plan of portions of the Blue Ridge and Senator mine.

The Blue Ridge vein, as stated, is in most places barren or only feebly mineralized. In a few places narrow veinlets of galena and sphalerite were noted. The mineralization of the Senator vein is also of the galena-sphalerite type, the ore minerals being sphalerite and galena with a little local chalcopyrite and pyrite in a gangue of quartz and calcite. Some barite is locally present.

The ores exposed in the middle and lower tunnels are in general unoxidized, oxidized ore being observed only in the upper tunnel, where remnants of galena and sphalerite occur in a porous iron-stained matrix in which small acicular crystals of cerusite are abundant.

Specimens of ore from the Senator vein taken from the bins at the Middle West tunnel are of especial interest because they show the importance of downward sulphide enrichment in the mineralization of the vein. Small crystals of proustite (ruby silver) and of polybasite [1] are developed along fracture seams in the original ore and upon crystals of quartz in vugs. Mostly they are associated with secondary chalcopyrite in aggregates or coatings of minute crystals and in less degree with secondary galena. Part of the chalcopyrite is later than the secondary silver minerals, for in places it coats them.

Microscopic study of polished sections of ore from the Senator vein shows that the secondary silver minerals are not confined to fractures in the original ore but also occur, as in a number of other silver veins, in the solid ore as metasomatic replacements of the primary minerals. (See fig. 14, p. 144.) It is believed that galena originally occupied the entire space between the sphalerite and the galena shown in this figure and that the polybasite has developed by metasomatic replacement of the galena. Secondary chalcopyrite is also present, partly deposited contemporaneously with the polybasite and partly later, replacing the polybasite along fractures, as shown in the figure. It is significant that in the enriched ores of this vein, as in those from other silver veins, the galena has undergone replacement while the sphalerite has been wholly immune. This is a reversal of the relations characteristic of the oxidized zone and is attributed (see p. 142) to the neutral or alkaline nature of the waters which deposited the secondary silver minerals.

The ore of the Blue Ridge and Senator veins is probably of workable grade only in those parts of the veins where enrichment in silver or in gold has taken place. Most of the unaltered primary ore appears to carry only small amounts of the precious metals, as shown by the two following assays of heavy sulphide ore free from secondary silver minerals. Both assays were made for the Survey from samples collected from the Senator vein by Mr. Bastin—No. 1 from 115 feet above the tunnel level in the raise, 675 feet southwest of the shaft, and No. 2 from a point near the tunnel level.

Assays of unenriched silver ores from the Senator vein.

	Gold.	Silver.	Copper (wet).	Lead.	Zinc.
	Ounce.	*Ounces.*	*Per ct.*	*Per ct.*	*Per ct.*
No. 1.......	0.03	7.17	0.20	76.50	1.20
No. 2.......	.08	3.10	....	51.00	....

A shipment of 22½ tons of smelting ore from the raise above referred to showed gold 0.08 ounce, silver 47.5 ounces, lead 22.9 per cent.

This ore came from depths of about 500 to 600 feet vertically below the surface, and it is probable from the considerable silver content that it has suffered some enrichment. Secondary silver minerals were noted by the writer in ore from a depth of about 600 feet in another part of the Senator vein. The very rich silver ore thus far obtained in the mine has come from vertical depths not greater than 450 feet, and the evidence at hand indicates that silver enrichment extends to a depth as great as 600 feet only where local fracturing has rendered the vein unusually pervious to descending solutions. The most promising field for exploration would appear to lie on the Senator vein above the lower and possibly above the middle tunnel. As in most of the mines of this district, in which downward enrichment has been a prominent factor, the precious-metal content is exceedingly irregular. The few assays available show that some oxidized ore from near the surface carried several ounces of gold and only a few ounces of silver. On the other hand, two shipments of ore from stopes in the upper tunnel on the Blue Ridge vein are reported to have given gold 1.6 ounces and silver 3 ounces, and gold 2.55 ounces and silver 6 ounces. It appears, therefore, that gold has, as usual, been concentrated near the surface,

[1] Dark gray, metallic; reacts for silver, arsenic, antimony, and slightly for copper.

and that silver has been leached and redeposited at greater depths, enriching ore which succeeds the leached and oxidized ore. This enriched ore, which extends locally to depths of about 600 feet, has constituted the main resource of the mine. Its gold content is generally between a trace and 0.2 ounce, but its silver content generally exceeds 50 ounces, and in many shipments exceeds 100 ounces, varying with the abundance of the secondary silver minerals, polybasite and proustite. The following sampling-works assays of shipments from the Senator vein from 1891 to 1893 give some idea of the metal content of this class of ore:

Sampling-works assays of ore from Senator vein, 1891–1893.

Ore.	Gold.	Silver.	Lead.	Zinc.
Net pounds.	*Ounce.*	*Ounces.*	*P. ct.*	*P. ct.*
4,000	0.10	45.50	10.15	9.50
2,344	Trace.	49.50	14.50	7.00
860	Trace.	91.50	34.00	5.00
3,704	Trace.	45.50	....	10.00
3,109	Trace.	57.00	22.00	11.00

Below the zone of enrichment occurs the unaltered primary ore, whose content in precious metals appears in general to be low, as shown by the assays on page 346.

The gross production of the property is said to have been about $250,000.

OHIO CREEK TUNNELS.

Two tunnels belonging to the Ohio Creek Gold Mining Co. are in Ohio Gulch about a mile southwest of Dumont, at elevations of 8,250 and 8,400 feet. The country rock in the vicinity is granite gneiss, inclosing several small detached masses of schist of the Idaho Springs formation.

The lower tunnel, after trending N. 80° W. for 60 feet between schist walls, cuts a vein striking N. 25° E. and follows it southwestward for more than 100 feet to a door which prevented further examination. This vein, which dips 60° W., cutting schist of the Idaho Springs formation, consists of gouge and crushed rock in most places about 3 inches wide. A small amount of ore on the dump showed white quartz, siderite, and a little rather fine grained pyrite.

The upper tunnel is a crosscut 160 feet long that bears N. 17° W. and has intersected two veins. The first vein, which bears N. 32° E. and dips 35° NW., is cut 100 feet from the portal and has been followed for 20 feet east to where there is a raise to the surface and for 100 feet west to where progress is blocked by a cave. This vein has schist walls that in most places show only crushed rock and an inch or so of gouge next the hanging wall but that near the cave show a few 1-inch stringers of pyrite and calcite adjacent to the fracture.

The second vein is cut by this tunnel 160 feet from the portal. It strikes N. 22° E. and dips 55°–60° NW. Its west drift, which is over 300 feet long (the first 110 feet being in schist and the remainder in granite gneiss) cuts a 30-foot east-west bostonite (?) dike 250 feet from the tunnel. This vein varies from one-half inch to 10 inches in width and is almost entirely crushed wall rock with very little mineral. At 120 feet west of the tunnel the vein splits, and at 200 feet the footwall streak goes out of the drift. The hanging-wall streak continues along the drift to the porphyry dike but does not go through it.

No data were available as to the value of the ore or the production, but the production has evidently been small.

4-C TUNNEL.

The 4-C tunnel, on the north side of Clear Creek, about three-fourths of a mile west of Dumont, was not in operation at the time of this survey. The principal geologic features are shown in figure 74, to which the lettering of veins used below refers.

Vein A: About one-half inch of gray quartz and pyrite bordered by 6 inches of crushed wall rock.

Vein B: A vein showing, at the west face, 1 inch of gray quartz carrying pyrite and 1 inch of crushed schist.

Vein C: A vein showing a maximum of 4 inches of gray quartz carrying a little pyrite.

Vein D: A vein showing, on the east of the tunnel, about 1 foot of altered granite gneiss with a few small lenses and pockets of pyrite. West of the tunnel the mineralization is very weak. The porphyry occurring near this vein is too altered for precise identification but is probably monzonite.

No stoping of importance has been done on any of the veins cut by this tunnel, and no data as to the value of the ore are available.

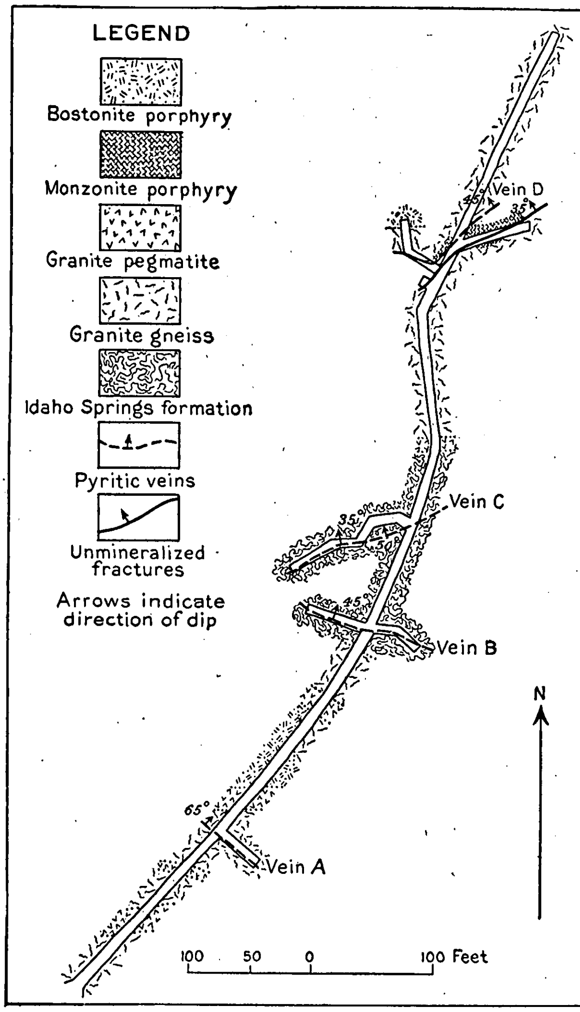


FIGURE 74.—Geologic plan of 4-C tunnel.

SILENT FRIEND VEIN.

The Silent Friend vein, on the south side of the valley of Clear Creek, about one-half mile south of the village of Dumont, is developed by two tunnels vertically about 172 feet apart. (See fig. 75.)

The Silent Friend vein strikes about N. 45° W. and dips 35°–65° NE. The wall racks are schist of the Idaho Springs formation and altered bostonite (?) porphyry, carrying more or less disseminated pyrite. The vein, which cuts sharply through the porphyry, than which it is distinctly younger, is a strong fracture zone following in general the northeast side of the dike, though in places cutting it and in places leaving it entirely. The lower tunnel shows a notable forking of the vein between 570 and 800 feet from the portal, but this is not apparent in the upper tunnel. The vein is offset slightly at several points by faults trending northeast and is offset for over 20 feet by a mineralized fracture known as the Fault vein, which strikes nearly north and dips 35°–40° W.

