CONTRIBUTIONS TO ECONOMIC GEOLOGY, 1911.

PART I. METALS AND NONMETALS EXCEPT FUELS.

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INTRODUCTION.

This volume is the tenth of a series that includes Bulletins 213, 225, 260, 285, 315, 340, 380, 430, and 470, "Contributions to economic geology" for 1902, 1903, 1904, 1905, 1906 (Pt. I), 1907 (Pt. I), 1908 (Pt. I), 1909 (Pt. I), and 1910 (Pt. I), respectively. These bulletins are prepared primarily to insure prompt publication of the economic results of investigations made by the United States Geological Survey.

As the subtitle indicates, the papers included are of two classes—(1) short papers giving comparatively detailed descriptions of occurrences that have economic interest but are not of sufficient importance to warrant a more extended description; (2) preliminary reports on economic investigations the results of which are to be published later in more detailed form.

These papers are such only as have a direct economic bearing, all topics of purely scientific interest being excluded. They have been grouped according to localities or subjects treated, and each group has been issued as an advance chapter as soon as it was ready.

By means of the bibliographies accompanying the several groups of papers, these volumes also serve as a guide to the economic publications of the Survey and afford a better idea of the work which the organization is carrying on for the direct advancement of mining interests throughout the country than can readily be obtained from the more voluminous final reports.

Brief abstracts of the publications of the year are given in the annual report of the Director. The complete list of Survey publications affords, by means of finding lists of subjects and of authors, further aid in ascertaining the extent of the Survey's work in economic geology.

Since 1905 the annual economic bulletin has been printed in two parts, the second part comprising papers on mineral fuels. These volumes for 1906, 1907, 1908, 1909, and 1910 are Bulletins 316, 341, 381, 431, and 471. Bulletin 531 will form Part II of the "Contributions" for 1911.

The reports on work in Alaska have been printed in a separate series since 1904, the volumes so far issued being Bulletins 259, 284, 314, 345, 379, 442, 480, and 520.

GOLD AND SILVER.

NOTES ON THE GOLD LODES OF THE CARRVILLE DISTRICT, TRINITY COUNTY, CALIFORNIA.

By Donald Francis MacDonald.

INTRODUCTION.

In the fall of 1909, the writer spent 10 days in the Carrville district, Trinity County, Cal., and, incidental to other work, gathered some data on its mining geology. A paper on the gold gravels [1] was published, but baggage and notes were burned before anything on the geology of the gold lodes was written. In November, 1910, another visit to the district was made, but inclement weather handicapped the work somewhat. Other pressing duties have retarded the preparation of this paper. The growing economic importance of this mining district merits notice, and it is hoped that this brief report will direct attention toward it, to the end that mining in general may be benefited.

For kindly interest, assistance, and valuable data the writer is indebted to Messrs. David Goodale, of the Headlight mine; Matthew MacIlwaine, of the Dorleska; W. L. Chapmen, of the Golden Jubilee; J. H. Porter, of the Bonanza King; Jack Reid, of Windy Camp; Earnest A. Wagner, of the Wagner properties; V. B. Allen, of Allens Camp; and many others in the district. Mr. Waldemar Lindgren, chief geologist of the Survey, very kindly made microscopic examination of some rock sections for the writer, and Mr. E. R. Lloyd, also of the Survey, gave helpful criticism of this paper. Articles by Diller,[2] Hershey,[3] Hughes,[4] and Stines [5] have furnished helpful information.

Trinity County, lying in northwestern California, is a region of high mountains separated by valleys some of which support productive ranches. Its mountain slopes are clothed with a magnificent stand

[1] MacDonald, D. F., The Weaverville-Trinity Center gold gravels, Trinity County, Cal.: Bull. U. S. Geol. Survey No. 430, 1910, p. 50.

[2] Diller, J. S., The auriferous gravels of the Trinity River basin, California: Bull. U. S. Geol. Survey No. 470, 1911, pp. 11-29; The Bragdon formation: Am. Jour. Sci., 4th ser., vol. 19, 1905, pp. 379-387.

[3] Hershey, O. H., Gold-bearing lodes in California: Am. Geologist, vol. 25, 1900, pp. 76-96; Sierran valleys of the Klamath region: Jour. Geology, vol. 11, 1903, p. 155.

[4] Hughes, A. F., Stripping a vein by hydraulicking: Min. and Sci. Press, Dec. 11, 1909, p. 788.

[5] Stines, N. S., Geology of the Coffee Creek mining district: Min. and Sci. Press, July 6, 1907, p. 25.

of pine and fir except where rugged crests spotted with glittering snow rise far above the dark green of forest and valley. In winter deep snow covers the higher lands, but in summer the climate is dry, bracing, and invigorating, so that the region, especially Carrville and Coffee Creek, is attaining popularity as a summer resort.

The villages of Carrville and Trinity Center are the distributing points for the region. They are 32 miles northwest of Delta, the nearest railway station, and 56 miles northwest of Redding, the largest distributing point in the northern Sacramento Valley. A daily stage connects the villages with Delta and there is a stage and freight service to Redding by way of the mining towns of French Gulch and Old Shasta. A wagon road leads northward into Scott Valley and another one westward to Minersville and Weaverville. The Le Moine Lumber Co. has a logging railroad from Lamoine station, on the Southern Pacific Railroad, to a point within 12 miles of Trinity Center, and it is said that this road may be extended to Trinity Center or to Carrville. The divides and drainages of the area, also the chief mining locations and their relation to land subdivisions, are shown on Plate I. It will be observed that the main lines of travel and the greatest marks of human interest are along Trinity River and its chief tributary, Coffee Creek. Trinity River rises 20 miles north of Carrville, among the rugged 8,000-foot peaks of the Scott Mountains, and Coffee Creek has its source in the Salmon Mountain divide near the northwest corner of the district. Many of the large tributaries of these streams head in old glacial cirques and flow through steep rocky gorges to join the main streams far below, each in its swift descent giving ample opportunity for water power. Farm produce and fresh vegetables can be grown in the district, game and fish are plentiful, the climate is good, and the geologic conditions are very promising, so that on the whole it is a very pleasant land for the prospector.

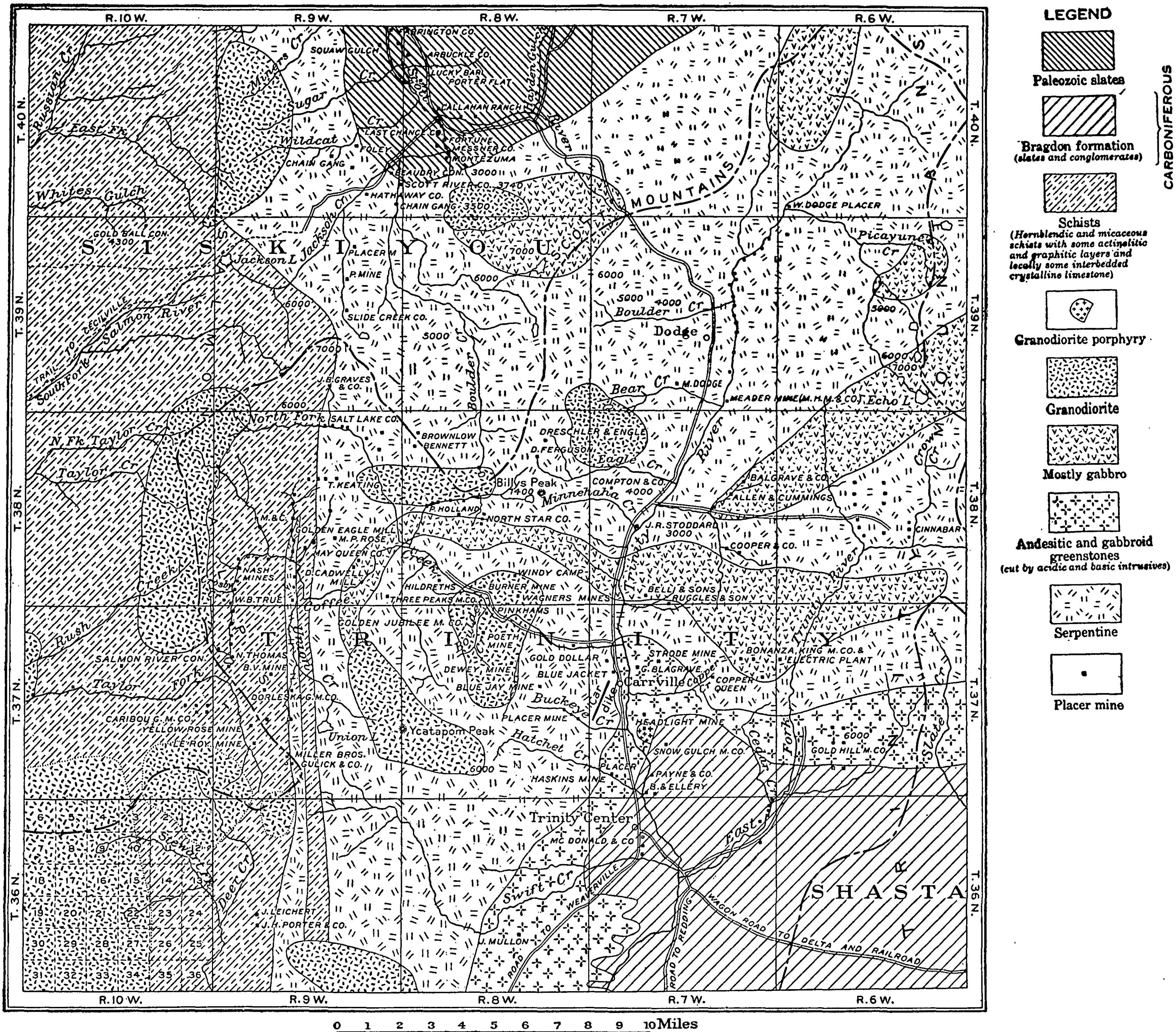
GEOLOGY.

The region has a complex geologic history. For detailed information regarding its geology and that of the surrounding country the reader is referred to the papers by Diller and Hershey already cited. Briefly, the rocks consist of (1) a schist series, (2) a complex of greenstones, (3) wide areas of serpentines, (4) a slate-conglomerate series, (5) granitic batholiths, and (6) basic dikes. The distribution of these rocks is shown in outline on Plate I.

SEDIMENTARY ROCKS.

The oldest rocks, the schist series, occur in the western part of the area, mostly west of a north-south line drawn along the axis of the Union Creek valley. Hershey[1] has divided this schist series into

[1] Hershey, O. H., Am. Geologist, vol. 27, No. 4, pp. 225-245.



MAP OF PORTIONS OF TRINITY AND SISKIYOU COUNTIES, CAL., SHOWING APPROXIMATELY THE CHIEF MINING LOCATIONS AND THE SURFACE GEOLOGY.

Compiled from notes, Land Office plats, and a manuscript sketch map furnished by Mr. M. MacIlwaine, of Dorleska. The geologic data were obtained in part in the field and in part from a manuscript geologic map of Trinity County, made by Mr. O. H. Hershey, dated January 16, 1901, and kindly loaned the writer by Mr. J. S. Diller, of the Survey. (See Diller, J. S., Klamath Mountain section, California: Am. Jour. Sci., 4th ser., vol. 15, 1903, pp. 342–362.)

(a) the Abrams formation, a grayish muscovite schist containing irregular bands of white quartzose material and locally some thin layers of blue and white crystalline limestone, and (b) the Salmon formation, a hornblende schist locally showing graphitic and actinolitic layers and some highly crystallized limestone lenses. These schists are considerably sheared and contorted and seem to represent highly metamorphosed sediments which Hershey thinks may probably be of Algonkian age.