Throughout most of its exposed portion the Silent Friend vein consists of 2 inches to 3 feet of wall rock traversed by numerous subparallel

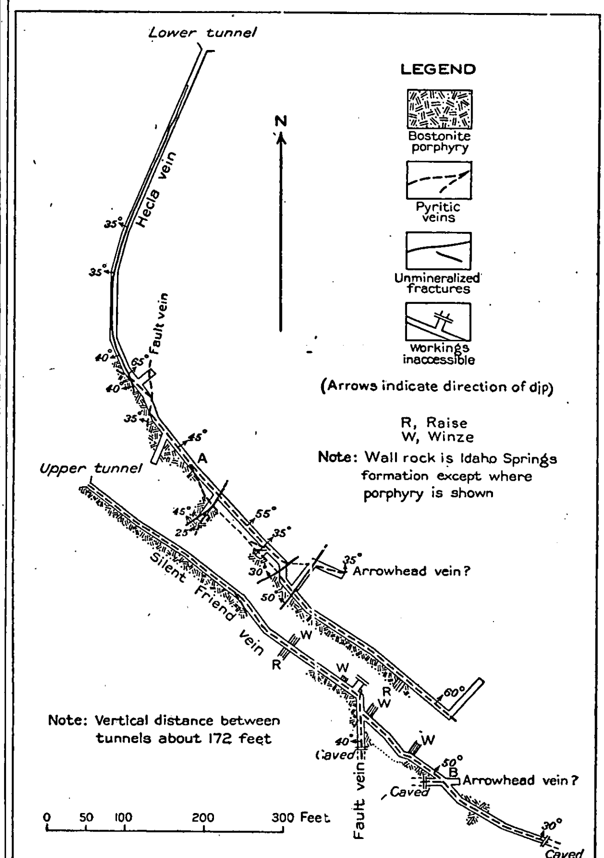


FIGURE 75.—Geologic plans of workings of Silent Friend mine. Platted from hand compass and pacing surveys.

fractures and carrying disseminated pyrite. In its more heavily mineralized parts it carries also distinct veinlets or irregular lenses of pyrite in crystals one-half inch in maximum size or of pyrite and gray quartz, ranging in width from less than an inch to 3 inches, and in one place to 1 foot.

The northeast fork of the vein in the lower tunnel (A, fig. 75) lies between schist walls and is known as the Arrowhead vein. The southwest fork, which may be considered the Silent Friend vein proper, follows the contact between schist and a porphyry dike. The mineralization in the two forks is of similar character.

About 600 feet from the portal of the upper tunnel (B, fig. 75) the main vein cuts through a porphyry dike and is joined by a branch vein which follows the southwest wall of the dike.

The Fault vein is cut in the lower tunnel 480 feet from the portal and in the upper tunnel 440 feet from the portal. It is a zone of fractured and decomposed schist and porphyry from 3 to 4 feet in width, along which the Silent Friend vein has been offset for a horizontal distance of over 20 feet. Most exposures of the Fault vein show no mineral, but a short crosscut following it in the lower tunnel shows 10 inches of gray quartz and pyrite in bands parallel to the general trend of the vein. Some of the pyrite has been crushed by postmineral movement along the vein, and breccia and gouge have been produced in many places.

A third vein known as the Hecla is exposed for the first 440 feet of the lower tunnel. Throughout most of this distance this vein shows only gouge or barren gray quartz, but about 300 feet from the portal several veinlets of quartz and pyrite up to half an inch wide are seen. The vein has no commercial importance.

That there has been much movement subsequent to mineralization along the Silent Friend and Fault veins is shown by the presence of gouge and breccia and by crushing of the ore.

The predominant mineralization of all of the veins of this mine belongs to the pyritic type, much of the ore consisting of a heavy dissemination of pyrite in schist, though in the more heavily mineralized portions veins of nearly solid pyrite are present. In a few places, however, as in the Silent Friend vein, near its intersection with the Fault vein, ore of the galena-sphalerite type is also present. In addition to its predominant sulphide, this ore carries chalcopyrite, pyrite, tennantite, and a little sphalerite in a quartz and calcite gangue. Specimens from the ore bins show the galena ore cutting the pyritic ore in irregular stringers. A pocket of rich ore containing free gold in white quartz was found in the Silent Friend vein in the lower tunnel about 40 feet beyond (below) its junction with the Fault vein.

Few data were obtained concerning the value of the ore from the Silent Friend workings, but over 6 tons showed, according to sampling-works assays, 0.08 to 0.2 ounce of gold and 2.1 to 62.9 ounces of silver. The higher silver values were in ore from slight depths and are probably attributable to downward enrichment. The largest and richest bodies of ore have been found in the Silent Friend vein near its intersection with the Fault vein, and it is significant that these ore bodies show not only pyritic ore but also ore of the galena-sphalerite type. The free gold occurring in quartz was probably of primary rather than of secondary origin.

According to Mr. Philip Stanhope one sample of ore from the Silent Friend vein just above its junction with the Fault vein assayed gold 10 ounces, silver 65 ounces, and copper 15 per cent; and ore from the Silent Friend vein just below the Fault vein carried from 1.5 to 7.5 ounces of gold.

The gross production is said to have been about $22,000.

EARL OF KENT MINE.

The Earl of Kent vein, on the south side of South Clear Creek opposite Dumont, is close to the valley bottom and is in consequence largely covered by slide. It is developed by four crosscut tunnels—the Puzzler, New, Lower Kent, and Upper Kent, named from west to east. The Puzzler inclined shaft, 275 feet deep, starts from the Puzzler tunnel.

The Puzzler tunnel, 245 feet long, cuts the Earl of Kent vein 120 feet from the portal. A drift easterly on the vein was followed for 290 feet to a point where the workings are caved.

The New crosscut, 470 feet long, cuts the Earl of Kent vein 370 feet from the portal and develops it by drifts that extend 80 feet west and 370 feet east. The Lower Kent tunnel is 260 feet long to the Kent vein with a 100-foot east drift and 160-foot west drift. The Upper Kent tunnel is 490 feet long and cuts the vein 180 feet from the mouth. A drift to the west is 150 feet long.

The predominant wall rocks in all the workings are schists of the Idaho Springs formation with rather abundant small lenses of granite pegmatite. In the New crosscut the Kent vein, where first intersected, has a porphyry footwall, which continues along the south wall of the west drift but is not exposed elsewhere. The vein is evidently younger than the porphyry, into which it sends two small stringers and which has been very much altered and impregnated with pyrite. The porphyry is probably bostonite, though it is so much altered that definite determination is not possible. The same variety is exposed in the Silent Friend mine.

The Earl of Kent vein strikes on the average about N. 55° W. and dips 15°–45° NE. Slight variations of dip where the vein is relatively flat produce large variations in the trend of the drifts, as, for example, at the Puzzler shaft where the drift turns through at least 50°. The vein has few branches. It varies from one-half inch to 4 feet in width with an average of about 10 inches and consists of altered, somewhat crushed wall rock that carries more or less abundant disseminated pyrite and is cut by narrow veinlets of pyrite and gray quartz one-eighth to 1 inch wide. In a few places a very minor amount of chalcopyrite is present with the pyrite, and at one place a few small crystals of galena were seen associated with dark-gray quartz.

The tunnels intersect a number of fractures whose strike parallels the Kent vein and whose mineralization is similar but whose dip is steeper. They also intersect a northeast-southwest series of barren fractures, one of which near the face of the east drift of the New crosscut strikes N. 50° E. and dips at 32° W., and has displaced the east side of the Kent vein 6 feet. The New crosscut south of the Kent vein follows a fault that dips 68° W., cutting both the porphyry and the vein and displacing the vein 8 feet. Postmineral movement along the Kent vein has developed in most places a small amount of gouge on one or both walls.

There has been some stoping from the shaft levels and the Lower Kent tunnel. From this material, which is said to average about $10 a ton, there has been a reported production of $12,000, including a small amount of smelting ore valued at $25 per ton. About 85 per cent of the valuable metal is gold and the other 15 per cent silver.

BIG DIPPER VEIN.

The Big Dipper vein is about one-fourth mile south of South Clear Creek, opposite the east end of the town of Dumont. It is opened by a 150-foot crosscut to the vein and by a 110-foot drift eastward on the vein. A shaft near the crosscut extends 50 feet below the tunnel level. The country rock is schist of the Idaho Springs formation, with some pegmatite lenses.

The vein strikes N. 76° W. and dips 40° N. It varies from 8 to 18 inches in width (average about 10 inches). The vein material is largely crushed wall rock with abundant disseminated pyrite, but in most places carries a 1½ or 2 inch veinlet of quartz and coarse pyrite next the hanging wall and has one-half inch to 1½ inches of gouge on each wall.

A fault that cuts off the Big Dipper vein 110 feet east of the crosscut strikes N. 32° E. and dips 77° NW. It is unmineralized, but contains 6 to 12 inches of crushed schist and shows a slickensided hanging wall with striæ about parallel to the dip. This fault also cuts but does not displace a very slightly mineralized north-south fracture dipping 80° W. A little drifting beyond the main fault has failed to expose the vein, though a crosscut 20 feet south and 10 feet east of the place where the Big Dipper vein was lost cuts a small fracture plane, which strikes N. 85° W. and dips 48° N. If this is the continuation of the vein, the displacement has been about 25 feet, the east side of the fault having moved southwest.

A little stoping has been done west of the shaft for 40 feet along the vein, but no data concerning the value of the ore were available.

SYNDICATE MINE.

The Syndicate workings, on the south side of Clear Creek valley a short distance southeast of Dumont, include four drift tunnels—two lower ones, on a western hillslope, known as the Western Syndicate workings and two higher ones, on the eastern slope of the same hill, known as the Eastern Syndicate workings. The exact correspondence of the veins developed in the eastern and western workings has not been determined, and they will therefore be separately described.

The Eastern Syndicate workings consist of two tunnels at an elevation of approximately

8,700 feet, the portal of the upper being about 75 feet above and 150 feet southwest of the portal of the lower. The upper is about 250 feet long and is entirely on the vein. The lower, which alone was carefully studied, is about 450 feet long and follows a well-defined vein that strikes generally nearly east-west and dips 35°–40° N. In general this vein is not a fissure filling but is made up of fractured and altered schist and pegmatite, in places barren but elsewhere carrying abundant pyrite as a replacement of the wall rock near a number of subparallel fracture planes. Silication has locally replaced the schist with white and gray quartz in the more pyritic portions. The vein varies from 2 to 5 feet in width. Although mainly a replacement vein, it consists in one place of network of small quartz-pyrite stringers traversing pegmatite for a width of 1½ feet.

About 350 feet from the portal a vein striking N. 20° E. and dipping 75°–80° W. is cut and has been followed by a branch drift for about 130 feet. Though barren in most places this vein shows locally 1½ inches of gray quartz carrying a little pyrite. The lower and upper tunnels are connected by a raise.

The upper tunnel of the western workings starts in the small gulch due south of Dumont. (See fig. 76.) The wall rock is entirely schist of the Idaho Springs formation. As exposed in this tunnel the Syndicate is a branching vein in places barren and elsewhere heavily mineralized. Although in most places less than 6 inches in width the vein locally widens to several feet, in one place to 5½ feet. For the last 250 feet of the main drift it shows only sparse mineralization but becomes well mineralized west of its junction with two branches (A, fig. 76). The branch exposed in the short crosscut 560 feet from the portal is 14 inches wide and consists of a granular association of quartz and pyrite, the latter being most abundant in the 6 inches next the footwall. The branch 450 feet from the portal is unimportant. The short crosscut to the south 425 feet from the portal exposes two nearly parallel veins having several seams of gray quartz and pyrite as much as an inch across, bordered by several inches of wall rock carrying disseminated pyrite. These veins are replacements of the wall rock rather than fillings of open fractures.