A slate-conglomerate series occurs in the southeast corner of the area. It is the Bragdon formation of Hershey and of Diller,[1] and is probably of early Carboniferous (Mississippian) age. It consists of fine-grained dark to dark-gray slates with some beds of sandstone and conglomerate. This formation extends from about Trinity River on the west to the Southern Pacific Railroad on the east. Its northern boundary is approximately an east-west line through Carrville, from which it extends southward beyond French Gulch. It contains the gold deposits of French Gulch and Deadwood and those in the vicinity of Minersville.

IGNEOUS ROCKS.

The oldest igneous rocks are a complex of andesites and gabbros of several distinct types but all so intimately associated with one another that it was impossible to differentiate them in the short time of the writer's visit. This greenstone complex presents puzzling problems in crystallization, for within an area of a few hundred square yards may be found rocks which vary in texture and composition from very fine grained andesites to very coarse grained gabbros. These greenstones outcrop as a fringe half a mile to a few miles wide bordering the Bragdon formation. The part of this fringe between Minersville and Trinity Center lies west of Trinity River. North of Trinity Center it crosses to the east side of the river and extends north as far as the mouth of Coffee Creek. The rock is locally ore bearing.

Next younger are the intrusive acidic rocks. These occur not only in small masses and dikes but also in large masses up to several miles in diameter, cutting schists, greenstones, and locally slates. These masses consist mostly of coarse-textured light-gray granodiorite, locally called granite. Microscopically the rock is granular and contains quartz, feldspar, flakes of biotite, and large grains or rough prisms of hornblende, with local variation in the relative amounts of the last two minerals. The feldspars are plagioclase (andesine) in well-developed and roughly prismatic grains, in a cementing mass of orthoclase and quartz. The quartz content varies locally. Magnetite and apatite are present as accessory minerals, and secondary alteration has produced some sericite and epidote. These rocks contain important ore bodies.

[1] Diller, J. S., Am. Jour. Sci., 4th ser., vol. 19, 1905, pp. 379-387.

Another important intrusion of acidic rock is the granodiorite porphyry,[1] locally called "Headlight porphyry," which cuts the greenstones in large irregular dikes and branching masses. It has a marked porphyritic or "bird's eye" texture and is associated with the Headlight, Blue Jacket, Gold Dollar, Strode, and other ore deposits. No definite relation has been established between these dikes and the large granodiorite masses a few miles to the north, but they are thought to be offshoots from the same magmatic mass. Microscopically this porphyry shows an abundance of large, well-defined andesine crystals; large quartz grains, some of which are rounded, corroded, and fractured; variable amounts of prismatic hornblende; and flakes of biotite. The groundmass is microgranular to granular and consists of quartz, orthoclase, plagioclase, accessory pyrite, and magnetite, and a little secondary chlorite and needles of uralitic hornblende. Hydrothermal action has produced calcite, sericite, and a little epidote. A considerable variation in texture and composition characterize this rock. Locally hornblende prisms are conspicuous, especially near the center of the mass, but near the contacts biotite flakes are much in evidence and very little hornblende occurs. Quartz seems to be more plentiful where the hornblende is scarce. It was thought at first that there were two distinct intrusions, one rich in biotite and the other in hornblende, but subsequent work failed to establish this, so the variation is thought to be the result of magmatic differentiation.

Certain dikes and masses, intimately associated with this porphyry, are comparatively rich in quartz and nearly barren of ferromagnesian minerals. These are believed to represent aplitic dike phases, though they are in the main much larger, less rich in quartz, and less clear cut than most aplitic dikes. They are not known to have any special mineralizing significance.

The large serpentine areas of the region are thought to be altered peridotite intrusions. Near the Lily of the Valley tunnel serpentine dikes branching from the main mass cut the granodiorite, showing that they are later than the granitic rocks. The boundaries between the granodiorite and serpentine where observed are zones of shearing. The mineralizing influence of the serpentine is shown at the Copper Queen mine, where it has favored the precipitation of copper sulphides. It was intruded in latest Jurassic or earliest Cretaceous time.

Basaltic dikes are very important, especially where they cut the porphyritic rocks, for there they are generally "ore makers." They are conspicuously fine grained and dark green in color and, like the

[1] This rock is probably the same as that described as dacite porphyry by Iddings (Bull. U. S. Geol. Survey No. 150, 1898, p. 233) and Diller (Redding folio (No. 138), Geol. Atlas U. S., U. S. Geol. Survey, 1906).

serpentine and gabbro rocks, form a red soil. Locally they contain finely divided pyrite and some secondary quartz. Under the microscope they show lime-soda feldspars, much chloritized augite, a few magnetite grains, and some uralite and zoisite. Where the dikes dip at low angles, as at the Headlight and Copper Queen properties, the upper parts have been replaced. This indicates that downward-moving solutions found them relatively impervious and characterized by chemical affinity for certain dissolved substances, causing the solutions to part with several of these substances, depositing gold; pyrite, and quartz, and taking in exchange some nonmetallic dike material. Such a phenomenon is known as replacement or substitution.

Lamprophyre dikes are numerous in the district. Those in the granodiorite have about the composition of vogesite and have in general a northeast-southwest trend. The amounts of hornblende and biotite vary so that the dikes range in composition from camptonite to kersantite. A large lamprophyre dike outcropping at the Dorleska and Yellow Rose mines has on one side about the composition of camptonite and shows aggregates of hornblende needles with some suggestion of radial grouping, hence the local name "crow's-foot porphyry;" on the other side the ferromagnesian mineral is, in the main, biotite, so that the rock is a kersantite, grading into vogesite. Microscopically many of these dike rocks show long prisms of greenish hornblende and some biotite in a fine granular mass consisting of orthoclase, plagioclase, a little quartz, some augite altered into green hornblende, accessory magnetite, and some secondary sericite and epidote. These rocks have a direct relation to at least two ore deposits, the Dorleska and the Yellow Rose.

With the intrusion of the lamprophyre dikes the igneous history of the district seems to have closed, but not the earth movements; their later activity is recorded in numerous faults and shear zones. Most of the shear zones that were observed trend about N. 30° E. Some of them are mineralized and are of considerable value to the prospector in locating ore deposits.

In summary, then, we find that the Carboniferous slates were probably deposited on an old eroded greenstone surface and that both were later cut by granitic intrusions. It is interesting to note that in the cycle of igneous activity the great masses of acidic rocks were formed after a period of far more basic greenstone eruptions had closed. These acidic granodiorites were followed by the extremely basic peridotites from which the serpentine was derived, and these again by the slightly more acidic lamprophyre dikes. The acidic intrusions are a notable factor in the geologic story of this region, and around them are grouped the phenomena of primary mineralization.

The intrusions of granodiorite probably occurred in the same general epoch as those of the Sierra Nevada—that is, in the earliest Cretaceous or latest Jurassic.

ORE DEPOSITS.

TYPES OF DEPOSIT.

The ore deposits of this district are characterized by variety of form. Though nearly all have the general unity of being gold lodes, yet they may be arranged into five separate groups, or types, each distinct from the others, and the members within each group having a strong resemblance to one another. These types are (1) the Headlight type, (2) the Golden Jubilee type, (3) the Dorleska and Yellow Rose type, (4) the Strode and Bonanza King type, and (5) the Blue Jay type.

The Headlight type, so called because best exemplified in the Headlight deposit, is at present most important. The country rock is the greenstone complex cut by large irregular dikes of granodiorite porphyry, basalt, and lamprophyre. The ores occur as a replacement of basaltic and other basic dikes where they cut or are closely associated with the porphyritic masses. The ore is, in the main, highly oxidized and sheared, and its value is generally not over $7 a ton except where there are small rich pockets. The mineralization locally extends a short distance into the porphyry in more or less irregular form, and where the dikes lie at a low angle the replacement seems to have been most active on their upper sides. Small amounts of pyrite and some chalcopyrite are present in the less sheared and therefore less oxidized parts, but not in sufficient quantity to interfere with cyanidation of the ores. Because of their occurrence in large, more or less sheared masses, these ores are cheaply mined and milled. The Headlight is the best example of the type, but there are other deposits which, though they may vary somewhat in form, yet have the same general class of ore and are characterized by similar geologic conditions. These are the Blue Jacket, the Gold Dollar, Carr's iron-capped dike, and some of the Ramshorn properties. A subgroup under this heading consists of the Copper Queen and True Blue deposits, which are similar to the Headlight in form and may be on a continuation of the Headlight lode. They differ from that deposit, however, in that they are not closely associated with "bird's eye" porphyry and in that the Copper Queen lode is partly in a large serpentine mass which seems to have favored the deposition of copper minerals. The irregular form of this type of deposit and the soil mantle which commonly obscures the outcrops render it difficult for the prospector to get a correct idea of the probable limits of his lode; hence development work is often improperly planned.

The Golden Jubilee type of deposit is very important and distinctive. It consists of fissure veins and narrow well-defined shear zones in granodiorite, close to the northwestern edge of a very large granitic intrusion. These veins nearly all trend N. 30° E. and are paralleled by many and cut by a few small lamprophyre dikes. It is not uncommon for one of the vein walls to be formed by a small lamprophyre dike, and it is said that in the vicinity of such contacts values are higher than elsewhere. The lodes of this type vary in width from a few inches to a few feet and contain some locally enlarged ore shoots, especially at fissure intersections. It is noteworthy that the granodiorite near these deposits is in contact with a large mass of younger serpentine, that this contact is at right angles to the trend of the veins, and that as distance from the contact increases the veins are on the whole, larger and the values less. Near the contact they are smaller, more numerous, richer, and more pockety. Oxidation is confined to a comparatively shallow zone, except where it has followed postmineral shear planes to maximum depths of about 200 feet. The gold is associated with iron oxide and pyrite, and tellurides are not uncommon. The ore varies in richness and high-grade pockets are found, especially in the shear-zone type of these deposits. Calcite was observed with the quartz and crushed country rock, and the sulphides and tellurides present render the ore less amenable to treatment than the more oxidized Headlight material. Crushing and amalgamation to recover coarse gold, with concentration and cyanidation of tailings and slimes, has so far proved the most satisfactory treatment. The concentrates are hauled by wagon to the railroad and sent to the smelter. They are, in the main, high enough in grade to pay a good profit in spite of the cost of mining and marketing, which averages over $40 a ton. These deposits, which are best exemplified by the Golden Jubilee mine and the group of properties near it, present simpler problems for the prospector than those of the more complex Headlight type.

The Dorleska and Yellow Rose type of lode, best illustrated by the Dorleska and Yellow Rose mines, includes also the Thomas Keating and other smaller properties. It comprises mineralized shear zones in and along the contacts of large lamprophyre dikes, where these dikes cut serpentinized basic rocks. These lodes are partly direct deposits in shear planes and partly a widening out of such planes by replacement processes, especially where side fissures come in. They are more or less pockety and contain some shoots of very rich ore. Tellurides are reported and in the main the ores are similar to and require about the same treatment as those of the Golden Jubilee group, but a larger percentage of the gold content could probably be recovered by crushing and amalgamation.

The Strode and Bonanza King type is best exemplified by the deposits at these two mines. They are essentially sheared fissures veins which cut the greenstone complex, have locally enlarged ore shoots, and may have small parallel and branching stringers. Lamprophyre dikes occur in their vicinity, and at the Strode property, at least, a large mass of granodiorite porphyry outcrops near by. The values in the ore shoots are, in the main, fairly high and are recovered by crushing and amalgamation at both properties, supplemented by cyanidation of tailings and slimes at the Bonanza King. These deposits are fairly clear cut and comparatively easily followed by the prospector.

The fifth type of lode, the Blue Jay, is best represented by the Blue Jay property, which is especially famous for its rich pockets. It is characterized by the irregular shearing and fissuring of a large mineralized dike or elongated mass of fine-grained dark-greenish metabasalt and of small associated masses of granodiorite porphyry, all of which cut a country rock of greenstone and serpentine. Time to make a study of mineralizing conditions was not available, but primary mineralization seems to have left finely divided pyrite in the dike mass, and some rich pockets have accumulated where shear zones and fissures cut the mineralized areas of the dike. The great bulk of the dike mass outside of these narrow fissures is of too low grade to mill.

HYDROTHERMAL ACTION.

Hydrothermal alteration is not especially marked in this district. In the country rock near the veins, however, as well as in the veins, small amounts of secondary quartz and calcite have been deposited and the feldspars have undergone some sericitization. In the more sheared lodes alteration seems to have gone beyond the sericitization stage and formed considerable kaolin. The ferromagnesian minerals have been considerably altered near the deposits, especially in the basaltic dikes, where so much chlorite has been developed as to give the rocks a greenish color. In some of the rocks chlorite and quartz occupy the place of disintegrated feldspar crystals; there is some uralite, mostly after pyroxene, and small amounts of epidote and zoisite. A thin section of replaced dike material from the Headlight mine showed extreme alteration. This material consisted in the main of aggregates of crushed quartz and grains, veinlets, and streaks of pyrite. Sericite was extensively developed and probably some kaolin occurs, but practically no calcite, although secondary calcite was seen in the porphyry near the lode. The original character of the rock was almost completely masked and most of the larger grains of quartz were crushed and deformed. A thin section of wall rock from an ore shoot in the Strode mine showed a crushed and roughly schistose structure. It was semiopaque from the kaolin present and showed lenses of crushed quartzitic fragments, veinlets of calcite, and small scattered cubes of pyrite.

The large areas of serpentine are alteration products from basic igneous rocks, and the so-called "iron caps" and "iron dikes" are the result of oxidation or "rusting" by surface waters carrying atmospheric oxygen downward along cracks and fissures. Similar oxidizing processes work on the dark iron silicates and where these are plentiful, as in the darker rocks, weathering into red soil results. Dark-brown powder or almost black stains in the oxidized ore indicate the presence of manganese oxide, which is usually a favorable indication of values.

SUMMARY OF THE CHIEF MINERALS OF THE DISTRICT.

Gold.—Gold occurs in quartz, in pyrite, in the oxidized products of pyrite, in mineralized pockets of country rock as irregular grains and threads, and in the form of tellurides. A considerable proportion of the free gold is coarse enough to see and amalgamates readily, but much of it is so fine as to be invisible and can be recovered only by cyanidation.

Silver.—Silver occurs in very small amount, probably in alloy with gold.

Pyrite.—Pyrite is present in small primary crystals disseminated through dike material and country rock, in primary form in most of the unoxidized ores, and in local masses and kernels in partly oxidized ore, where it suggests secondary enrichment.

Chalcopyrite.—Chalcopyrite is the primary ore of the Copper Queen and is present in small quantity, where not reached by oxidation, in the Headlight and other mines.

Chalcocite.—Chalcocite, the dark sulphide of copper which has locally enriched the upper part of the Copper Queen lode, is a secondary mineral derived from chalcopyrite.

Copper carbonate.—The bright-green mineral, copper carbonate, is sparingly present in the weathered portion of the Copper Queen.

Limonite.—The iron oxide or iron rust which stains much of the ore near the surface and near crushed zones is limonite. Large cubes of it, after pyrite, occur in the Golden Jubilee and contain high gold values. Locally it cements together brecciated fragments of rock.

Manganese oxide.—The dark-brown powder or stain commonly associated with iron oxide and in places with rich pockets of ore is manganese oxide.

Quartz.—Quartz is present in original grains and crystals in the porphyry, the granodiorite, and most of the lamprophyre dikes, as a replacement product in some of the dikes and as vein-filling material.

Feldspar.—Andesine occurs in phenocrysts in the porphyry and in fairly well defined crystals in most of the other igneous rocks. Orthoclase occurs in the groundmass of the porphyry and among the smaller generation of crystals in the granodiorite and some of the lamprophyres. No clear case of secondary feldspar was noted.

Chlorite.—Chlorite is abundant in all the basaltic dikes and tinges them green. It is present to some extent in most of the igneous rocks near lodes and is a secondary mineral.

Magnetite.—Magnetite occurs in minute grains in many of the igneous rocks; also in small secondary grains derived from the alteration of ferromagnesian minerals.

Calcite.—Veinlets and small irregular masses of calcite occur in many of the ore deposits, and calcite is disseminated in small amounts through some of the country rock near them.

Sericite.—Minute foils and shreds of sericite replace feldspar and invade quartz grains in or near the ore bodies.

Kaolin.—In small local areas of ore and country rock the feldspars have been reduced to white powdery kaolin.

Uralite.—Uralitic pyroxene and hornblende were found in small amounts.

Epidote and zoisite.—Locally some epidote and zoisite were observed, especially in some of the basic rocks near the ore deposits.

NOTES ON PROSPECTING.

With the decline of placer mining the early prospector turned from gravel bars and benches to find the source of the gold among the mountains. He believed that the gold came from fissure veins and that all deposits worth while were of the fissure-vein type. His development work was therefore planned in terms of hanging wall and footwall, and where these did not occur he selected the nearest fissure or joint plane and called it a wall bounding his deposit. Thoughts of limiting depths to his valuable ore rarely darkened the fair horizon of his dreams. That these "fissure vein" ideas filtered down even to some of the present generation of mining men is shown by at least one case in this district. A few years ago a company got an option on a property which showed a good outcrop and spent many thousands of dollars driving tunnels to tap the deposit at depth. The "fissure vein" in this instance happened to be a large, almost flat contact deposit, and the expensive tunnels were in the country rock well below it. The property was "turned down," of course, and the district pronounced poor, but to-day that property is paying a rich reward to more discriminating and more scientific miners.

The outcrops of the district are in part prominent and in part inconspicuous. The prominent croppings are "iron-capped" dikes and lodes rendered more resistant than the surrounding rock by the quartz which they contain. The lodes of the Headlight type and other lodes filled with hard quartz are characteristic and are usually of rather low grade at the surface. On the other hand, the outcrops of the lodes that have undergone shearing since deposition are inconspicuous and can be recognized at the surface only by careful search. Ordinarily such lodes may be traced on the surface by panning. In hunting for these veins little gulches and gullies should be panned and any values obtained should be traced up to their source. Mineralized quartz float is also most likely to appear in streams below a lode and may be found in the wash up to the point where the stream crosses the vein. In answer to the question, Where is the most likely place to prospect? the following may be said: The contacts of all "bird's eye" porphyry outcrops should be searched by the prospector, especially where this porphyry is cut by dikes of dark-green fine-grained rocks. The outer zone of all granite areas should be examined, and all large dikes of the Dorleska type are worthy of close search. The region between the Headlight and the Copper Queen properties should be carefully prospected for a continuation of the Headlight mineralized dike. Mineralization similar to that at the Headlight continues to the southwest of that mine. When a location is made the prospector should find out what type of deposit he has, in order to plan development work to the best advantage. Of course he can not figure on ore values until ore has actually been developed on three sides and carefully averaged samples across his ore body at 5 or 10 foot intervals have been taken. From the average assay value of these samples, occasional assays which run far above the general average having been rejected, he can estimate the gross value of his ore block. Before the net value of his "ore in sight" can be estimated, the prospector needs to know what process will give best and most economical extraction. This knowledge should be obtained by sending samples of both oxidized and sulphide ores to reliable ore-testing plants and having reports made on them. Oxidized ores such as those of the Headlight and ores that are nearly free of copper and contain little pyrite will ordinarily be found suitable for cyanidation. The telluride and sulphide ores, such as most of those in the granodiorite area, will probably be best treated by crushing and amalgamation to recover the coarse gold, concentration, and then cyanidation of tailings and slimes. It is of the highest importance, however, that every ore be tested before any plan of treatment is adopted. Where pyrite and chalcopyrite are present in large amount, pyritic smelting might be adopted, as such an operation requires but a small percentage of coke, the heat being furnished largely by oxidation of the sulphides. If the process to be used will extract 85 per cent of the gold, then the remaining 15 per cent which can not be recovered must be deducted from the gross value of the ore in sight. Other charges to be deducted are costs of mining and milling, costs of marketing bullion and concentrates, 10 to 12 per cent of the value of the plant for yearly depreciation, interest on capital tied up in the venture, etc. These items pertain to the business end of developing a property but constitute a phase of mining which the up-to-date prospector should know and which is clearly explained in detail by several comparatively new and valuable technical books on mining advertised in the leading mining journals.

PAST OUTPUT AND FUTURE PROSPECTS.

It is very difficult to get at the total output of the quartz mines of the district. From opinions obtained from different persons, each knowing something of some of the properties, it is estimated that the production has been close to a million dollars. The production of the county since 1890 is given below:

Production of gold and silver in Trinity County, Cal., 1890 to 1904.

[From reports of the Director of the Mint.]

Year.	Gold and silver.		Total silver.	Total gold.	Total gold and silver.
	Placers.	Lode mines.			
1890			$258	$1,192,789	$1,193,047
1891			2,248	1,327,786	1,330,034
1892			168	1,446,603	1,446,771
1893				1,122,994	1,122,994
1894			1,072	1,012,665	1,013,737
1895			257	1,166,745	1,167,002
1896				1,296,330	1,296,330
1897	$722,858	$355,773	259	1,078,372	1,078,631
1898	578,514	281,055	314	859,255	859,569
1899	371,943	219,653	1,086	590,510	591,596
1900	324,233	263,939	16,567	571,605	588,172
1901	327,114	360,237	2,668	684,683	687,351
1902	389,757	330,785	550	719,992	720,542
1903	333,471	275,342	2,085	606,728	608,813
1904	364,068	210,881	135	574,814	574,949
	3,411,958	2,297,665	27,667	4,251,871	4,279,538

Production of gold and silver in Trinity County, Cal., from 1905 to 1910.

[From Mineral Resources of the United States.]

Year.	Gold (value).			Silver (fine ounces).		
	Lode mines.	Placer.	Total.	Lode mines.	Placer.	Total.
1905	$351,826	$424,209	$776,035	3,759	2,218	5,977
1906	147,164	413,679	560,843	1,881	2,584	4,465
1907	180,120	355,196	535,316	1,271	2,364	3,635
1908	185,634	417,310	602,944	4,057	3,998	8,055
1909	151,782	368,264	520,046	2,144	2,283	4,427
1910	126,768	374,083	500,851	2,037	1,592	3,629
	1,143,294	2,352,741	3,496,035	15,149	15,039	30,188

The future prospects of the district are believed to be very good and it is thought that before long several small to moderate-sized gold properties will be put on a paying basis. Of course a branch railroad connecting with the Southern Pacific Railroad would greatly benefit the district. Such a railroad would derive income not only from the quartz and placer mining interests but from the rich agricultural lands in the valley bottoms and from the lumber business. It is true that much of the timber is within the Trinity National Forest, but the ripe product is sold off at intervals and this together with the timber from private holdings makes the lumbering industry important.

DESCRIPTION OF MINES.

HEADLIGHT TYPE.

HEADLIGHT MINE.

Situation and geologic relations.—The Headlight is the youngest producer and at present the most important mine in the district. It is 3 miles north of Trinity Center and 1½ miles southeast of Carrville, the nearest post office. The present workings are in the NW. ¼ sec. 21, T. 37 N., R. 7 W., on the eastern slope of the Trinity Valley 600 feet above Trinity River. The property is owned by the Trinity Gold Mining & Reduction Co.

The geology of the mine is complicated, but figures 1, 2, and 3 show the general geologic relations. Soil covering and hydrothermal action have obscured the details, hence some modifications of the views here expressed may be necessary as development work affords new data. The rocks in the sequence of their age are andesitic greenstones, slates, granodiorite porphyry or "bird's eye" porphyry, fine-grained greenish basaltic dikes, and lamprophyre dikes of about the composition of vogesite. These rocks have already been described, but it may be noted here that the porphyry intrusion cuts andesitic greenstones, is several hundred yards in diameter, has obscure boundaries, shows a hornblendic and a biotitic facies, and is cut by lamprophyre dikes and by ore-bearing greenish metabasaltic dikes.