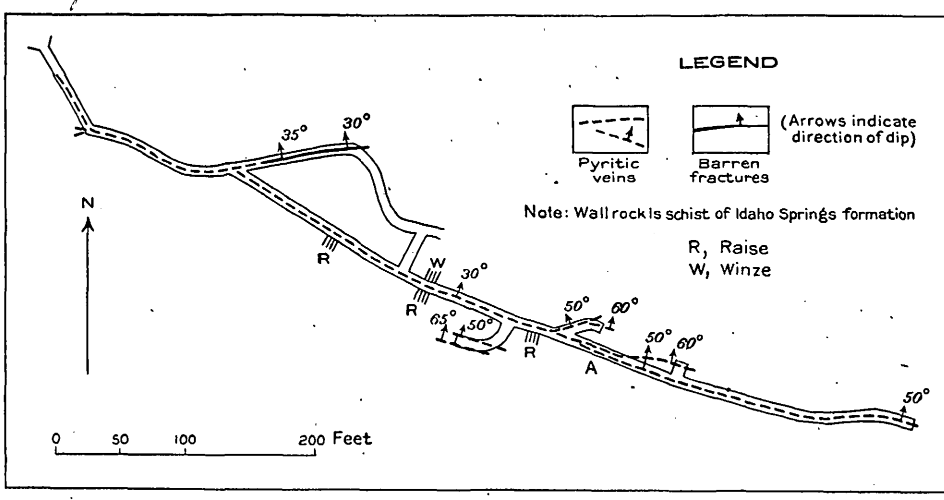


FIGURE 76.—Geologic plan of upper Western Syndicate tunnel.

About 300 feet from the portal the Syndicate vein obtains its greatest exposed width of about 5½ feet, its detailed character being as follows:

Section of Syndicate vein about 300 feet from portal of upper western tunnel.

	Ft.	in.
Hanging wall.		
Pegmatite, traversed by ill-defined stringers of quartz and pyrite and carrying some disseminated pyrite		3
Pegmatite, carrying only a little pyrite along small fractures	1	3
Silica, cherty, nearly barren		1
Pegmatite, with sparsely disseminated pyrite		5
Pegmatite, carrying abundant disseminated pyrite.	2	0
Rock, crushed and altered, with very little pyrite	1	0
Footwall.		
	5	0

The vein, as exposed in the lower western tunnel, is similar to that in the upper tunnel, except that it sends off no important branches. About 650 feet from the portal the vein is 4 feet wide and shows next the hanging wall a slip plane with little gouge, the remainder of the vein consisting of pegmatite traversed by obscurely bounded veinlets of quartz and pyrite. Pyrite is disseminated throughout the pegmatite, but becomes more and more abundant as the veinlets are approached. Some of the pyrite crystals are one-half inch across. A few small vugs in the veinlets are lined with crystals of quartz and pyrite.

Assays from various parts of the mine, taken from a report on the property by Mr. George Collins, show that the gold content usually lies between 0.1 and 0.5 ounce, though occasionally reaching 1 or even 1.5 ounces. No progressive change in the gold content with depth after the oxidized zone has been passed can be traced. The silver content in the western workings is usually between 1 and 4 ounces but is occasionally as great as 6 ounces. In the shallower workings of the Eastern Syndicate silver occasionally runs as high as 40 ounces and may be the result of enrichment by descending surface waters. The richer bodies of ore appear to be very irregular and are more like pockets than persistent and well-defined shoots.

The gross production of the property is said to be about $16,000.

FREELAND TUNNEL.

The Freeland tunnel, which begins on the south side of South Clear Creek, about half a mile east of Dumont, is a crosscut, bearing S. 12° E. and extending south for a little over a mile. It was driven to develop the Freeland and other veins at the head of Turkey Creek near the town of Freeland. A cave about 5,210 feet from the portal bars access to the principal veins.

The country rock is largely schist of the Idaho Springs formation for the first 3,600 feet from the mouth and beyond 3,600 feet is granite gneiss with lenses of schist and pegmatite. (See fig. 77.) Dikes of several varieties are cut by the tunnel. The 20-foot bostonite porphyry dike, cut 2,745 feet from the portal, contains disseminated pyrite throughout and

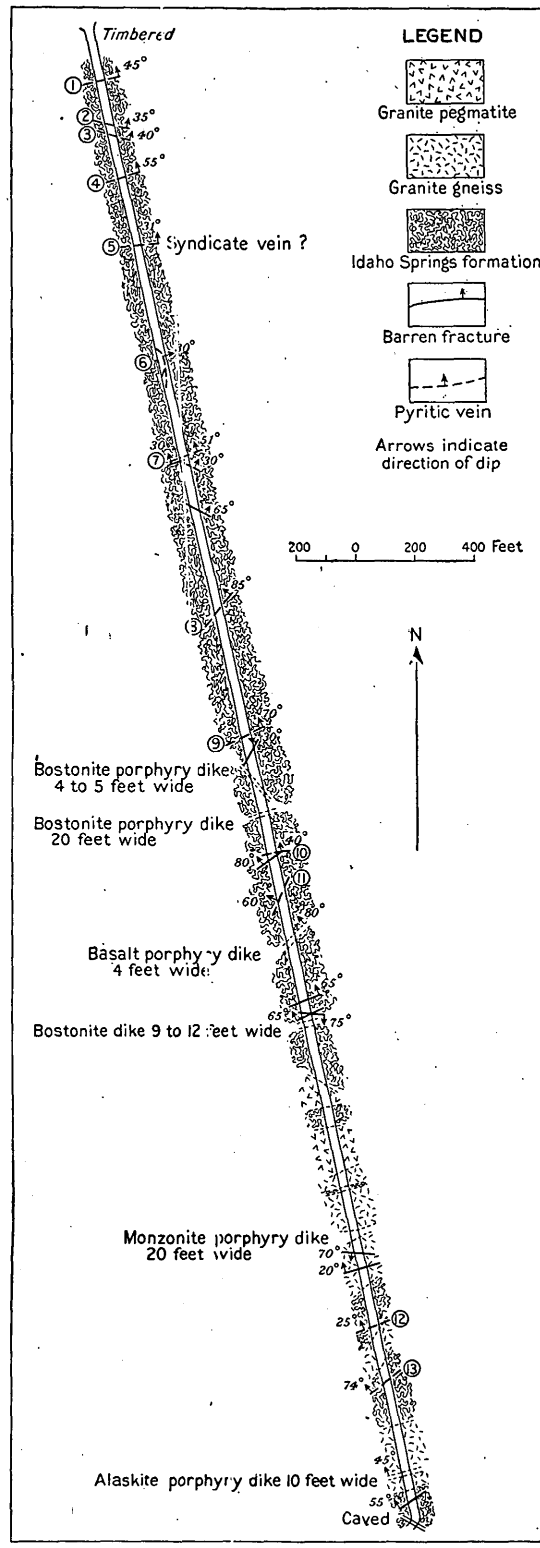


FIGURE 77.—Geologic plan of Freeland tunnel. Surveyed by compass and pacing.

carries on its footwall 1 inch of gray quartz and pyrite which in places follows the contact and elsewhere lies in the schist about a foot below the contact. A dike of basalt porphyry 4 feet in width, cut 3,185 feet from the mouth of the tunnel is amygdaloidal, the amygdules being calcite. A dike of bostonite, cut 3,475 feet from the mouth, is traversed in all directions by small seams of pyrite. A 20-foot dike of much altered porphyry (probably monzonite porphyry), cut 4,200 feet from the portal, contains abundant disseminated pyrite. The adjacent granite gneiss is also mineralized for a few feet from the contact.

Numerous fractures are cut by the tunnel and several of them are mineralized. The numbers in the following descriptions correspond to those in figure 77.

1. A vein striking N. 79° E. and dipping 45° N., in general parallel to the schist foliation. At its widest part it is 1½ feet wide, the lower half consisting of gray quartz containing some pyrite and the upper half of a postmineral breccia of schist fragments. At one place it carries a 1½-inch veinlet of solid pyrite.

2. A 1 to 4 inch sharp-walled vein of gray quartz carrying pyrite.

3. A 1½-inch stringer of dark-gray quartz and pyrite, separated from the hanging wall by one-half inch of gouge.

4. A one-fourth to 1 inch tight stringer of gray quartz and pyrite.

5. A zone 4 inches to 2 feet wide of crushed wall rock somewhat impregnated with pyrite. Some of the crushing is later than the mineralization. This is supposedly the Syndicate vein. Two parallel fractures lie 4 and 6 feet above this vein.

6. A flat branching vein of gray quartz and pyrite that runs about parallel to the line of the tunnel. At its widest it shows 4 inches of gray quartz carrying pyrite.

7. Two intersecting fractures—a 5-foot northwest to southeast zone traversed by numerous stringers of quartz and pyrite and a narrow northeast to southwest zone containing crushed quartz and pyrite.

8. Two veins which strike parallel but dip toward each other. The northern vein is 4 inches wide and is a breccia of pyritiferous quartz cemented by quartz. The south vein is 2 to 3 inches wide and consists of irregular stringers of white and gray quartz and pyrite. The country rock between these veins is altered and contains fine-grained disseminated pyrite.

9. A one-fourth to 1 inch veinlet of gray quartz containing pyrite.

10. A fracture zone along which the country rock is altered and contains abundant disseminated pyrite. A one-fourth to 4 inch veinlet contains only clear quartz.

11. A sharp-walled vein, three-fourths inch to 2 inches in width, of white and gray quartz, with pyrite irregularly distributed throughout and with some small vugs in its central part.

12. A white and gray quartz vein 2 to 7 inches wide, which carries pyrite and in places consists of nearly pure pyrite in stringers 1½ inches in maximum width.

13. A fracture about 3 inches wide, containing 1½ inches of decomposed schist next the footwall, one-half inch of siderite and pyrite and 1 inch of altered schist containing disseminated pyrite.

None of the veins described have been worked from the tunnel, but it is reported that the Freeland vein, beyond the cave in the tunnel, has been drifted on to some extent.

The unmineralized fracture zones vary in width, reaching a maximum of several feet. One of them, 4,340 feet from the mouth of the tunnel, is a 2-foot zone of brecciated schist and pegmatite, well cemented by finely crushed wall rock.

So far as known there has been little production from the Freeland tunnel.

GILPIN AND CLEAR CREEK TUNNEL.

The Gilpin and Clear Creek tunnel, on the north side of South Clear Creek about one-fourth mile east of Dumont, is a crosscut driven N. 10° W. for 870 feet to develop a large group of claims in the ridge between Spring Gulch and Clear Creek. The country rock throughout the tunnel is schist of the Idaho Springs formation.

Seven veins have been cut by the tunnel, though practically no drifting has been done on any of them. The first, exposed 220 feet in from the mouth, strikes N. 50° W. and dips 40° NE. It consists of one-half to 1 inch of altered schist that carries gray quartz and a little pyrite.

Three veins are cut 260 feet from the mouth of the tunnel. The first of these veins strikes

N. 75° W. and dips 85° N. and consists of 4 to 8 inches of altered wall rock containing disseminated pyrite and transversed by a 1-inch stringer of quartz and pyrite. This vein is cut off by a flat vein, 2 to 4 inches wide, striking N. 55° W. and dipping 30° N. and consisting of gray quartz with pyrite. The third vein, consisting of about 1 inch of quartz and pyrite, strikes N. 75° W. and dips 80° N. The wall rock between this vein and the flat vein is more or less altered and contains disseminated pyrite near the crossing.

A ½-inch stringer of quartz and pyrite, 340 feet from the mouth of the tunnel, strikes N. 75° W. and dips 80° S. A vein 605 feet from the portal strikes N. 70° W. and dips 40° N. and is developed by short drifts east and west. The vein is about 2 feet wide, consisting of crushed, somewhat silicified schist and pegmatite containing disseminated pyrite. In the east drift a 2-inch stringer of quartz contains galena, sphalerite, pyrite, and chalcopyrite, with some barite as a gangue mineral just below the hanging wall. In the west drift the vein is represented by four fractures, with the intervening schist more or less altered and pyritized. The pyrite here is coarse grained, cubes half an inch on a side being common. At the face of the tunnel there is a ½-inch veinlet of gray quartz carrying pyrite and chalcopyrite; it strikes N. 73° W. and dips 55° N.

No ore has been mined from this tunnel except a small amount taken from the drifts on the vein 605 feet from the portal.

A concentration and amalgamation mill on the south side of Clear Creek a short distance west of the mouth of the tunnel is part of the mine property.

SUNSHINE MINE.

The Sunshine tunnel, on the north side of Clear Creek valley immediately northeast of the village of Dumont, is about 200 feet in length and develops a single vein striking about N. 60° E. and dipping about 70° NW. The wall rock is schist of the Idaho Springs formation. The vein shows a maximum width of about 3 inches and consists of gouge and of gray quartz carrying pyrite. Locally the vein has been reopened and some veinlets of siderite deposited. A specimen from the dump shows a small veinlet of quartz, chalcopyrite, and galena traversing the pyritic ore.

The Sunshine shaft, 30 feet deep, near the mouth of the tunnel, is on another vein which strikes N. 75° W. and dips about 40° N. The ore on the shaft dump is largely quartz and pyrite with some later siderite and a little secondary specularite.

A composite sample including both milling and smelting ore from the tunnel vein is said to have assayed gold 0.64 ounce and silver 5.4 ounces.

Other assays are reported as follows:

Assays of ore from the Sunshine mine.

Gold.	Silver.	Copper (wet).
Ounces.	*Ounces.*	*Per cent.*
3.24	15.00	....
1.60	11.40	3.20
2.40	17.60	....
3.10	18.13	....
3.40	22.80	7.10

Practically no ore has as yet been shipped.

ALBRO VEIN.

The Albro vein on the north side of Clear Creek about one-half mile northeast of Dumont is developed by several shafts and drift tunnels, most of which have long been idle and are inaccessible. At the time of this survey mining was in progress through a shaft 185 feet deep with short levels at 70, 150, and 175 feet. The general strike of the vein is nearly east and west and the dip 30°–50° N. One of the best exposures is in a stope near the east end of the 150-foot level, where the vein has a width of 3 feet, consisting, next the hanging wall, of 6 inches of silicified schist and pegmatite carrying much disseminated pyrite, succeeded below by 1½ feet of much less altered schist carrying only small amounts of disseminated pyrite but traversed by a few small sulphide veinlets, and by 8 inches of schist and pegmatite carrying very abundant disseminations of pyrite, galena, sphalerite, and chalcopyrite. In most places on the 150-foot level the vein is 8 inches to 1 foot in width and consists of altered schist and pegmatite which carries disseminated pyrite and is cut locally by veins of solid sulphides. One vein, 3 inches wide, consists almost wholly of sphalerite and chalcopyrite. Some of the pyrite of the vein is extremely fine grained. The ore now being mined from the Albro vein, although somewhat similar mineralogically to that of the Lawson group of silver mines, differs from it by containing more chalcopyrite and more gold. In general it is more comparable with that obtained farther east from such veins as the Gladstone, near Idaho Springs, and the Topeka, near Russell Gulch. Smelting ore from a stope above the 150-foot level is said to have run as high as 2½ or 3 ounces in gold. Silver averaged 12 to 14 ounces (maximum 25 ounces) and copper 7 to 8 per cent.

Ten lots of smelting ore shipped in 1909 and aggregating about 160 tons showed, according to sampling-works assays, gold 0.39 to 1.02 (average 0.65) ounces, silver 7.6 to 21 (average 10.09) ounces, copper (wet) 3 to 10.2 (average 4.45) per cent.

Similar assays for 202½ tons of smelting ore shipped in 1908 give gold, 0.48 to 2.77 (average 0.54) ounces, silver 2.5 to 13 (average 5.65) ounces, copper (wet) 2.4 to 17 per cent.

The total gross production of the property is said to be about $500,000.

DUMONT GROUP OF PYRITIC VEINS.

A group of pyritic veins striking a little north of west and dipping 40°–60° N. apex on the ridge between Spring Gulch and Clear Creek, about three-fourths of a mile northeast of Dumont. They have been developed by several shallow shafts, all of which are now idle. The ore on the dump showed coarse pyrite and gray quartz in irregular association.

CARTER TUNNEL.

The portal of the Carter tunnel, in the north side of Clear Creek, about three-fourths mile west of its junction with Fall River, was closed at the time of survey. The wall rock on the dump was mainly schist from the Idaho Springs formation, and the ore was pyrite in a white quartz gangue. A few vugs lined with quartz crystals were noted.

MILL CREEK.

GOLDEN HOPE VEIN.

The Golden Hope vein, on the north side of Mill Creek about 1¼ miles northwest of Dumont, is developed by a drift tunnel 320 feet long and a winze that was filled with water in 1911. The vein strikes N. 60° E., dips at 35°–65° NW., and about parallel to the foliation of the schist wall rock (Idaho Springs formation).

The vein consists of fractured and altered country rock containing more or less disseminated pyrite. The hanging wall is marked throughout by one-half to 1 inch of gouge and generally by a slip plane, 16 inches to 5 feet below the hanging wall, that limits the mineralization on the other side. The better ore is near the hanging-wall slip and averages 10 inches in width. In this part of the vein numerous stringers of white quartz and siderite 1½ inches in maximum width carry pyrite and a little chalcopyrite and locally a little galena. These stringers show a narrow band of comb quartz on either wall.

The winze is sunk where a fracture strikes N. 35° E. across the main vein on a pocket of ore about 10 feet across.

The ore from the Golden Hope vein is said to carry about $18 in gold and a very little silver, which, however, is somewhat augmented where the ore carries galena.

CINCINNATI VEIN.

The Cincinnati vein, on the south side of Mill Creek 1½ miles northwest of Dumont, is developed by a drift tunnel that in 1911 was caved near the mouth. The country rock is granite gneiss. The ore on the dump was altered wall rock containing disseminated pyrite and cut by stringers of quartz and siderite which carried pyrite and, more rarely, sphalerite, galena, pyrite, and chalcopyrite. Some of the ore was brecciated and recemented by buff-colored cherty silica or by finely ground country rock.

The smelting ore is said to carry $15 to $20 in gold and silver (the gold being by far the most important) and, rarely, 2½ per cent of copper. The lead and zinc are very low.

The vein is said to have produced $2,000 to $3,000 worth of ore, most of which was taken out in 1905.

KEITH TUNNEL.

The Keith tunnel, on the north side of Mill Creek 1½ miles northwest of Dumont, is a northward-trending crosscut 690 feet long, that intersects five fractures. The country rock is largely schist with lenses of pegmatite but near the face of the crosscut is granite gneiss.

At 90 feet the tunnel cuts a 2-inch barren fracture that strikes N. 74° E. and dips 54° N.

Between 300 and 430 feet it follows a westward-dipping barren fracture, and at 440 feet it cuts an 8-inch fracture containing unmineralized crushed rock that strikes N. 45° E. and dips 37° NW. A drift follows the fracture northeast for 80 feet; at 610 feet a 2-foot zone of crushed schist and pegmatite is cut and has been drifted on for 50 feet west of the tunnel. It strikes N. 80° W., is vertical, and is unmineralized. The Keith vein cut 650 feet from the tunnel mouth, strikes about east and west, and dips on an average 50° N. It consists of about 1 foot of crushed wall rock somewhat silicified and altered and carrying scattered crystals of pyrite.

GREAT NORTHERN VEIN.

The great Northern vein is exposed on the north side of Mill Creek, just west of its first branch, about 2 miles northwest of Dumont. It is opened by a drift tunnel 1,200 feet long and by an old, apparently abandoned tunnel about 30 feet below the present workings. The country rock is granite gneiss, cut by a 12-foot quartz-bearing monzonite porphyry dike striking N. 85° E. The vein follows the north side of the dike and commonly stands nearly vertical though in some places it dips very steeply south. In most places it is a barren fracture 1 inch to 3 feet wide filled with gouge and crushed granite gneiss. In the last 200 feet of the tunnel some white quartz partly fills small anastomosing fractures between the walls. Where the filling is not complete the druses are in places coated with a thin layer of small yellowish calcite crystals. About 100 feet from the face of the drift a streak of fine-grained galena and sphalerite 1 inch wide and 15 feet long occurs near the center of the silicified vein filling.

As far as could be learned there has been no production from and almost no stoping on this vein.

TRAIL CREEK AND AREA BETWEEN IDAHO SPRINGS AND FALL RIVER.

MIAMI TUNNEL.

The Miami tunnel (see fig. 78), which starts in Dry Gulch near Idaho Springs at an elevation of about 7,900 feet, has been idle for some time and is in fact supplanted by the Big Five tunnel, which cuts the same veins at greater depth and offers better transportation facilities. At the time of this survey all the machinery on the property was being removed. The principal veins cut are as follows, the letters referring to those in figure 78.

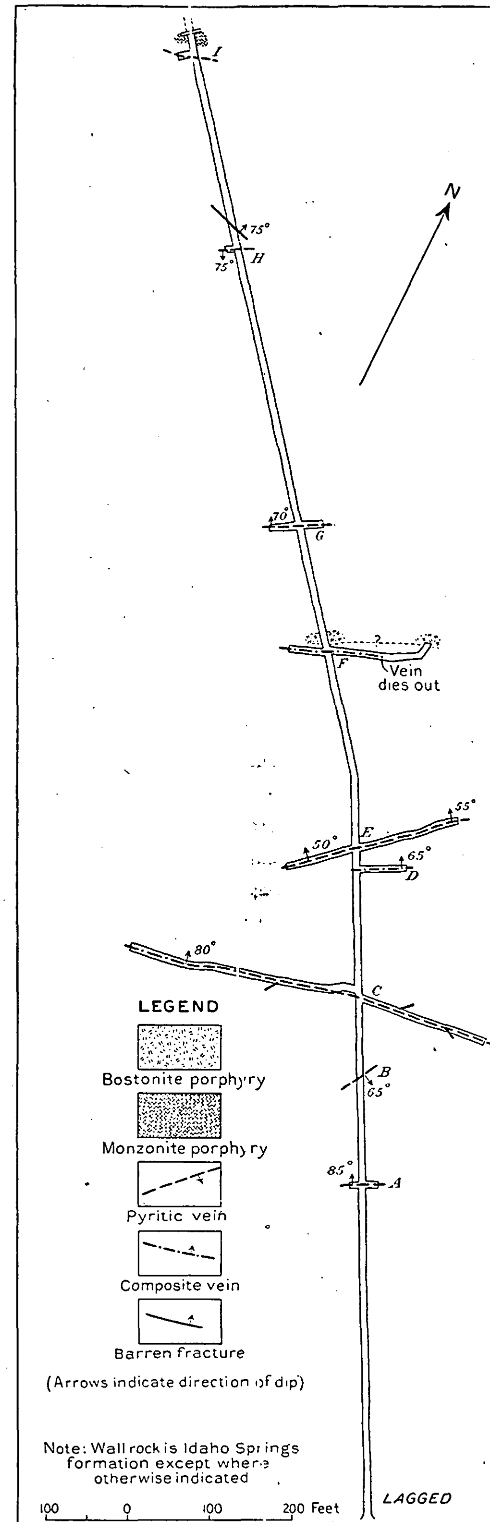


FIGURE 78.—Geologic plan of Miami tunnel.