Ore deposit.—The Headlight has a conspicuous "iron-capped" outcrop. In form the lode is a large, comparatively flat-lying body, 40 feet thick and having a surface exposure of 2.1 acres. (See fig. 1.) The ores are of low grade, averaging about $6 a ton, and the values are fairly evenly distributed. Faulting has largely broken up the mass, making it more irregular and giving ready access to oxidizing surface waters. This ore body might be put in the category of contact deposits, for it occurs where a basaltic dike cuts porphyry; it is of the replacement type, because it largely replaces the basaltic dike and the adjacent porphyry. It is thought that no mineralization exists where the dike passes into the slates, although there is no definite evidence of this. Also it is not known whether the dike at the left-hand end of figure 2 is a faulted-down portion of the dike in which the main body of ore occurs, or another similar intrusion. The evidence of slip faulting, as shown in figure 2, as well as the iron-stained mineralized character of the dike, points toward the former of these alternatives. Near the dry gulch southwest of the mine iron oxide and considerable secondary quartz mark the outcrop of this dike, at intervals, for several hundred feet. This corner of the property looks favorable for new ore bodies, and it is likely that the company will shortly begin systematic prospecting here. Extension of the lode toward the northwest may also be revealed by further development.

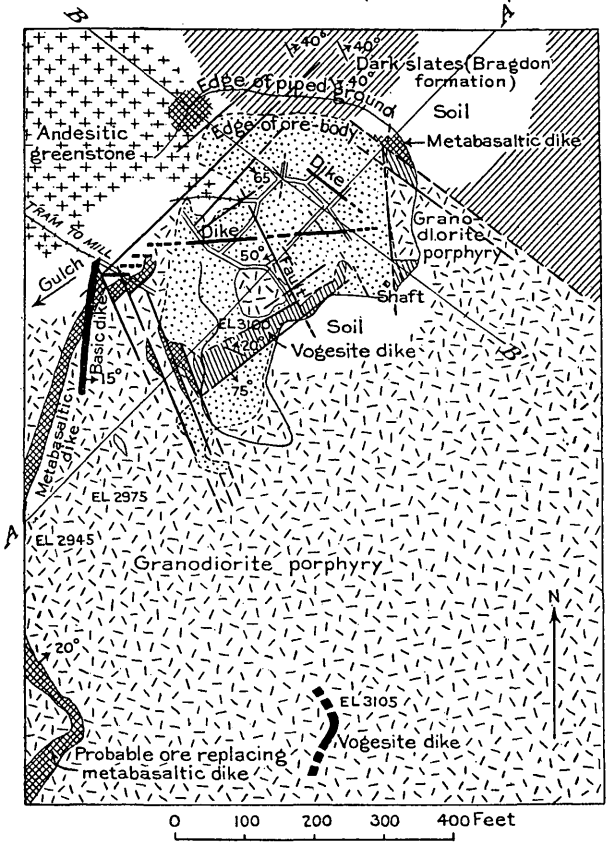


FIGURE 1.—Sketch map showing geologic relations of Headlight ore body, Trinity County, Cal. *A-A'*, *B-B'*, lines of sections, figures 2 and 3.

The ore contains free gold with a little silver and is in the main oxidized and much iron stained, except where a few kernels and small areas of pyrite with some chalcopyrite have not yet been altered. The gold is finely divided and is easily recovered by cyanidation. The gangue materials are quartz, partly replaced country rock, iron oxide in considerable quantity, and small amounts of calcite and manganese oxide.

The genetic history of this deposit is not clear in all its stages, but the following is a summary of the chief facts pertaining to it: (*a*) It occurs as a replacement deposit in a basaltic dike where this dike cuts a larger dike of granodiorite porphyry, in a country rock of andesitic greenstones, which is in contact with slate. The whole complex is cut by lamprophyre dikes. (*b*) Remnants of the bottom part of the ore dike remain unmineralized and these have undergone some shearing parallel to the dike. This is evidence that descending solutions effected at least the final mineralization. (*c*) The ore dike is best mineralized near its contact with the vogesite dikes, although the latter are not mineralized except along local shear zones. It is believed that the vogesite dikes played little part in the mineralization except that, being more impervious than the rocks which they cut, they somewhat obstructed and deflected the mineralizing solutions. Though no conclusive evidence on the matter was found, it is thought that the basaltic dikes were planes of weakness which yielded to shearing and thus afforded easy access to the acidic mineralizing solutions from the granite porphyry.

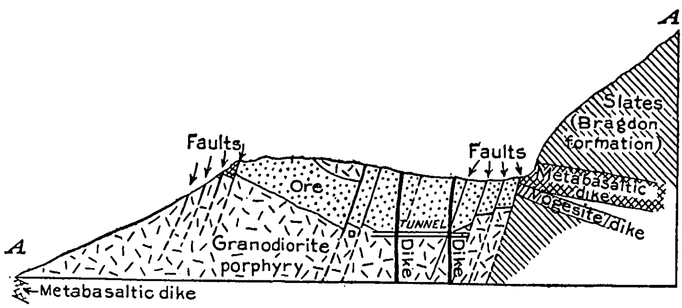


FIGURE 2.—Northeast-southwest section through Headlight ore body, along line *A-A'*, figure 1.

Mining.—The conditions as regards timber, water power, and topography are exceptionally favorable near the mine. The extent of the work, both in underground development and in the area of overburden removed, is shown in figure 1. Since the time of visit, however, much more has been accomplished. The work is carried on from two levels, the upper, more extensive one immediately beneath the main body of the ore, and the other 50 feet lower, beneath a faulted-down corner of the ore mass.

The methods of mining and development work are worth careful study. It is noteworthy that instead of trying to find the limits of the outcrop by shaft sinking and open trenching, Mr. Goodale used a small giant with a 2½-inch nozzle, under a head pressure of about 350 feet, to remove the overburden and lay bare the ore body.[1] This method was aided by blasting simultaneously sets of eight to ten 6-foot holes, placed 7 feet apart. It was very successful and removed overburden at a cost of less than 2 cents a cubic yard. The broad, flat form of the lode made the work of maximum importance.

[1] Hughes, A. F., Stripping a vein by hydraulicking: Min. and Sci. Press, Dec. 11, 1909, p. 788.

This deposit is worked by a system of tunnels immediately below the ore body, from which upraises extend through the ore to the surface. Beginning at the top these upraises are enlarged and caved into the shaft to form a system of "glory holes." The sheared and oxidized condition of the ore causes a minimum expense for drilling, caving, and milling. From the upper level the ore is trammed to a chute and ore bin leading to the lower level, and thence it drops into 6-ton cars which bring it to the ore bins at the mill a few hundred yards distant.

Milling.—The ore is treated in a new 10-stamp mill which crushes it in a cyanide solution, and in a cyanide plant with a capacity of 200 tons of sands and slimes each day.

Power.—The company owns its own hydro-electric plant, which is located in the Trinity Valley nearly 2 miles north of the mine. A 3 by 4 foot flume 9,000 feet long brings a maximum flow of 3,000 cubic feet a minute from Coffee Creek and delivers it under a head pressure of 107 feet. The plant is designed to generate a maximum of 470 horsepower, which is amply sufficient for power and lighting at the mine, mill, and sawmill.

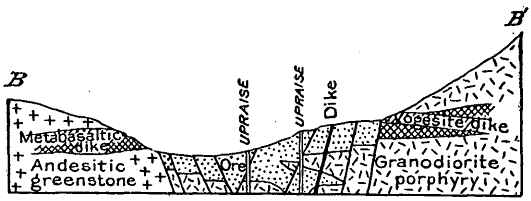


FIGURE 3.—Northwest-southeast section through Headlight ore body, along line *B–B'*, figure 1.

Costs.—The costs established at this mine are important as a basis of comparison for other properties. Conditions are more favorable than at other mines of the district, still the practice successfully established here will be of great benefit to mining men wishing to estimate the cost of developing other properties. Wagon haulage from Delta, 32 miles, costs 1 cent to 1¼ cents a pound; from Redding, 56 miles, 1¼ to 1½ cents a pound. The estimated cost of mining by the glory-hole method is 40 cents a ton; of tramming, 10 cents a ton. The cost of milling the present daily average of 225 tons is, for labor, $33; chemist, $4; cyanide, $103.50; lime, $23; power, $9; zinc, $10.75; filtering, $4; miscellaneous, $10; depreciation of milling plant at 10 per cent a year, $34.50; total, $231.75, or $1.03 a ton. The actual milling costs since the mill was opened have been found to range between 85 cents and $1.05 a ton, depending on local variations in the consumption of cyanide. Electric power, which when purchased usually costs $6 a horsepower a month, costs here only $1, the hydro-electric power plant being installed by the company. The high freight rates, however, $20 a ton on cyanide, lime, and mill supplies, go far to offset the low cost of power. The cost of cyanide here is 23 cents a pound and the average consumption is 2 pounds to the ton of ore. The total cost, then, for mining, tramming, and milling this ore is about $1.53 a ton. In figuring the net value of the ore in sight, a 90 per cent extraction was allowed, though in practice it is lower than this; also, 10 per cent off per year was allowed for depreciation of plant and 10 per cent interest on the capital locked up in the development of the property. Other general items of cost are 9,000 feet of 3 by 4 foot flume; lumber, $4,834.50; cost of building, $3,933.50; cost of grading, trestles, and foundations, $3,601; water wheels, generators, and power house, complete, $12,000; power line, 9,000 feet long, $1,292; head gate, concrete, penstock, turnouts, etc., $1,500; substation transformers and equipment, $2,827.50; total cost of hydro-electric power plant, about $30,000; total cost of mill and power plant, $156,000.

History.—The property was first opened by Frank Fletcher and his associates in 1900. They erected a cyanide plant for wet crushing and direct treatment, but over 50 per cent of slimes were produced in their mill and, as no provision had been made for treating these, the venture was not successful. The slimes are said to have contained $7 to $11 a ton; the sands averaged $4.80, making an average of $6 a ton for the ore. Later the plant burned and the owners let the property stand idle. In 1907 a Philadelphia company spent considerable money in development, but the work did not reveal the extent and value of the ore body. During the money crisis of the fall of 1907 the property reverted to the owners. The present company took hold about the beginning of 1909 and has turned this low-grade property into a prosperous mine.

Production and future prospects.—The old mill is thought to have turned out about $5,000 before it was destroyed, and the new mill was only starting at the time of visit. The ore now in sight is said to be sufficient to keep the plant running for several years.

BLUE JACKET PROPERTY.

Introduction and geology.—The Blue Jacket property, owned by the Adams Exploration Co., is about one-fourth of a mile northwest of Carrville and consists of four claims and a mill site. Figure 4 shows something of the complicated geologic conditions. The mapping of the boundaries, except those in the underground workings, is not necessarily exact, because the outcrops are much obscured by soil, weathering, and hydrothermal action. The rocks in the order of their age are andesitic greenstones, granodiorite porphyry or "bird's eye" porphyry, aplite, serpentine, and a few small green metabasaltic lamprophyre dikes. These rocks have already been described, but it may be added that the aplitic material here is cream colored, is hydrothermally altered, and contains quartz, probably largely secondary, in small irregular aggregates, little veinlets, and larger veins. Green basaltic dikes and lamprophyre dikes are numerous and vary from less than an inch to a few feet in width.

Ore deposits.—The mineralization is associated with the sheared and hydrothermally altered parts of the diorite porphyry and aplitic rock. It is said that the contacts of the basaltic dikes and some of the lamprophyre dikes with these rocks, especially where these contacts are sheared, carry high values. A 2½-foot quartz vein cuts the porphyry and aplite (see fig. 4), trends northeast approximately parallel with the dike system in tunnel *a*, and dips steeply northwest. The vein contains ore of very low grade, but it is said that gold occurs in the gouge locally formed along its sides. So far no well-defined ore body has been developed, but the mineralization of the porphyritic and aplitic rocks has geologic significance as well as prospecting value.

At the time of visit exploration work was going on and pannings from the little shear zones and gouge streaks in the "rotten porphyry" showed colors. The important question, however, is how large a mass of this fractured and hydrothermally altered porphyry will be rich enough to pay to mine. The deposit is not of a vein type but seems to consist in an impregnation of the hydrothermally altered porphyry and aplitic rocks near the serpentine contact, where they were opened by fissuring and jointing and cut by little dikes. The nonexistence of any definite lode does not argue against the property; on the contrary, if any considerable mass of the mineralized porphyry averages over $5 a ton the success of the mine is assured. The gold is all free, with considerable iron oxide stain. A little pyrite still remains in the less crushed places, though oxidation to the lowest workings, 150 feet below the surface, is pretty complete.

Mining and milling.—The conditions of timber and water power are favorable. The topography is such that backs of 165 feet may be obtained from the main tunnel, which is about 150 feet above the Trinity River valley. The surface equipment consists of a rock breaker and a 3½-foot Huntington mill driven by a 16-horsepower engine. This mill was being put in at the time of visit and was expected to have a capacity of 10 tons per 24 hours. There is more than 1,000 feet of underground workings on the property, about half of which was put in by the present company, and further development was in progress at the time of visit. Cheap methods of mining could be used here, because if any large body of porphyry is found to be sufficiently mineralized it can be mined by the "glory hole" method at a cost of probably less than 50 cents a ton.

History and future prospects.—Gold was first discovered on the Blue Jacket ground in 1897 by G. L. Carr. He confined his attention, however, to exploring the quartz vein through tunnel *b* and in some open cuts but found it too low in grade to pay. The present company got

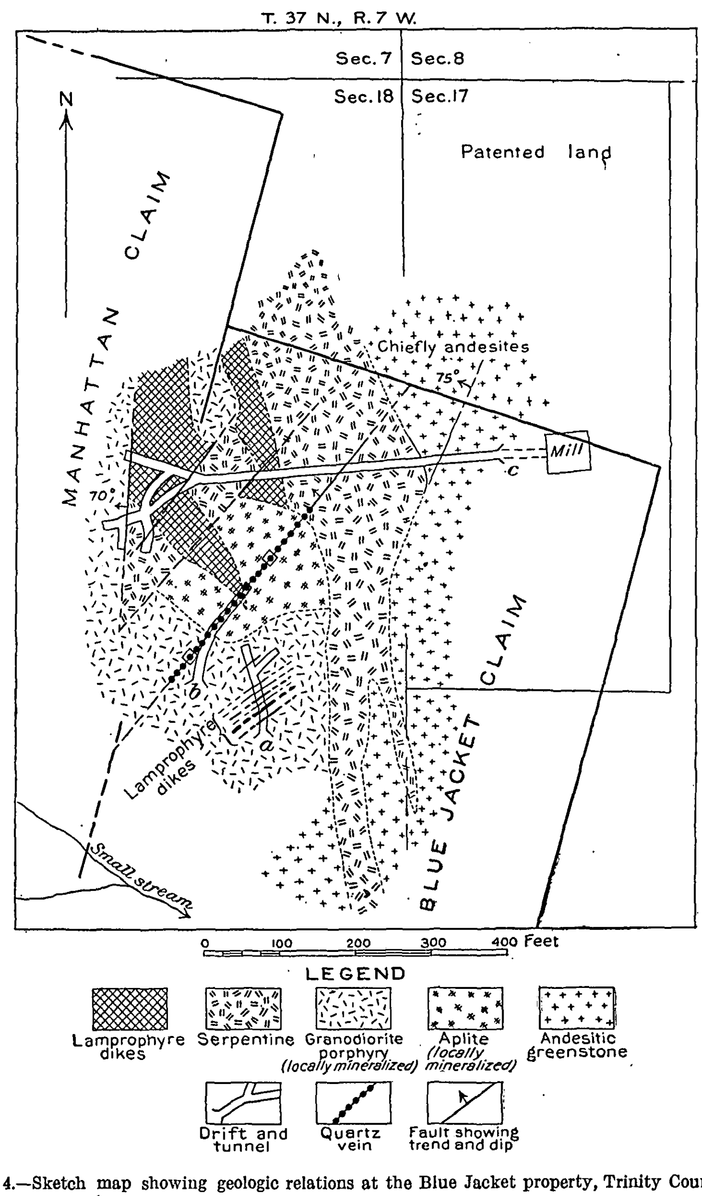


FIGURE 4.—Sketch map showing geologic relations at the Blue Jacket property, Trinity County, Cal., *a*, *b*, *c*, Tunnels.

control in 1909. The future depends on whether a large enough mass of the altered porphyry and aplite will be found to contain gold to the extent of over $5 a ton.

GOLD DOLLAR GROUP.

The Gold Dollar group of claims, the property of Miss Pansey Safford, of Carrville, is located about three-fourths of a mile north of Carrville, half a mile west of the main road, and about 400 feet above the Coffee Creek valley. A small mass of granodiorite porphyry cuts serpentinized basic rocks and is cut by an aplitic dike 25 feet thick. (See fig. 5.) The porphyry and aplite have been highly altered by hydrothermal action, but surface material considerably obscures the outcrops, so that the contacts as shown in figure 6 are exact only where exposed in the workings. The vein is a quartz filled, subsequently sheared fissure vein 2½ feet wide, which trends N. 70° W., and is nearly vertical. It cuts both the basic and the acidic rocks and is close to the contact of the two, though it is not yet known whether the mineralization is equal in the two varieties. The ore contains free gold associated with a little pyrite and iron oxide. It would probably be amenable to cheap treatment, but more development work is needed to reveal its extent.

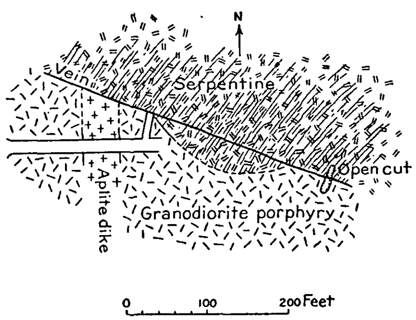


FIGURE 5.—Sketch plan showing geologic conditions at Gold Dollar claims, north of Carrville, Cal.

CARR'S IRON-CAPPED DIKE.

A large mineralized dike a few hundred yards west of and 300 feet higher than Carr's Hotel, Carrville, is owned by the Carr estate. It is fine-grained greenish metabasaltic rock which cuts serpentinized rocks and has some more or less obscure outcrops of granodiorite porphyry associated with it, especially along the footwall. It trends N. 30° E., dips 45° or more westward, and is traceable on the surface for more than a mile. The dike has been locally replaced by quartz and iron pyrite. Postmineral shear planes, many of which trend N. 40° W. and dip steeply westward, have given access to oxidizing solutions that have stained the mass with iron oxide.

The very large size of this dike and the fact that it nearly everywhere contains a little gold have given it considerable local importance. If its length, say 5,000 feet, is multiplied by its average width, almost 60 feet, and by the depth exposed where it is cut by the creek below Carr's, 100 feet, we get the enormous mass of 2,500,000 tons. Even 25 cents a ton profit on this quantity would render it a very valuable property. It is well situated topographically for mining, because it parallels the Trinity Valley at an elevation of several hundred feet above the river and could be worked by tunnels and "glory holes" at comparatively low cost. Probably much of the ore could be cheaply treated by cyanidation, though some of it might require concentration. It is thought that any returns over $3 a ton which it might yield would be profit. However, so far no ore which would average near this sum has been found. It is believed that a search should be made for ore bodies where "bird's-eye" porphyry masses are in contact with or are close to this dike, and that shear zones in the dike itself should be carefully prospected.

RAMSHORN DISTRICT.

The setting in of winter weather prevented a visit to the Ramshorn district, but the following general information regarding it was kindly given by Col. V. B. Allen. The Ramshorn basin is 9 miles northeast of Carrville, on the headwaters of Ramshorn Creek. The chief claims are located in secs. 14, 15, 22, and 23, T. 38 N., R. 7 W., at elevations ranging from 3,200 to 7,000 feet. The country rock is mostly andesite and gabbro, cut by serpentine belts and by granodiorite porphyry similar to that at the Headlight. The Golconda vein lies between serpentine and porphyry, trends northwest and southeast, and dips 70° SW. It maintains a thickness of 5 feet and an average value in gold and copper and iron sulphides of $9 a ton. It is said that the district gives considerable promise.

COPPER QUEEN PROPERTY.

The Copper Queen property is on the head of Copper Creek, some 3 miles east of Carrville, and 2 miles northeast of the Headlight mine. The country rock is andesitic greenstone, in contact with serpentine, both cut by an almost horizontal metabasaltic dike, and the whole intruded by lamprophyre dikes which trend N. 70° W. and dip 80° W. (See fig. 6.) Figure 7 shows a cross section of the ore body as it appears from the rather meager data which the obscured outcrops reveal.

The ore body replaces the upper part of the green fine-grained metabasaltic dike and the country rock just above it. Where this dike cuts serpentine the ore is rich in copper and carries some gold; where it is in contact with andesite the copper veins are small. It is not known whether the gold values are the same in these two formations or whether they vary with the copper content. The primary minerals are chalcopyrite and pyrite; the secondary minerals dark chalcocite and some green carbonate; and the gangue materials quartz, some calcite, and chloritized, highly altered basaltic dike rock. The rich chalcocite of the upper part of this deposit bears witness to the secondary enrichment processes that have been active here. The richest ore seems to be on the western or hanging wall of the small lamprophyre dikes where they cut the ore body. This local enrichment seems to be due to the formation of flat V-shaped, relatively impervious troughs which have impeded the descent of the mineralizing solutions and thus induced deposition.

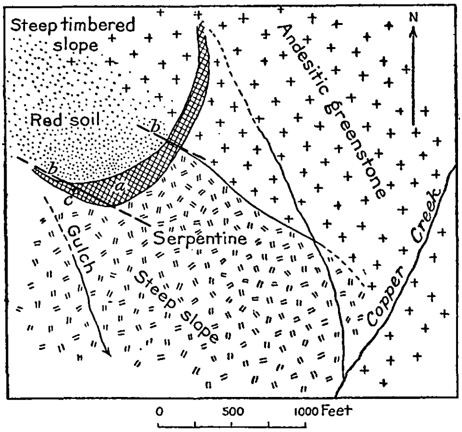


FIGURE 6.—Sketch plan of Copper Queen lode, 3 miles east of Carrville, Cal. *a*, Metabasaltic dike largely replaced by ore, lying nearly flat and outcropping on slope; *b*, lamprophyre dikes; *c*, small shaft.

The development work which has been done is not sufficient to demonstrate the extent of the ore, so that no definite value can be placed on the property at present. The deposit may be irregular in form and somewhat difficult to follow. Conditions are very favorable for mining; timber and water power are at hand, and the slope insures drainage, dumpage, and backs. The ore would have to be concentrated and the concentrates shipped or smelted on the spot. Mining, concentrating, shipping, smelting, and other charges would probably amount to about $40 a ton, so that the concentrated product shipped would have to be worth considerably more than this to pay expenses. The future of this property depends on whether or not the high-grade ore which now locally appears at the surface will be found to be sufficiently extensive when the lode is opened.