A. Two to three inches of crushed schist carrying a little disseminated pyrite.

B. A small pyritic vein showing 2 inches of white quartz and pyrite. Fracturing along the vein subsequent to mineralization has locally produced 6 inches of crushed rock and vein material. The vein is undeveloped.

C. A zone of fractured schist and pegmatite 14 inches in maximum width. It is only faintly mineralized, the wall rock in places carrying a little disseminated pyrite. A number of branch fractures enter the walls and toward the face of the west drift the vein becomes very weak. One ¾-inch tight stringer of galena and sphalerite was observed.

D. A composite vein, which, about 50 feet east of the tunnel, is 7 inches wide, comprising 6 inches pyrite and gray quartz and (next the hanging wall) 1 inch galena and sphalerite in a gray quartz matrix. The contact of the two is sharp and regular. The galena-blende veinlet has locally been cut by small stringers of cherty silica.

E. A mineralization along fractures about parallel to the foliation of the schist walls. At the west face the vein shows a 3-inch hanging wall streak of highly silicified schist carrying disseminated pyrite. A similar streak 6 inches wide occurs 3 feet below. In places the vein narrows to 1 inch of quartz and pyrite.

F. A small tight vein of solid galena, sphalerite, and pyrite 1 to 1½ inches wide. A nearly vertical dike of bostonite porphyry showing a very fine groundmass in which only scattered feldspar phenocrysts occur lies just north of this vein.

G. A 1-inch veinlet of quartz and pyrite and some disseminated pyrite in the bordering wall rock.

H. A fracture zone 4 to 6 inches wide, locally showing a little disseminated pyrite.

I. A tight vein of quartz and pyrite 1 to 1½ inches wide.

The Edgar vein is cut by the tunnel a short distance beyond the cave.

BIG FIVE OR CENTRAL TUNNEL.

The Big Five tunnel starts near the road bridge across Clear Creek at the west end of the town of Idaho Springs and runs due north. The tramway from the tunnel continues eastward along the south side of Clear Creek to the mills near the mouth of Chicago Creek, where much of the ore is treated. In 1911 the tunnel had been driven 8,975 feet, and had cut four veins belonging to the Big Five Co. and several belonging to others, as shown on Plate XXI, *B* (in pocket).

The tunnel cuts mostly schist of the Idaho Springs formation but also intersects many small lenses of granite pegmatite, 1 of granite gneiss, and 12 porphyry dikes, 9 of which are of monzonite porphyry and 3 of bostonite.

Most of the dikes are more or less altered and mineralized. The second dike from the portal (10 feet south of the Edith S. lateral) is bostonite porphyry, 6 feet wide. The fourth dike is a monzonite porphyry, 5 feet wide, that occurs 130 feet south of the Edgar vein. It is much altered and carries disseminated pyrite and pyrite coatings along joint planes.

The larger veins cut by the tunnel have also been developed through other workings and are described elsewhere. Minor veins cut by the tunnel are described below.

The first vein of any consequence, cut 1,150 feet from the mouth of the tunnel, strikes N. 75° E. and dips 85° N. It consists of 2 feet of crushed silicified schist carrying disseminated pyrite, and is separated from the footwall by one-half inch of gouge and from the hanging wall by a tight slip plane.

The Edith S. vein is cut 1,240 feet from the portal and has been drifted on for 450 feet east from the tunnel. The vein strikes about N. 78° E. and dips 75°–80° N., cutting schist, pegmatite, and bostonite porphyry. The 6-foot dike of porphyry near by is cut by the vein 140 feet east of the tunnel and from there on forms the hanging wall. The vein varies from 2 inches to 1 foot in width but averages less than 6 inches. It consists of crushed, somewhat silicified schist that contains in a few places abundant disseminated pyrite and in some places narrow stringers of gray quartz that carry pyrite and locally galena. On the whole the vein so far as developed is not well mineralized, the ore being said to run $5 to $18 a ton in gold, with some narrow stringers that are reported to assay as much as $20 gold a ton.

A 4 to 8 inch vein of crushed schist carrying abundant disseminated pyrite, cut 2,405 feet from the portal, strikes N. 57° E. and dips 58° NW. The vein material, which is all more or less iron stained, is separated from the hanging wall by one-fourth inch and from the footwall by one-half inch of gouge.

Fifteen feet beyond the vein last described a 4-inch quartz vein carries pyrite and chalcopyrite. Above the quartz there are 2 inches of crushed schist and one-half inch of gouge lies next the footwall.

The Edgar vein is cut 2,510 feet from the mouth of the tunnel, and short drifts are run both ways on it. (See p. 360.)

An 18-inch zone of crushed altered schist, 100 feet north of the Edgar, carries throughout a small amount of disseminated pyrite.

The Jenny Lind vein is 3,690 feet from the portal. A drift east on this vein could be entered for only 250 feet, though it is said to be 625 feet long. The Jenny Lind vein strikes N. 71° E. and dips 32°–52° N. (average about 45°). A fracture striking N. 21° E. and dipping 63° W., intersected 200 feet east of the tunnel, is probably the Jenny Lind No. 1 vein. The Jenny Lind vein is bent northward by this fracture and dips 85° W. As far as seen neither of these veins is strongly mineralized, both consisting of crushed wall rock in which minor amounts of pyrite are disseminated. The Jenny Lind No. 1 measures 20 inches to 4 feet between walls and is said to average about 0.2 ounce gold and 2 to 6 ounces silver a ton.

The Shafter vein is cut by the Big Five tunnel 4,250 feet from the portal. (See pp. 360–361.)

At 40 feet north of the Shafter a 4 to 6 inch quartz-pyrite vein strikes N. 66° E. and dips 83° NNW. It has tight slip planes along both walls.

At 730 feet north of the Shafter vein an east-west zone of crushed schist about 2 feet wide carries a little disseminated pyrite. One-fourth inch of gouge is next the footwall of this vein, and a 2-inch open watercourse is next the hanging wall.

The Strong vein, cut by the Big Five tunnel 5,660 feet from the mouth, is developed by a lateral that is caved 50 feet west from the tunnel. The vein strikes N. 75° E. and dips 75°–85° N. The small part of it exposed shows only a very slight pyritic mineralization. It varies from 7 inches to 1 foot in width and consists of crushed silicified schist carrying sparingly disseminated pyrite. The ore is separated from the hanging wall and the footwall by narrow seams of gouge. Neither the value of this ore nor the production from the vein could be learned.

The Hudson vein, cut 6,445 feet from the portal, has been opened by short drifts both east and west. It strikes N. 65° E. and dips about 65° NNW., cutting schist of the Idaho Springs formation. It consists of 6 to 12 inches of crushed and silicified wall rock that carries more or less abundant disseminated pyrite and is cut by small stringers of quartz, galena, and dark sphalerite.

The Good for Nothing and Great Center veins intersect without displacement 7,000 feet from the mouth of the tunnel. The Great Center vein strikes N. 47° W. and dips 65° NE. It consists of 2 to 10 inches of crushed schist in which there are a few short, narrow stringers of quartz and pyrite. The Good for Nothing vein strikes N. 70° E. and dips 60° NNW. It varies from a tight slip to 6 inches in width and consists in its wider portions of white quartz with rather abundant pyrite in coarse crystals.

The Kentuck vein is cut by the tunnel about 7,320 feet from the portal, and short drifts east and west have been driven on it. The vein strikes N. 78° E. and dips 55° NNW. It consists of 4 to 12 inches of silicified schist that carries disseminated pyrite and is cut by a one-half to 2 inch stringer of galena and dark sphalerite. This stringer is generally frozen to the hanging wall, but in some places occupies the center of the vein. There has been very little post-mineral movement along the vein, but in one place a tight slip separates the lead-zinc ore from pyritic material.

The Lake vein is developed by short drifts that leave the tunnel at 8,345 feet. (See pp. 284–285.)

The Belman vein is cut by the Big Five tunnel 8,905 feet from the mouth. In 1911 lessees were working both east and west from the crosscut. (See pp. 283–284.)

The Big Five tunnel is 8 by 8 feet in cross section for its first 1,850 feet, beyond which it is of single-track width, with the exception of switching room at several points. Driving is done by air drills, and ventilation beyond the Shafter vein is maintained by fans and air pipe. The power house, offices, etc., are near the tunnel mouth.

MAYFLOWER TUNNEL.

The Mayflower tunnel, on the south side of Clear Creek about 1¼ miles west of the central part of the town of Idaho Springs, has been described in detail by Spurr and Garrey.[1] The vein is evidently of the composite type. Spurr and Garrey regarded the pyritic mineralization as later than the galena-sphalerite mineralization. This is the reverse of the relationship observed in most of the composite veins of the district, but as the workings were inaccessible at the time of this survey the writer had no opportunity of checking their conclusion.

CROCKET VEIN.

The Crocket vein is developed by a tunnel on the north side of Clear Creek near the mouth of Hukill Gulch and by a shaft on the hillslope above at an elevation of about 7,800 feet. The tunnel is about 550 feet long, mostly on the vein, which strikes about N. 50° E. and dips 55°–60° NE. The wall rock is mainly schist of the Idaho Springs formation, but in places is monzonite porphyry. The vein cuts through the porphyry in one place, and the distribution of the porphyry underground and on the surface shows that it is a dike nearly parallel to the course of the vein. In general, the vein is a zone of fractured rock impregnated with pyrite and varies from a few inches to 2½ feet in width. Where the vein cuts through the porphyry it becomes a single tight fracture filled with quartz and fine pyrite. In one place a tight veinlet one-half inch to 1½ inches wide shows galena, sphalerite, and pyrite.

Sampling-works assays of 14 lots of smelting ore shipped between 1891 and 1902 show gold 0.4 to 1.8 ounces, silver 13.2 to 88 ounces, copper (wet) 2.1 to 8.5 per cent, zinc 8 per cent or less, silica 21 to 52 per cent. The notable feature of the assays is their high copper content, which is normally 3 to 7 per cent.

CENTENNIAL-TWO KINGS VEIN.

The Centennial-Two Kings vein outcrops on the west side of Hukill Gulch and is developed by the Centennial tunnel and Two Kings shaft, about one-fourth mile above the mouth of the gulch. The tunnel starts as a crosscut running nearly north, intersects the vein 75 feet from the portal, and continues 115 feet beyond. A drift on the vein 330 feet long connects with the tunnel and also with the shaft. No work has been done below the tunnel level. The workings are all in schist of the Idaho Springs formation.

The average strike of the vein in the tunnel is about N. 60° E. and the average dip 70° NW. This or a closely parallel vein is traceable northeastward into continuity with the Edgar vein. The mineralization is in the main pyritic but locally galena-blende ore is prominent. A typical exposure of the pyritic portion about 280 feet northeast of the shaft showed, frozen to the hanging wall, 6 inches of gray quartz containing scattered quartz crystals below which came 3 inches of schist more or less impregnated with pyrite and, next the footwall, a band of nearly solid pyrite one-half to 1 inch wide. Ore from the shaft shows double mineralization, portions of the vein consisting almost exclusively of pyrite, chalcopyrite, and gray quartz and other portions consisting of galena and sphalerite with subordinate pyrite. The presence in one specimen of a band of comb quartz separating the two types of ore shows that they were not formed contemporaneously.

Few data are available in regard to the value of the ore. According to sampling-works assays quoted by the company six lots of smelting ore, aggregating about 18 tons, shipped in 1911, showed 1.08 to 2.84 ounces of gold and 11 to 24 ounces of silver.

As the property has been actively developed only for a short time the gross production is small.