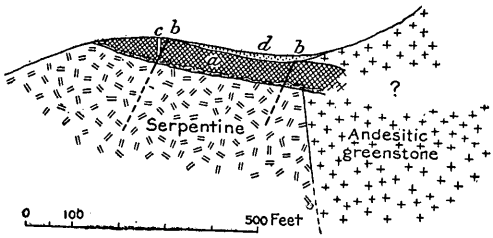


FIGURE 7.—Approximate north-south cross section of Copper Queen lode. *a*, Metabasaltic dike largely replaced by ore, fragments of dike material being left along bottom part; *b*, lamprophyre dikes; *c*, small shaft in chalcocite and chalcopyrite ore; *d*, red soil covering.

TRUE BLUE PROPERTY.

The True Blue prospect, a few hundred yards northwest of the Headlight mine, is owned by George Le Blanc. The country rock is andesitic greenstone, of which the outcrops are somewhat obscured by soil mantle. The ore body is a low-grade, almost flat-lying quartzose iron-stained mass, bearing some likeness to the Headlight ore deposit. It is possible that this True Blue is a continuation of the Headlight deposit, but no granodiorite porphyry was found associated with it. The outcrops and red surface soils are said to give encouraging results, but the prospecting work, so far, has not properly tested the ground. The tunnel, several hundred feet of which is completed, seems to be below the ore body and of little value in the way of development. Systematic surface trenching and sampling, or surface sluicing, would do much more to test this ground than all the underground work that has been done.

GOLDEN JUBILEE MINE.

The Golden Jubilee mine, the property of the Golden Jubilee Mining & Milling Co., is situated 5 miles northwest of Carrville, near the junction of Coffee and Boulder creeks, and embraces nine claims, which stretch over nearly a mile of vein. The country rock is granodiorite, cut by some lamprophyre dikes of about the composition of vogesite. The outcrops are not prominent, largely on account of the postmineral shearing, which has somewhat broken the vein material. The vein is a fissure filling with ore shoots, separated by narrow pinches. These shoots or lenses vary from 3 to 16 feet in maximum thickness and extend 30 to 150 feet in horizontal direction, with an average of about 25 feet from the end of one to the beginning of the next.

The veins trend N. 30° E., dip 75° E., and consist of quartz, crushed country rock, and some calcite and iron oxide. The values are free gold, associated with iron oxide and pyrite, and gold tellurides. Some crystals of galena were observed, and very large cubes of iron oxide, after pyrite, said to assay as high as $3 a pound, occur in the upper workings. Pyrite corresponding to these cubes has not been found in the mine. Oxidation has followed some of the postmineral fissures to extreme depths of 250 feet, but the average depth is much less than this. The vein is larger and the ore said to be richer in the vicinity of a lamprophyre dike, which is exposed in tunnel No. 4 and has been jogged some 30 feet by vein faulting. Mining conditions are favorable, and the topography is such that the lower workings can be made to develop nearly a thousand feet of backs. A wagon road extends to the mine. Several thousand feet of tunnels and several hundred feet of upraises and stopes have been made. It is said that there are over 2,000 tons of ore blocked out which will average $7 a ton in gold and that there are other ore shoots which will assay over $30 a ton. Because of the sulphides and tellurides which they contain these ores do not give up their gold as readily as those of the Headlight group. In practice fairly good results have been obtained by crushing and amalgamation to remove coarse gold, concentration to remove sulphides, and cyanidation of slimes and tailings. The concentrates are said to average about $120 a ton, and are therefore rich enough to ship in spite of the high cost of haulage and other charges.

The mill equipment consists of an older part, two Huntingtons and a cyanide plant, and a newer part, a 10-stamp 30-ton cyanide mill.

The mine has been worked at intervals for 15 years. At first it was merely a shipper of rich ore, then the two Huntingtons and small cyanide plant were installed, and as this equipment became inadequate the new 10-stamp mill and cyanide plant were added. Litigation is said to have resulted in the closing of the property a few years ago, but operation may be resumed before long. It is stated on good authority that the old records of the mine show a production of over $25,000 and that the earliest production was not recorded.

WAGNER PROPERTIES.

Location and country rock.—The properties owned by the Wagner Mining & Milling Co. are on the northeast slope of Coffee Valley, extending from Coffee Creek a thousand feet up the slope. There are five claims in the group, all in sec. 34, T. 38 N. R. 8 W.; also 320 acres of patented land near by. The country rock is granodiorite cut by numerous small lamprophyre dikes, many of which parallel the lodes and several of which form the hanging walls of veins. The serpentine contact is only a few hundred feet to the northeast.

Ore deposits.—The ore deposits are all of the fissure-vein or narrow sheared-zone type. Their outcrops are mostly inconspicuous, on account of the postmineral shearing which they have undergone. The average trend of the lodes is N. 30° E., and they dip eastward, in the main steeply. Cross fissures trend about northwest, but these are not important, except that some enlarged ore shoots occur where they intersect the main veins. The lodes vary from narrow shear zones to ore bodies several feet wide, and though values as high as $100 a ton are found in pockets and small shoots the average value of the ore is not high. Oxidation has not gone deep except along well-sheared fissures; probably 50 feet is the average depth. The gold in the oxidized zone is free and occurs with some iron oxide. Below this it is associated with pyrite and in the telluride form. The vein material is quartz, crushed country rock, and a little iron oxide and calcite. There are several different veins on the property.

Black Warrior vein.—The best-known vein on the claims, though perhaps not the most valuable, is the Black Warrior. It is the flattest vein in the district, dipping 35° E., and is of uneven thickness, though 17 inches is perhaps close to the average. Locally it has been jogged by faulting, as shown by figure 8. The fault plane is almost vertical, the dip of the vein giving the apparent horizontal displacement. The lode has been worked on two levels, the lower reached by crosscuts Nos. 1 and 2 and the upper by crosscut No. 3. Of these, No. 1 is 225 feet long and connects with 70 feet of drift and 125 feet of raise; No. 2 is 435 feet long and connects with a 320-foot drift and a 75-foot raise to the upper level. No. 3, on the upper level, is 48 feet long and connects with 170 feet of drift and 72 feet of upraise to the surface. Some stopes have also been worked.

Mizpah veins.—The Mizpah veins are in the southeast corner of the group near Coffee Creek and consist of a series of small parallel veins and dikes, as illustrated in figure 9. Of these, lode A is the southernmost, lode B is 125 feet north of A, and lode C is 50 feet north of B. In lode A ribbon structure is developed, showing five different reopenings and quartz fillings, separated by thin films of country rock. The small veins on the footwalls of dikes are evidence of deposition by ascending solutions. Lode C (fig. 9) shows, in plan, a change of direction, but the evidence in the tunnel does not show whether there are two intersecting veins or one vein jogged by successive shearing. About 300 feet northwest of lode C there is another small parallel vein, lode D. The development work on this group consists of 70 feet of drift on lode A, nearly as much on lode B, and 50 feet of crosscut and 150 feet of drift on lode C. The workings in lode D were caved in and could not be entered.

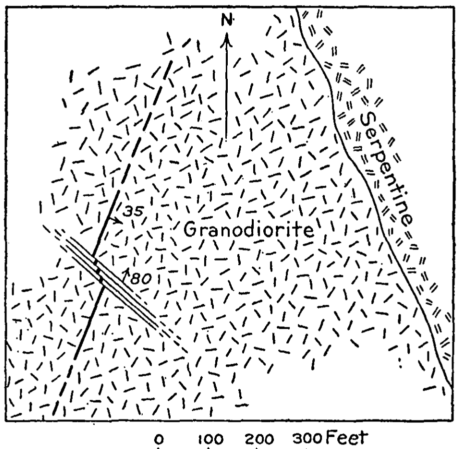


FIGURE 8.—Plan of Black Warrior lode, Trinity County, Cal., showing jog faulting.

Other veins of the Wagner group.—Other important veins near the Black Warrior are as follows: On the Red Flag claim, 1,700 feet south of the Black Warrior, a 30-inch vein is separated from a smaller parallel vein by 20 feet of country rock. A lower tunnel, 80 feet long, crosscuts both of these, and 30 feet of drifting has been done on the larger vein. An upper tunnel of 20 feet has opened the smaller vein. These workings are in the oxidized zone and reveal free gold in ore said to have a high value. The Brush Brothers vein, a few hundred feet farther southeast, varies in width from 20 to 30 inches and is considerably oxidized and sheared. It is opened by a 20-foot drift which shows ore that is said to be of fairly high grade. The Reindeer vein parallels the veins above described and is probably a northeast continuation of the Red Flag vein zone. The development work consists of 200 feet of drifting and a 15-foot shaft in the granodiorite and serpentine contact. The vein is 2½ feet wide and gives returns, especially from the shaft in the crushed contact material, that are said to be high.

Plant.—In 1899 the owners, having made some headway in development work, built a mill. It consisted of a Gates crusher, 12 stamps of 620 pounds each, three concentrating tables, and a slime table, all driven by water power, and designed to treat 14 to 16 tons of ore in 12 hours. This plant ran five months, the concentrates being shipped to the Keswick smelter; then a snowslide swept the plant away. That it was not a success is shown by the large amount of gold in the tailings. The 1,000 tons of these that are ponded are said to average over $10 a ton. Experiments have been carried on to find a treatment suitable to this ore, and at the time of visit it was thought that the Clancey process might be installed. The power plant has a 1½-mile ditch which will deliver a maximum of 400 miner's inches of water to a penstock 500 feet above the water wheel. This generates power that is more than sufficient for all the needs of the plant.

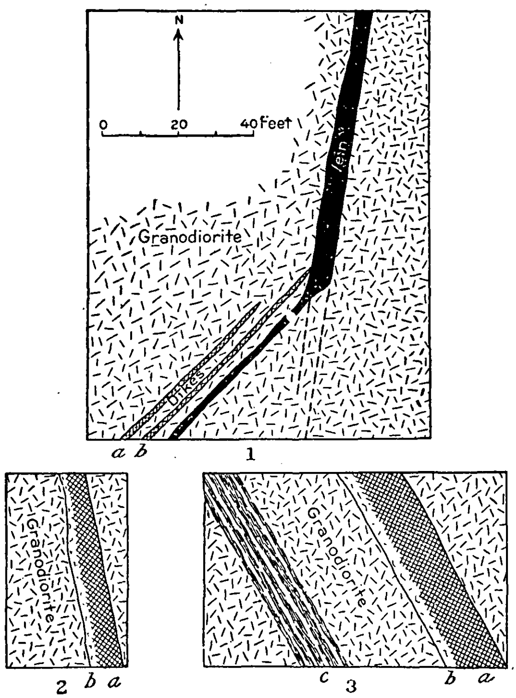


FIGURE 9.—Plan and cross sections of some lodes in the Mizpah group, Wagner properties, Trinity County, Cal. 1, Plan of part of lode C, showing parallel dikes (*a* and *b*) and change in direction of vein or intersection of two veins. 2, Cross section of lode B; *a*, lamprophyre dike, 6 inches; *b*, quartz vein, 3 inches. 3, Cross section of lode A; *a*, lamprophyre dike, 24 inches; *b*, quartz vein, 4 inches; *c*, ribbon quartz vein, 22 inches, consisting of five different fillings separated by thin partings of country rock.

History.—In 1890 Frank Bighouse discovered the Mizpah group. Three years later the Brush Brothers discovered the vein which bears their name. The following year Amos Hill opened the Reindeer claim, which he sold to Wagner & Son in 1895, about the time they had located the Black Warrior property. E. A. Wagner found the Red Flag vein in 1897, and subsequently all these properties came into the hands of Wagner & Son.

Production.—Since their discovery these properties are said to have produced over $8,000. With a successful method of ore treatment they may give profitable returns in the future.

POETH MINE.

The Poeth property, recently incorporated as the Gold Ridge Mining & Milling Co., is on the west side of Boulder Creek, a few hundred yards from the Golden Jubilee mine. The country rock is granodiorite cut by a few lamprophyre dikes. The chief veins, two in number, are parallel, 175 feet apart, and of the fissure type. Their outcrops are not prominent, probably on account of the postmineral shearing which they have undergone. The north vein seems to be the smaller, but it is not yet well opened; the south vein shows narrow pinches and ore shoots several feet wide, the average width being nearly 3 feet. Oxidation has not gone below 25 feet, except along certain shear zones. The development work is confined chiefly to the southern lode and consists of a 40-foot crosscut, 75 feet of drift, a 45-foot upraise, and a 100-foot shaft. The chief minerals are gold, both free and in the form of tellurides, some pyrite, and locally some iron oxide. The vein consists mostly of quartz, with a little crushed country rock, and some calcite. The values are said to be high, and some rich pockets have been found. A shipment of 5 tons of carefully picked ore is said to have averaged into the thousands of dollars a ton; and a second shipment of 6 tons is said to have brought, without sorting, $21 a ton. The concentrates are high enough in grade to bring a good profit in spite of the high cost of shipping. Mining conditions are favorable, especially with regard to timber and water power. A wagon road extends into the property.

The lodes were discovered in 1900 by John Poeth, who has done most of the development work and still has an interest in the property. The installation of a small plant that will successfully treat the ore will probably greatly enhance the value of the claims.

BURNER MINES.

The Burner group of four claims, recently acquired by the Coffee Creek Mining & Milling Co., is a mile north of the Jubilee mine, on the northeast slope of Coffee Valley a hundred feet or more above the valley bottom. The country rock is granodiorite cut by lamprophyre dikes, the serpentine contact being only a few hundred feet distant. The veins are not of the large fissure type, like those of the Dewey and the Golden Jubilee, but are small parallel stringers, with ore bodies developed at fissure and dike intersections. The vein system trends about N. 30° E. and dips steeply. The veins are smaller, richer, and more pockety than those which occur farther away from the serpentine contact. The vein material is mostly quartz with a little mineralized country rock. It contains gold, free and in the form of tellurides; pyrite is common and some galena is present. Oxidation extends only a few yards below the surface.

The property is opened by 17 small tunnels and shafts. The longest tunnel is 200 feet long, but the present company is starting a main adit to crosscut as many of the ore veins as possible, and, as planned, it will have maximum backs of 600 feet. Some ore recently sacked, it is said, averaged $300 a ton. The mining conditions are very favorable and there is a wagon road to the property.

A crushing and cyanide plant is projected and the ore treatment will be crushing and amalgamating to get the free gold, then concentration to remove the sulphides, and cyanidation of the slimes and tailings. The concentrates will probably be hauled out by wagon to the railroad. Rich pockets are said to have yielded several thousand dollars since the discovery of the property.

LILY OF THE VALLEY GROUP.

The Lily of the Valley property, locally known as Windy Camp, is under the management of Reid Brothers and lies on the northeast slope of Coffee Valley, 1,200 feet above Coffee Creek, at an elevation of 4,500 feet. The country rock is granodiorite cut by several lamprophyre dikes and by dikes from the main serpentine mass, which is close at hand, but separated from the granodiorite by a large shear zone along the contact. The Lily of the Valley vein is a narrow shear zone which locally widens out into ore shoots that are somewhat related to fissure intersections and to lamprophyre dikes. It trends about northeast, is nearly vertical, averages 10 inches in thickness, and is made up of quartz, crushed country rock, and some calcite. The ore contains free gold, with tellurides reported. Some pyrite is present, grading into iron oxide at the surface. Assays from the lamprophyre dikes near the ore body are said to show gold values of $1 to $2.60 a ton. The average tenor of the ore shoots is said to be $25 a ton, but some assays have registered values more than ten times as high. Timber and water power are readily available and the slope insures good backs, drainage, and dumpage. A wagon road extends to the lower part of the property. The development consists of 125 feet of lower tunnel, mostly on the vein, with a 23-foot upraise at the face; also a 75-foot upper tunnel, with a 30-foot winze, from the bottom of which extends a 20-foot drift.

Another deposit on this group of claims is known as the Hill-Farmer lode. It is a fissure vein in the granodiorite, trends northeast, is about vertical, averages 15 inches in thickness, and is said to give an average assay of $7 a ton near the surface. It is about 445 feet east of the Lily of the Valley workings and is developed so far only by an open cut.

A small mill, consisting of a 3½-foot Huntington and a cyanide plant designed to treat 10 tons each 24 hours, has recently been purchased for this group. A quarter-mile ditch carries a maximum of 40 inches of water, which discharges under a 175-foot head against a Pelton wheel. This will generate some 30 horsepower, a third of which will be required to run the present plant. The extraction by cyanidation is said to be 90 per cent.

DEWEY PROPERTY.

The Dewey property is on Little Boulder Creek, 1½ miles southwest of Coffee Creek. The country rock is granodiorite, cut by some lamprophyre dikes, one of which locally forms the southeast wall of the lode. The serpentine contact is not far distant. The vein is a large, clear-cut quartz fissure filling which has been very little broken up by the small amount of postmineral shearing which it has undergone. It trends N. 30° E., dips 85° E., and averages 4 feet in width. Oxidation extends only a few feet below the surface except where it reaches down along fissures to depths of 20 feet or more. The ore is of low grade. The gold is associated with pyrite and some crystals of chalcopyrite and, on the surface and in some of the postvein fissures, with iron oxide. The vein material is largely quartz, with some siderite and calcite.

The development consists of a 130-foot crosscut tunnel which taps the main vein 65 feet below the surface; from this a 100-foot drift has been run southward and a 50-foot drift northward. The property was discovered in 1899 and was purchased by James Medary and T. S. Leever, its present owners, in 1902. Soon after the discovery an arrastre was put in, and a considerable quantity of oxidized croppings was worked, giving a yield, it is said, of $700. No system of treatment for the sulphide ores has yet been installed. This is one of the largest and clearest cut veins observed in the district.

OTHER PROSPECTS.

Among the prospects not visited because of lack of time are the claims of the Nash Mercantile Co., in the Copper district. It is reported that the vein is 2 feet wide and that it assays well, carrying gold with a considerable amount of copper. Not far from these is the Morning Star claim, which is said to have a well-defined vein that averages $7 a ton in free gold near the surface.

DORLESKA AND YELLOW ROSE TYPE.

DORLESKA AND YELLOW ROSE MINES.

The Dorleska and Yellow Rose properties were visited in the fall of 1909, but the data then gathered were lost in a fire. A second visit was prevented by a snowstorm, which cut short the work that was being done in the district in the fall of 1910. The facts here presented are derived from memory and from some notes furnished by Mr. MacIlwaine, superintendent of the Dorleska. The treatment is not adequate for the importance of the properties.

Both of these mines are at an elevation of 6,550 feet, one on each side of the Coffee Creek and Salmon River divide, near its summit. They are reached by a trail up Coffee and Union creeks from the end of the wagon road north of the Jubilee mine; also by trail up Swift Creek from Trinity Center. The distance from Trinity Center by the latter route is 16 miles, and by the former 26 miles.

The country rock is a serpentine mass, cut by large and small lamprophyre dikes. A few hundred feet north of the ore deposits is a series of highly metamorphosed schists, thin limestone, and limy shales. A lamprophyre dike 50 feet or more thick cuts the basic country rock in a direction N. 16° E. and dips about 75° W. Near the Yellow Rose mine the east side of this dike contains hornblende prisms and is the "crow's-foot porphyry" of the prospector. The west side shows biotite and some quartz. Near the Dorleska mine, however, these relative positions of the dike material have been reversed. The dike is paralleled by the schist contact and by a fault zone of considerable magnitude.

The ore deposits of these mines are similar. The fault zone is mineralized along the footwall of the composite dike, which is also locally mineralized where cut by side fissures. Rich shoots of clayey material, which dip 45° N., characterize some of the fissure intersections. The ore contains gold, with some silver, associated with pyrite. Tellurides and a little galena are reported.

The conditions affecting mining are favorable. The mines require but little timbering, lumber sufficient for all mine purposes is available, and the slope is such that backs can easily be developed. Over a thousand feet of drift and upraise work has been done on each property.

The milling equipment at the Yellow Rose consists of a Huntington, driven by steam, with a capacity of 7 tons in 24 hours. At the Dorleska there are two 5-stamp batteries and a Huntington mill, driven by steam, with a total capacity of 30 tons in 24 hours. The Huntington mills are especially well adapted to the talcose ores.

The Yellow Rose was discovered by Messrs. Hill and Farmer in September, 1897, and shortly afterward Mr. Lawrence located the

Dorleska. These men were "pocket hunters" and they worked some rich pockets on both properties, treating the ore in arrastres and later at the Dorleska in a small 5-stamp mill. A few years later new interests acquired the properties and they were very active for a time, producing some high-grade ore. Recent changes have been made among the holders and new plans for development work are reported.

It is said that the Yellow Rose has produced $100,000 and the Dorleska $200,000 since discovery. The large extent of lode which is yet to be explored before the workings of the two mines join indicates that much ore-bearing rock is still undeveloped.

OTHER PROPERTIES.

Several properties of more or less promise occur in the general vicinity of the Dorleska and Yellow Rose mines. They are mostly associated with dikes and shear zones in serpentinized rocks. Their ores carry free gold and are said to contain some small rich pockets, as well as larger bodies of lower-grade ore. Of these Thomas Keating's property, a few miles north of the Dorleska and characterized by similar geologic conditions, has already produced considerable gold. It has recently been acquired by a company which has put in a small plant for treating the free-gold ores, so that the property now bids fair to become a producer.

Not far distant from this are properties owned by Mr. MacIlwaine and others, some of which are promising prospects. South of the Yellow Rose are some prospects which have very inconspicuous outcrops but give free gold by panning the adjacent soil. Many of these are well worth investigation and on the whole the field is very interesting for the prospector.

STRODE AND BONANZA KING TYPE.

STRODE MINE.

The Strode mine is half a mile northeast of Carrville, on the steep eastern slope of the Trinity Valley, about 700 feet above Trinity River. The country rock is a complex of andesitic greenstones cut by some small masses of granodiorite porphyry; by dikes of aplitic rock, one of which is parallel to and not far distant from the vein; by dikes of fine-grained green metabasalt; and by a few lamprophyre dikes.

The vein occupies a fissure and is paralleled by smaller veins of the same type, the whole somewhat sheared and locally having the appearance of a double vein. It trends N. 60° W., is nearly vertical, and averages about 2 feet in width but is locally considerably wider. The ore contains gold, associated with iron oxide, a little manganese stain, and, in the less sheared parts, pyrite. The gangue is largely quartz, with some crushed country rock and a little calcite. The value of the ore taken out is said to be high, especially in some of the ore shoots. Mining conditions are favorable and a good wagon road leads to the workings. From the mine the ore is hauled by wagon to a 3-stamp battery, where the gold is recovered by crushing and amalgamation. The property has been worked more or less regularly in a small way for several years and is said to have yielded good profits. Though working in 1909 it was not active in the later part of 1910. It is believed by those familiar with the district that this mine still contains valuable ore.

BONANZA KING MINE.

The Bonanza King mine is well known in the district but was not visited in 1910 on account of snow. The notes from the writer's previous short visit were destroyed by fire, hence the brief description here given is quite inadequate to the importance of the property. The mine is about 4 miles east of Trinity Center on the face of a steep mountain slope some 1,200 feet above Trinity River. The country rock is a complex of andesitic and gabbroic greenstones, cut by lamprophyre dikes. The lode is a mineralized shear zone, locally well defined and in places widening out into large ore shoots. These shoots are mostly located at fissure intersections and some of them are very rich, one having yielded, it is said, about $80,000. The ore contains gold, with a little silver and considerable pyrite. The development consists of several thousand feet of tunnels, drifts, and stopes, and well-equipped tramways. An aerial tram a few thousand feet in length brings the ore down to a 30-stamp mill and cyanide plant.