U. S. TUNNEL.

The U. S. crosscut tunnel, starting on the west side of Hukill Gulch at an elevation of 8,050 feet, is 600 feet long and bears N. 26° W. The country rock is schist of the Idaho Springs formation, cut by three monzonite porphyry dikes, one of which is 8 feet wide and 140 feet from the portal, another 10 feet wide and 350 feet from the portal, and the third, 3 feet wide and 550 feet from the portal. Three fracture planes, cut in the central part of the tunnel, are all nearly parallel to the schistosity, which strikes N. 80° to 85° E. and dips 60°–70° N. All of them are practically barren gouge-filled fissures, carrying in most places a little disseminated pyrite. At one place 2 inches of quartz carrying a minor amount of pyrite was seen frozen to the hanging wall.

[1] Economic geology of the Georgetown quadrangle, Colo.: U. S. Geol. Survey Prof. Paper 63, pp. 365-366, 1908.

EDGAR VEIN.

The Edgar vein, which cuts across Hukill Gulch at an elevation of about 8,125 feet, is in alignment with and may be the eastward continuation of the Centennial–Two Kings vein. The developments near the head of Hukill Gulch include four drift tunnels and three shafts, the lowest of which reaches 250 feet below the lowest tunnel level. Most of these workings were inaccessible because of caving. The vein is also cut by the Big Five tunnel, but the laterals there are caved 130 feet from the tunnel.

The wall rock is mostly schist of the Idaho Springs formation, but is monzonite porphyry at one place in the Hukill Gulch workings.

The Edgar vein strikes N. 65° E. on the average and dips 70°–85° NW. It consists of crushed wall rock, slightly silicified, from a few inches to 3 feet in width, containing more or less abundantly disseminated pyrite. In the tunnels subparallel stringers of galena and sphalerite traverse the vein where it cuts the monzonite porphyry, and the porphyry between these veinlets contains abundant disseminated pyrite and some sphalerite and galena. Though no galena and sphalerite were observed in the short length of this vein exposed in the Big Five laterals, their presence at this depth is shown by the following assays:

Assays of ore from Edgar vein in the Big Five tunnel lateral.

Gold.	Silver.	Lead.	Zinc.
Ounces.	*Ounces.*	*Per cent.*	*Per cent.*
0.51	39.50	17.00	10
.48	67.20	26.50	15

Sampling-works assays of 176 tons of smelting ore sold from 1898 to 1909, inclusive, show an average content of gold 0.6 ounce and silver 16.07 ounces per ton. In these lots copper was from less than 1.5 to 6.5 per cent, lead 59 per cent or less, and zinc 16 per cent or less.

According to Raymond,[1] ore obtained in the early seventies carried much more silver than any now obtained, first-class ore averaging 0.5 ounce gold and 80 ounces silver and seldom less than 45 to 50 per cent of lead. Some lots of ore carried as much as 165 ounces of silver per ton. The high silver content in the upper levels was probably the result of downward enrichment.

The gross production is not known.

SHAFTER VEIN.

The Shafter vein runs northwestward across the middle portion of Hukill Gulch, about half a mile north of its junction with South Clear Creek. It is developed by the Shafter, Fairmont, and Summit shafts, by the Adit and Waterbury drift tunnels, and by the Anon and Shafter crosscut tunnels. On the Shafter ground there are said to be 10,425 feet of drifts on the vein. The Shafter shaft is 893 feet deep on the dip of the vein and connects by a lateral, which follows the vein, with the Big Five tunnel (4,250 feet from the portal). The Fairmont shaft is 464 feet deep and is connected with the first, second, and third levels of the Shafter.

The vein between the Shafter and Fairmont shafts has been largely stoped out to the seventh level, and east of the Shafter shaft it has been extensively stoped for 300 to 400 feet to widths of 2 to 7 feet. On account of the open character of some of these stopes many of the levels can be entered for short distances only, and those that are accessible contain only small pillars or relatively barren stretches of vein that have not been mined.

The wall rock is schist of the Idaho Springs formation injected by granite pegmatite. A 35-foot dike of monzonite porphyry that runs about parallel to the vein and 200 feet south of it is shown both in the Anon and the Big Five tunnels but is obscured on the surface by the extensive dumps.

The Shafter vein strikes from N. 40°–60° E., the average bearing of the drifts being about N. 47° E. In some places the vein dips as low as 65° NW., and in others it stands vertical, but in general it dips 78°–80° NW. This strike and dip are nearly parallel to the foliation of the schist wall rock. The vein varies from a few inches to 10 feet in width, though most of the stopes, carried the full width of the vein, are from 2 to 4 feet wide. The vein consists of crushed silicified schist and pegmatite with abundant disseminated pyrite, cut by stringers of white quartz and pyrite with a little local light-colored chalcopyrite. These stringers are in general 2 to 5 inches wide, though in some

[1] Statistics of mines and mining in the States and Territories west of the Rocky Mountains, 1871, p. 350, 1873.

places they attain a width of 2 feet. On the seventh level the stopes were originally 6 feet wide, but in 1911 it was found that the hanging wall was mineralized for at least 10 feet beyond what was originally considered the vein. The same conditions have since been found on the third level near the Fairmont shaft.

Later veinlets of chalcopyrite, galena, sphalerite, and a little tennantite have been formed in openings in the dominantly pyritic Shafter vein, particularly west of the Shafter shaft and above the fifth level. Few of these veinlets exceed 2 inches in width, and most of them are less than 1 inch. They apparently favor the hanging wall of the vein, and in some places are frozen to it and separated from the pyritic ore by a narrow seam of gouge. In other places the later minerals are found in veinlets cutting the pyritic ore or forming a matrix around fragments of pyrite and quartz. Polished sections show relations similar to those noted in ore from the Specie Payment vein. (See figs. 9 and 10, p. 113.) Above the fifth level fractures in the chalcopyrite are coated with secondary chalcocite. The lead and zinc sulphides are most abundant above the second level, though they are present in the ore from a stope above the Big Five tunnel on the eighth or lateral level. These narrow stringers constitute the richest ore in the mine; a ¼-inch streak in a stope 550 feet west of the shaft on the third level is said to carry as high as 17 ounces of gold per ton.

According to sampling-works assays the average content of 1,428 tons of smelting ore shipped in 1909 and 1910 was gold, 1.14 ounces, and silver, 5.75 ounces. The copper content in many shipments was less than 1.5 per cent, but in many others was 3 to 4 per cent, and in some 6.9 per cent. Most of the shipments do not show lead or zinc in commercial amounts. Where lead is present it is accompanied by unusually high silver values. Sampling-works assays of 243 tons of smelting ore from the Shafter vein within the limits of the Refuge claim, shipped in 1908–1910, show gold, 1.33 ounces; silver, 1.63 ounces; copper, usually below 1.5 per cent, and no lead and zinc.

SUMMIT TUNNEL.

The Summit tunnel, on the west side of Hukill Gulch, at an elevation of 8,350 feet, forms apparently the continuation of the Refuge-Shafter lode. The tunnel is caved 150 feet from the portal, but in the distance accessible it exposes two northeast-striking veins. These veins are nearly parallel and show sharp-walled stringers of pyritiferous quartz, 4 inches in maximum width, bordered by more or less silicified schist cut by very minute ore stringers.

BULLION KING MINE.

The following account of the Bullion King mine is quoted from the report of Spurr and Garrey.[1]

The Bullion King mine is located at an elevation of over 8,400 feet near the top of the north slope of the ridge separating Clear Creek from Spring Gulch, about 1,700 feet south 20° west of the ore house of the Stanley mine. An underground study of this mine was not made, as the openings to the mine were closed and the owners were not to be found. * * *

The vein seems to have a general north 55° east trend. It is probably a branch of the Little Mattie-Newton system of veins and joins the vein along the porphyry dike, which is located farther southwest. It is probably also the same vein as is developed in the Mayflower mine to the northeast.

The low-grade ore found on the mine dump contains galena, pyrite, and black sphalerite, and occurs as small seams running through granite and pegmatite or as a cementing material inclosing angular fragments of the same rocks. A few small specks of tetrahedrite or polybasite were also found associated with the galena.

Considerable ore is reported to have been obtained from the Bullion King workings.

Sampling-works assays of three lots of smelting ore shipped from the Bullion King mine in 1902–3 are as follows:

Sampling-works assays of ore from Bullion King mine, 1902–3.

Ore.	Gold.	Silver.	Copper (wet).	Lead.	Zinc.	Silica.	Iron.
Net lbs.	*Oz.*	*Oz.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
8,864	0.08	32.40	4.60	33.20	12	......	......
18,266	.22	25.30	2.50	13.70	......	......	......
31,732	.18	18.80	2.80	21.50	12	40	4

STANLEY MINE.

The Stanley mine is in the valley of South Clear Creek just west of Idaho Springs. Its history, development, and geologic features have been described at length by Spurr and Garrey,[2] and the portions of the mine accessible for study at the time of the writer's visit

[1] Economic geology of the Georgetown quadrangle, Colo.: U. S. Geol. Survey Prof. Paper 63, pp. 364–365, 1908.

[2] Idem, pp. 341–349.

revealed no significant facts not presented by these writers. The most significant geologic feature of the mine is the occurrence at several places of biotite-latite porphyry which is not only younger than bostonite porphyry but younger than the mineralization as well, as conclusively shown by Spurr and Garrey. In only one other mine in the quadrangle (the Blue Bird mine, near Nederland) was porphyry younger than the mineralization noted. The writer observed the latite porphyry in contact with bostonite porphyry on the third level of the main shaft workings, but the mutual age relations at that place were obscure.

The following sampling-works assays of smelting ore shipped in 1910 give some idea of the ore mined in recent years:

Sampling-works assays of ore from Stanley mine, 1910.

Ore.	Gold.	Silver.	Copper.	Lead.	Zinc.
Net lbs.	*Ounces.*	*Ounces.*	*Per cent.*	*Per cent.*	*Per cent.*
5,450	0.40	18.60	....	....	....
12,700	.18	2.00	....	....	....
3,770	1.31	14.20	....	....	....
25,150	.42	6.70	....	....	....
35,070	.94	13.00	2.9	12.0	3.0
8,610	1.24	7.20	....	....	....
20,840	.62	11.70	1.4	11.2	4.6
26,210	1.06	21.70	2.4	18.6	5.0
23,620	.37	9.00	1.3	6.2	5.0
24,750	.18	7.00	....	3.0	....
6,390	.77	24.90	....	43.5	....
7,520	.91	10.70	3.8	....	....
26,730	1.00	19.80	2.1	29.6	7.0
2,230	2.00	30.00	....	....	....
21,130	1.46	19.50	1.2	....	....
39,160	.75	19.80	2.4	....	....
26,660	1.23	18.50	1.5	2.5	....
37,840	1.28	25.20	3.5	....	....

The average content of the smelting ore shipped in 1910 was gold 0.85 ounce, silver 15.3 ounces, copper 0.70 per cent, and lead 1.4 per cent.

The total gross production is said to have been about $3,650,000.

SALISBURY VEIN.

The Salisbury vein and the development on it have been described by Spurr and Garrey [1] and need not be repeated in this report. In 1911 some work was being done by lessees above the tunnel level in stopes where small stringers of galena-sphalerite ore clearly cut the original pyritic vein.

According to sampling-works assays the average metallic content of 140 tons shipped from 1908–1910 was gold 0.84 ounce and silver 8.91 ounces. The percentage of copper in most shipments was too small to be paid for, but occasionally reached 11 per cent; several shipments showed 2 to 3½ per cent. Lead is occasionally present to the extent of 4 to 23 per cent. Zinc is usually not determined, but one assay showed 5 per cent. The percentage of silica in seven shipments ranged from 40 to 70 per cent.

CARDIGAN VEIN.

The Cardigan vein, in Cardigan Gulch about a mile west of Idaho Springs, is developed by three drift tunnels at different elevations on the mountain side and by a connecting shaft. Most of the workings are inaccessible, but the following description of the vein is given by Spurr and Garrey: [2]

> Near the shaft on the lower level, where two nearly parallel leads were noted, the vein consists of leads of crushed gneiss and clay 2 inches to 1½ feet in width. In places these leads contained vein quartz and pyrite. The general trend of the vein, as seen from the mine maps, was about N. 60° E. and the dip about 40° NW.

The most abundant ore on the dump consisted of pyrite and chalcopyrite in a matrix of quartz and some calcite. Thin coatings of secondary chalcocite occurred along fractures in the chalcopyrite. Some galena and sphalerite lined vugs in the pyritic vein or formed small stringers in rather sharp contact with the pyritic ore. The mineralization plainly belongs to the composite type.

Excellent exposures of typical bostonite porphyry occur near this vein.

Sampling-works assays of six shipments of ore in 1898 and 1909 show gold 0.7 to 2.9 ounces, silver 6.6 to 27.25 ounces, copper 1 to 5.5 per cent, silica 36 to 58 per cent. A lot of 560 pounds shipped in 1898 sampled gold 5 ounces, silver 51 ounces, copper 4 per cent, silica 36 per cent.

ENGLAND MINE.

The following data on the England mine is in part from the report of Spurr and Garrey.[3] The England mine consists simply of a tunnel whose portal is at an elevation of 8,550 feet a little more than a mile due west of Idaho Springs. The wall rocks of the vein consist wholly of granite gneiss and pegmatite, but

[1] Op. cit., p. 354.

[2] Idem, p. 353.

[3] Idem, pp. 352–353 and fig. 134.

two dikes of bostonite porphyry outcrop a short distance to the east.

The strike of the vein, which is developed by a drift approximately 400 feet in length, is about S. 60° W., and its dip is about 45° to 50° NW. The vein is not an especially strong one, being formed of a series of connected minor fractures. Locally, the vein consists of a series of stringers of quartz, here and there showing comb structure, in gneiss; elsewhere it consists of gray quartz containing a few angular fragments of wall rock, and showing some little replacement by mineral. The vein is only slightly mineralized, but in places carries a little ore consisting of galena, pyrite, quartz, and both brown and resin zinc blende.

GLADSTONE VEIN.

The Gladstone vein is developed by a tunnel and shaft on the south side of Clear Creek, near the mouth of Cardigan Gulch, about a mile west of Idaho Springs. The tunnel, which is about 630 feet long, is entirely in Idaho Springs formation and pegmatite. The following description is quoted from Spurr and Garrey:[1]

The main vein strikes about N. 65° E. and dips from 60° to 70° NW. The vein consists of a quartz lead, ranging from 2 inches to over a foot in width, which locally is made up solely of quartz with a little pyrite, though elsewhere it is composed of quartz, pyrite, galena, and brown sphalerite.

About 370 feet from the mouth of the tunnel the main vein is joined from the west by a clay lead several inches wide, which runs in contact with the vein for about 50 feet and then crosses it and disappears in the footwall.

Since Spurr's description was written development has been carried below the tunnel level by a winze 85 feet deep and 100 feet from the tunnel portal, and by a shaft sunk to an equal depth just outside the portal. A second level about 75 feet below the tunnel level connects the new shaft with the old winze, and extends 155 feet beyond, making its total length 265 feet. Much stoping has been done between the two levels.

As exposed in the stopes and the second level the vein lies approximately parallel to the planes of foliation of the schists. At one place the vein is 2 inches wide and is frozen to the walls. It consists of pyrite, chalcopyrite, gray copper, and some galena in a gangue composed of white quartz and some calcite. At another place the vein shows 7 inches of fractured schist next the footwall, succeeded by 2 to 4 inches of gray to white quartz carrying pyrite and chalcopyrite, and is traversed by a more or less definite band of galena and sphalerite $1\frac{1}{2}$ inches wide. A specimen from an ore bin showed a small amount of bornite intimately intergrown with galena. Postmineral movement along the vein has in places crushed the galena and chalcopyrite to an aggregate of very fine grains of luster much duller than the normal.

As at many other mines in the district, the geologic evidence suggests two mineralizations. Films of native copper have been deposited by mine waters along seams in some of the ore, but otherwise no evidence of downward enrichment was seen.

About 320 feet from the portal a crosscut to the west cuts a vein at 45 feet from the Gladstone vein and another at 70 feet. The vein cut at 45 feet strikes N. 60° E., dips 70° W., and may be a branch of the Gladstone. It shows 1 to 2 inches of gray quartz and pyrite frozen to the walls. The vein cut at 70 feet strikes N. 30° E. and dips 35° W. It shows 3 to 4 inches of somewhat crushed schist next the hanging wall, followed by 2 inches of somewhat vuggy white quartz carrying pyrite. Neither of these veins has been worked to any important extent.

Smelting ore shipped in 1908 contained gold 1.25 to 1.65 ounces and silver 5 to 14 ounces; that shipped in 1911 contained gold 0.5 ounce to 8.82 (mostly 2 to 3) ounces, and silver 6 to 50 (mostly 10 to 20) ounces. Copper in the 1911 shipments ranged from 1 to 11 per cent, though 2 to 5 per cent was more common.

DONNA JUANITA VEIN.

The small Donna Juanita vein, about 300 feet northwest of the Gladstone vein, strikes N. 65° E. and dips 40° NW. It is developed by a small tunnel 250 feet long that was inaccessible at the time of this survey.

READY CASH VEIN.

The Ready Cash vein is developed by a shaft 36 feet deep about 175 feet northwest from the mouth of the Gladstone tunnel. A drift 50 feet long extends southwest from the shaft along the vein, which strikes N. 60° to 65° E. The footwall streak dips 45° NW. and consists of 6 to 10 inches of silicified schist impregnated in various degrees with pyrite. An irregularly

[1] Op. cit., p. 353.

bounded band one-half to 1½ inches wide is a black powdery aggregate apparently of crushed sulphides. The footwall vein is said to run about $8 per ton. The hanging-wall streak, which lies about 6 feet above and about parallel to the footwall streak, consists of 10 inches of more or less silicified schist, carrying disseminated pyrite and cut by veinlets of white quartz and pyrite three-fourths inch in maximum width and by others of galena, sphalerite, chalcopyrite, and pyrite one-half inch in maximum width. The hanging-wall streak is said to have an average value of about $28 a ton.

A. MAUDE MUNROE VEIN.

The A. Maude Munroe vein is developed by a drift tunnel about 400 feet long, with portal on the north side of Clear Creek about three-fourths mile west of Idaho Springs. The vein, which is of the pyritic variety, was not studied underground. The following sampling-works assays of lots of smelting ore and concentrates shipped between 1891 and 1898 give some idea of the ore.

Sampling-works assays of ore from A. Maude Munroe vein.

	Ore.	Gold.	Silver.	Copper (wet).	Silica.
	Net lbs.	*Ounces.*	*Ounces.*	*Per ct.*	*Per ct.*
Smelting ore	5,584	1.08	13.50	....	....
	2,982	.90	22.00	....	23
	230	.40	17.00	....	65
	1,720	2.65	24.00	....	....
	7,500	.42	6.00	2.65	61
Concentrates	4,732	.95	19.30	....	13
	2,924	.55	2.50	....	18

LOST VEIN.

The Lost vein outcrops on the south side of the ridge between South Clear Creek and Georgia Gulch. It is developed by a 690-foot drift tunnel, which starts 300 feet east of Georgia Gulch below the wagon road on the north side of Clear Creek. A crosscut 440 feet from the mouth extends 80 feet south to a second vein, which has been followed 150 feet. The country rock is Idaho Springs formation.

The Lost vein strikes about N. 75° E. and dips 60° N. near the mouth of the tunnel and 65° N. in the last few hundred feet of it. The vein at the end of the crosscut strikes N. 47° E. and dips 70° NW. Both veins have small branches near the ends of the drifts. Both are small fractures, the Lost vein being nowhere over 8 inches (commonly about 2 inches) and the other vein 2 to 5 inches wide.

The mineralization of the two veins is similar. A small stringer of quartz with some pyrite is more or less continuous throughout the main vein, usually next the footwall. On either side of the quartz, though more often in the hanging wall, the schist is somewhat crushed, bleached, and sparsely impregnated with pyrite. In the south vein the quartz is absent, but the crushed schist is somewhat mineralized.

No stoping has been done on either vein. One small lot of ore shipped in 1910 shows 0.2 ounce gold and 3.2 ounces silver, amounting to less than $6 per ton.

LITTLE SIX TUNNEL.

The Little Six tunnel, on the east side of Georgia Gulch about three-eighths mile north of South Clear Creek at an elevation of 8,050 feet, trends generally southeast for 425 feet to where a cave blocks further advance. Its extent beyond the cave is not known. At 320 feet from the mouth a drift runs east-northeast for 360 feet. The rock exposed in all the workings is schist of the Idaho Springs formation, in some places highly injected by granite pegmatite. The mouth of the tunnel is in a dike of monzonite porphyry, which runs north and is not elsewhere exposed.

The northwest-southeast part of the workings follows a barren tight fracture which in many parts is traced with difficulty and is nowhere wider than half an inch. The drift at 320 feet is on a 2 to 10 inch fracture that strikes N. 72° E. and dips about 70° N. In its wider portions it is filled with barren crushed schist, in places sparsely impregnated with pyrite and in its narrow portions by gouge that is locally mineralized.

WYANDOTTE TUNNEL.

The Wyandotte tunnel is on the east side of Georgia Gulch three-eighths of a mile north of South Clear Creek. A crosscut tunnel 140 feet long intersects two veins. A drift N. 45° E. on the Lilly vein is 900 feet long and another on the Gold Dust vein runs N. 75–87° E. and is 680 feet long. The country rock throughout is

Idaho Springs formation in some places intruded by much granite pegmatite.

The Lilly vein dips 65° N. and is not well mineralized except for 130 feet near its junction with the Gold Dust vein. In most places it consists of 1 inch to 4 inches of barren gouge or crushed wall rock impregnated with pyrite. Near the junction the vein broadens to 14 or 18 inches with 2 to 4 inches of white quartz and coarse pyrite below the hanging-wall slip. The remainder of the filling is crushed, somewhat silicified schist carrying disseminated pyrite.

The Gold Dust vein for 410 feet from the tunnel is a small barren fracture dipping 60°–70° N. and commonly containing 2 to 3 inches of crushed schist between walls that are bleached and in places silicified for 1½ to 2 inches. In a few places a little pyrite is disseminated in the vein filling and at one place a 1-inch stringer of white quartz and coarse pyrite was noted.

There has been a little stoping on the Lilly vein for 130 feet northeast of the junction and on the Gold Dust for 50 feet. Sampling-works assays of several lots of smelting ore shipped from the Wyandotte tunnel are as follows:

Sampling-works assays of ore from the Wyandotte tunnel.

Date.	Ore.	Gold.	Silver.	Copper (wet).	Silica.
	Net lbs.	*Ounces.*	*Ounces.*	*Per cent.*	*Per cent.*
1891–1898	2,058	1.85	7.00	....	....
	6,392	2.93	10.00	4.90	25
	14,538	3.20	11.50	7.65	23
	8,984	2.67	10.20	5.50	19
	8,270	2.60	17.00	11.50	22
1901	5,368	1.21	7.70	5.40	28
	5,702	1.49	6.60	4.75	30

Shipments made in 1908 and 1909 were comparatively low grade, the gold ranging from 0.16 to 0.4 ounce and the silver from 0.5 ounce to 2 ounces. In 1911 the tunnel was being reopened after several years of idleness.

JOSEPHINE AND BARBER & ELLIOTT VEINS.

The Josephine and Barber & Elliott veins on the south side of Clear Creek about a mile west of Idaho Springs were not visited during this survey. They were studied by Spurr and Garrey [1] to whose report the reader is referred.

[1] Op. cit., pp. 356–358.

LINCOLN AND SOUTH LINCOLN VEINS.

The Lincoln and South Lincoln veins, on the south side of Clear Creek about a mile west of Idaho Springs, have been described by Spurr and Garrey,[2] and as there had been no important developments since their survey the mines were not reexamined.

Sampling-works assays of smelting ore shipped from 1888 to 1902, inclusive, show that the metal content of the ore is very variable.

Sampling-works assays of ore from the Lincoln and South Lincoln veins.

Ore	Gold.	Silver.	Copper (wet).	Lead.	Zinc.	Silica.
Net lbs.	*Ounces.*	*Ounces.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
1,058	0.35	40.00	......	10	22	......
7,454	5.90	13.40	4.70	......	......	......
9,376	1.24	3.22	......	......	......	12.0
13,320	1.68	3.70	......	......	......	37.0
8,414	1.49	4.40	3.20	......	......	32.5

The vein is apparently of the composite type, certain portions being largely pyritic and other portions carrying abundant galena and sphalerite.

ORO-MORNING STAR VEIN.

The Oro-Morning Star vein crosses the ridge between Oro and Georgia gulches and is developed by two shafts, the Oro near the bank of Clear Creek and the Morning Star in Georgia Gulch at an elevation of about 8,350 feet. Two tunnels have been driven, the longest of which, the Syracuse tunnel, connects with the Morning Star shaft. The workings were not entered. The following are sampling-works assays of a few lots of smelting ore shipped between 1891 and 1894:

Sampling-works assays of smelting ore from the Oro-Morning Star vein.

Ore.	Gold.	Silver.	Copper (wet).	Silver.
Net lbs.	*Ounces.*	*Ounces.*	*Per cent.*	*Per cent.*
12,450	1.50	24.00	1.00	48
16,350	1.30	22.50	1.50	43
5,718	0.60	13.00	....	....
7,435	1.45	24.50	2.00	....

The ore is apparently of the pyritic type.

[2] Op. cit., pp. 354–356.

METROPOLITAN TUNNEL.

The Metropolitan crosscut tunnel starts at an elevation of about 7,750 feet near the mouth of Trail Creek and runs S. 23° W. for about 2,600 feet, S. 45° E. for 180 feet, and S. 28° W. for 330 feet to the face. The tunnel is headed for the Metropolitan vein, which crops out in Spring Gulch,[1] and in October, 1911, was said to extend to within 1,100 feet of the Metropolitan shaft.

The wall rock of the tunnel is schist of the Idaho Springs formation and a few small masses of granite gneiss. A dike of altered porphyry, probably bostonite, is cut at 250 feet from the portal and another dike, of bostonite porphyry, at 2,020 feet. The northernmost dike could not be found on the surface, although a special search for it was made.

The only vein of importance cut by the tunnel enters from the east wall about 750 feet from the portal and passes into the west wall 870 feet from the portal. It strikes about N. 20° E. and dips 35° W. As exposed in the tunnel the vein shows 2 to 3 inches of gray quartz carrying abundant pyrite and bounded on one or both sides by several inches of gouge. It has not been worked. Ore from this vein found on the dump showed some chalcopyrite and sphalerite and a little galena in addition to the pyrite.

HOOSAC TUNNEL.

The Hoosac tunnel, which was started about 1908 on the north side of Clear Creek, a little east of its confluence with Fall River, develops the Rising Sun, Martha Perks, and Hoosac veins. (See fig. 79.)

The Hoosac vein is a somewhat irregular zone of fracturing and mineralization with general east and west trend. In places it follows the contact between monzonite porphyry and pegmatite but elsewhere intersects both these rocks. In places the mineralization consists only of a dissemination of pyrite in fine grains in pegmatite and porphyry, evidently a result of metasomatic replacement by mineralizing solutions penetrating along minute fractures and working out into the wall rock. In other parts the mineralization assumes the form of well-defined veinlets bounded by altered wall rock carrying disseminated pyrite. At the east face of the drift a vein 3 inches wide at the contact between pegmatite and porphyry consists of quartz and pyrite and sends off narrow branches into both the pegmatite and porphyry. Some of the pyritic veinlets show small vugs lined with crystals of quartz and pyrite. At several points in the drifts on this vein a 1-foot unmineralized friction breccia is exposed.

Metasomatic alterations along the Hoosac vein were studied in two thin sections. The first showed mineralized granite-pegmatite in which the principal changes were the development of sericite and pyrite. The original minerals of the pegmatite appear to have been quartz, orthoclase, muscovite, and a little plagioclase. Sericite is largely confined to the feldspars, where it is usually most abundant in bands parallel to the cleavages. Pyrite may be inclosed either by feldspar or quartz crystals or may lie between them in grains, most of which are irregular and inclose small masses of quartz and sericite, but a few of which show crystal outlines. Calcite is developed sparingly in aggregates of minute grains.

The second thin section studied was of bostonite porphyry adjacent to the veins. The rock consisted originally of anorthoclase laths in somewhat fluidal arrangement, with some interstitial quartz. The metasomatism has not been severe. Sericite has been developed in the feldspar, aggregates of minute carbonate grains are moderately numerous, and there are a few small grains of pyrite.

The Martha Perks vein, as exposed in the east drift, cuts solely granite gneiss, but in the west drift it follows for some distance the south side of a monzonite porphyry dike and at two places cuts through the porphyry. The mineralization is entirely pyritic. The vein ranges from 3 to 6 inches in width and is formed for the most part by replacement of the wall rock along a zone of fracturing. About 215 feet east of the tunnel the Martha Perks fracture abuts against a mineralized fault. The mineralization, which is continuous with that of the Martha Perks vein, shows that the fault is not entirely postmineral, although it may have undergone some movement subsequent to mineralization. The vein shows 3 to 6 feet of more or less silicified granite gneiss traversed by small seams of pyrite and carrying more or less fine disseminated pyrite. Several fracture planes parallel to the trend of the vein and showing slickensides but little gouge are commonly present.

[1] U. S. Geol. Survey Prof. Paper 63, p. 352, 1908.

The Rising Sun vein, which is followed by the Hoosac tunnel for about 570 feet from the portal, is commonly 3 to 8 inches in width. At its easternmost exposure the vein proper is 6 inches wide and consists mostly of pyrite irregularly associated with some gray and white quartz gangue. Below the vein the granite gneiss for 4 to 5 feet carries a little disseminated pyrite and is traversed by small stringers of pyrite. Above the vein an unmineralized streak 1½ feet wide is apparently composed of schist now thoroughly consolidated. In places the vein shows 5 to 8 inches of white quartz unmixed with sulphides. The vein is later than the dike of bostonite porphyry, cut about 320 feet from the portal, for stringers of pyrite traverse the porphyry. The Rising Sun vein is

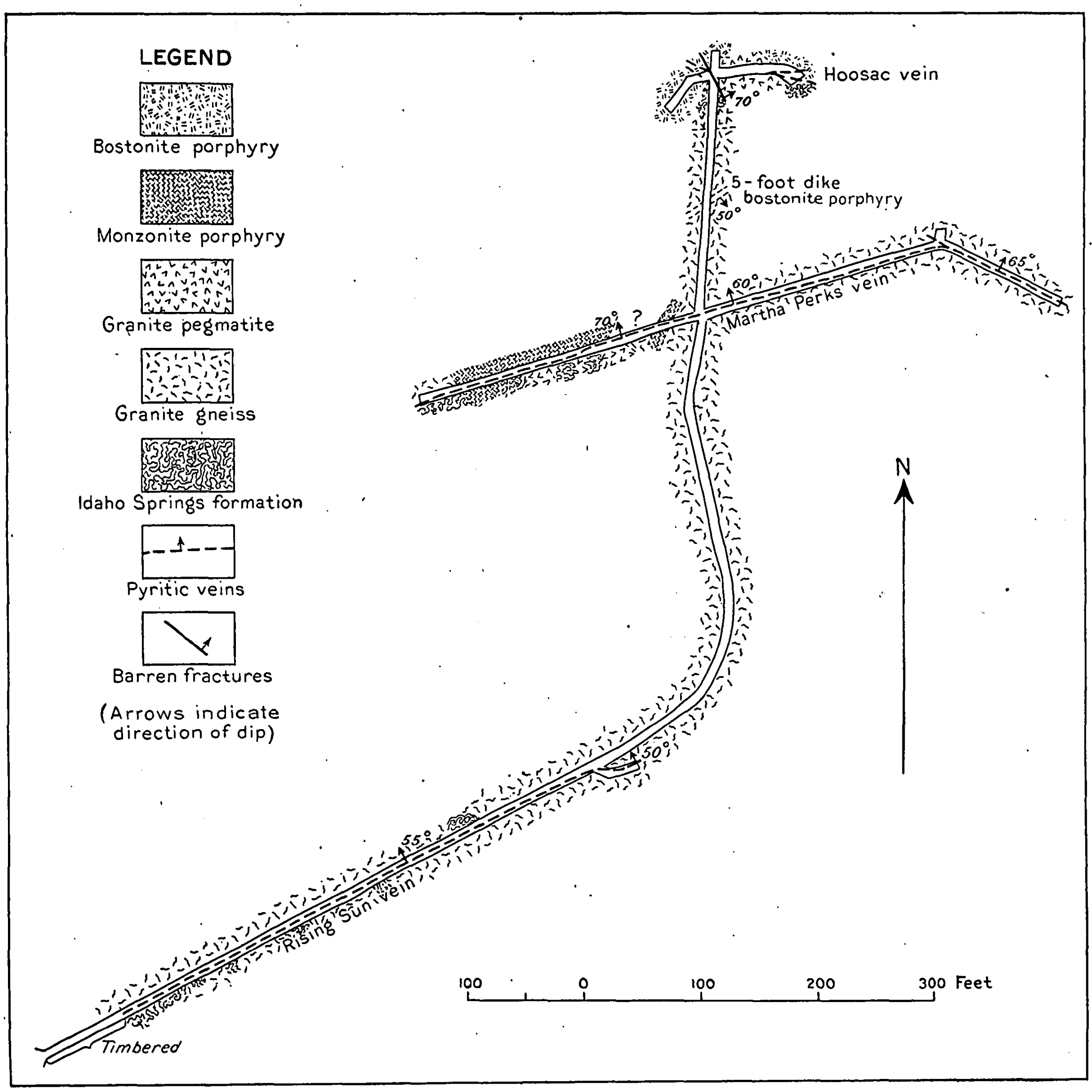


FIGURE 79.—Geologic plan of Hoosac tunnel. Surveyed by pacing and hand compass.

fragments of pegmatite in a matrix of ground the only one on which any important amount of stoping has been done.

The production of the Hoosac tunnel has been small and few details were available.

INDEX.