This mine became very prosperous shortly after the discovery because of the finding of an exceptionally rich ore shoot. After the exhaustion of this shoot the returns were not so high. A few years ago the failure of a trust company in San Francisco involved the property and it was turned over to a receiver who allowed it to stand idle pending the straightening out of the financial tangle. In 1910 it was reported that work might be resumed shortly.

BLUE JAY TYPE.

BLUE JAY MINE.

The Blue Jay mine is on Morrison Gulch, 1¾ miles west of Carrville, and is owned by the Blue Jay Mining Co. The visit to it was necessarily hurried and only a general idea of it is here presented. The country rock is serpentine cut by small masses of granodiorite porphyry, by lamprophyre dikes, and by a large dike of fine-grained green metabasalt. Shear zones are numerous, many of them trending northeast. The ore is in the metabasaltic dike in local fissures and shear zones, at the intersections of some of which rich pockets occur; in fact, the property is known as a producer of rich pockets. The pockets contain coarse free gold with some iron oxide and a little manganese oxide staining the clayey material in which they occur. Pyrite is peppered through certain parts of the dike and it is said that some gold is associated with the pyrite. In some portions of this dike the mineralized shear zones are spaced closely enough to permit mining and treating the whole dike mass. Prospecting with this end in view might be well worth while. The mining conditions, especially slope for back and dumpage, also water power and timber, are very favorable and at the time of visit active development work was in progress.

The property was discovered in 1892 by the Graves Brothers, who took out $60,000 in a few days from a very small pocket. This caused a "gold rush" and in 1893 thousands of gold seekers went into the Coffee Creek district, but a few months later there was an ebb tide of disappointed men. A year after the excitement had subsided the property was idle, and it remained so until a few years ago, when some lessees took out what were said to be good returns. Recently another company has started development work, from which it is hoped that this mine, which had such a spectacular beginning, may yet become a steady producer.

A PRELIMINARY REPORT ON THE GEOLOGY AND ORE DEPOSITS OF CREEDE, COLORADO.

By W. H. Emmons and E. S. Larsen.

INTRODUCTION.

LOCATION AND TOPOGRAPHY.

The Creede mining district is situated in Mineral County, southwestern Colorado, near the eastern border of the elevated region generally known as the San Juan Mountains. The town of Creede is situated on Willow Creek a few miles above its junction with the Rio Grande. The area shown on the map of Creede and vicinity published by the Geological Survey is about 4½ miles east and west and 5¾ miles north and south. The lowest portion of this area, about 1 mile below Creede, is 8,700 feet above sea level, and the highest is the summit of Nelson Mountain, near the north border of the area, which is 12,029 feet above sea level. The country consists mainly of steep slopes, although the uplands include some small, comparatively level stretches. Like most of the mountainous area of the San Juan the region is timbered and well watered. It is served by a broad-gage branch of the Denver & Rio Grande Railroad. The district is more accessible than many other camps of the San Juan region, and rates for shipping ore are lower.

FIELD WORK AND ACKNOWLEDGMENTS.

The geology of Creede and vicinity has been mapped by E. S. Larsen, who for several years has been associated with Whitman Cross in the study of the general geology of the San Juan Mountains. Mr. Larsen spent several brief periods in the study of the geology of the region near Creede incidental to work in the San Cristobal quadrangle, the border of which lies a short distance west of Creede, but the larger part of his work was done during the summer of 1911. W. H. Emmons was detailed to study the underground workings and the ore deposits, and spent about seven weeks, from July 28 to September 15, 1911, in this work.

The survey of the district has not yet been completed. This report is merely a preliminary statement of the principal conclusions and may later have to be modified. The thanks of the writers are due to the mining operators of the district for friendly cooperation and support, especially to the officers of the Solomon mines and Messrs. S. B. and Albert Collins for the use of mine maps and to Mr. William Barnett for many favors.

HISTORY AND PRODUCTION.

In the eighties the upper portion of the valley of the Rio Grande was a route of transportation between Wagon Wheel Gap and the flourishing camps near Silverton and Lake City. This route passed very near the present site of Creede and nearer still to Sunnyside, a small camp about 2 miles west of Creede. Some of the Argonauts halted on the way long enough to prospect the steep mountain slopes along the valley and, finding encouraging indications, located several claims. J. C. McKenzie and H. M. Bennett located the Alpha, at Sunnyside, April 24, 1883, and with James A. Wilson pegged out the Bachelor claim, near the present site of Creede, July 1, 1884. Some prospecting was done in the middle eighties, principally at Sunnyside, and futile attempts were made to work the ores in arrastres. There is no record of any new discoveries from 1886 until August, 1889, when N. C. Creede, E. R. Naylor, and G. L. Smith located the Holy Moses mine on Campbell Mountain. The following summer Mr. Creede located the Ethel and C. F. Nelson located the Solomon claim. The mining district that was formed was called the King Solomon district; it is east of and nearly contiguous to the Sunnyside district.

When it became generally known that Mr. Creede had sold an interest in the Holy Moses mine to D. H. Moffat, of Denver, prospecting was renewed with great vigor, and in June, 1891, several prospectors from Del Norte discovered the Last Chance mine on Bachelor Mountain. This was on the Amethyst or "Big" vein, upon which the Bachelor claim had been located six years before, but the two locations were nearly three-fourths of a mile apart. Soon after the location of the Last Chance Mr. Creede located the Amethyst claim, which joined it on the north, and within a few months the Amethyst vein was pegged for a distance of nearly 2 miles along its strike.

The railroad from Wagon Wheel Gap was extended to the district in 1891, and the first train arrived at Creede on December 16 of that year. It is credibly reported that the town housed 10,000 people in the early nineties. The district has been producing almost continuously since the advent of the railroad, and the daily tonnage in the nineties was large. During some of these years silver was at a very low price, but the mining operations were profitable nevertheless. The production has declined somewhat in recent years, and in 1910 it was $1,036,286.[1] No record has been kept for some of the mines, and

[1] Mineral Resources U. S. for 1910, pt. 1, U. S. Geol. Survey, 1911, p. 424.

the total production can not be stated accurately, but on the basis of data obtained from several reliable sources the total production is estimated at $37,500,000. This includes, in order of their value, silver, lead, gold, and zinc. About half this sum was paid as dividends, notwithstanding the low prices at which the metals were marketed. The Creede district is probably the most productive silver camp in the United States developed after the great slump in the price of silver. The mines on the Amethyst vein supplied over 90 per cent of the total production and paid an even larger proportion of the dividends. If the silver had been marketed at the same prices, the production of the Amethyst vein would compare very favorably with that of any other silver deposit in the United States except the Comstock lode.

MINING AND TREATMENT OF ORE.

The larger part of the ore of Creede was partly or completely oxidized. Such ore is not suitable for mechanical concentration and was shipped without dressing to smelters. The most of it went to the plant of the American Smelting & Refining Co. at Pueblo.

In the lower levels of the mines on the north end of the Amethyst vein, especially in the Amethyst and Happy Thought mines, large bodies of sulphides suitable for concentration were encountered. This ore was dressed in the Humphrey mill at North Creede. The Humphrey and Amethyst mills are of the same general type, the equipment including crushers, rolls, classifiers, jigs, tables, and canvas plants. The zinc blende and galena are readily separated, giving clean and satisfactory concentrates, and the pyrite is not so abundant as to reduce the grade of zinc concentrates greatly. Gold and silver are recovered mainly with the lead concentrates or in the slimes. Two smaller mills, the Solomon and the Ridge, are located on East Willow Creek about 1½ miles above North Creede. The ore of the Solomon vein is very soft and is crushed by rolls without preliminary breaking in a jaw crusher. Only the Humphrey and Solomon mills were in operation in the summer of 1911, the Amethyst having been closed early in that year.

Conditions are favorable for cheap mining, as the veins are nearly everywhere of good width and have been subjected to very extensive fracturing and crushing since they were formed, so that much of the work has been done with pick and shovel. One of the largest stopes was milled from the bottom without preliminary blasting or breaking the ore. At present all the stoping is done by hand. Owing to the fractured condition of the rock the miners find their labors lighter than in many neighboring districts.

The mines on the Amethyst vein and those on the Solomon are served by deep adits. The topography is so rugged that these gain depths of 1,000 to 1,400 feet within comparatively short distances.

The mines contain large quantities of water, which is drained through the adits and is used for milling. Although several deep shafts have been put down, all the mining is done at present through the adits.

GEOLOGY.

GENERAL FEATURES.

Creede lies within the great Tertiary volcanic area of the San Juan Mountains, and, so far as known, no rocks other than the Ter-

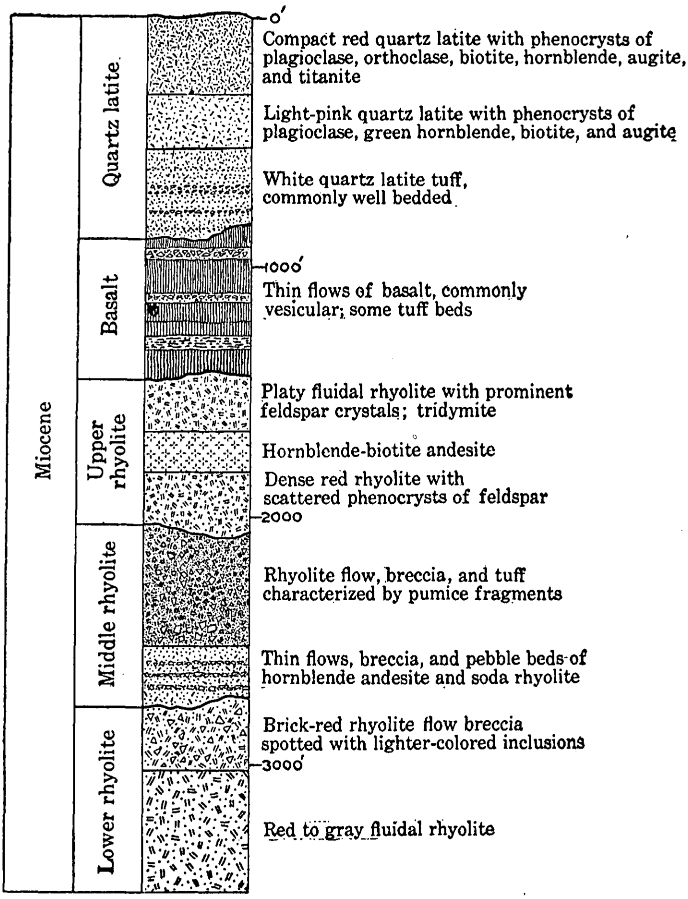


FIGURE 10.—Generalized columnar section of rocks on ridge east of Rat Creek, near Creede, Colo.

tiary volcanics are exposed within a radius of many miles. All the rocks of the area shown on the map of Creede and vicinity are thought to be included in the Potosi volcanic series, which is the third series of the Tertiary volcanic rocks thus far recognized in the region.

The rocks of this area are naturally separable into several divisions and most of these divisions are separated by erosion surfaces. Each division is generally made up of two or more flows or other subdivisions. Figure 10 is a generalized columnar section representing the succession of the rocks as seen on the ridge east of Rat Creek. This section does not show the quartz latite of McKenzie Mountain, which overlies a very irregular surface of the other rocks, nor the lake beds in the Rio Grande valley, nor the rhyolite near the Equity mine. The exact positions in the column of the latter two are not known.

THE ROCKS.

Lower rhyolite.—The lower rhyolite consists of two divisions, the lower of which is very prominently developed in the canyon of Willow Creek above Creede. Over 1,000 feet of this flow is shown in that canyon, although its base is not exposed. It extends on the slopes nearly to the summits of both Mammoth and Campbell mountains. The upper contact of the flow dips rather steeply to the north, so that it is not exposed above Phoenix Park on East Willow Creek, and it continues for only a short distance above Weaver on West Willow Creek. To the east it extends beyond Dry Gulch. This flow is exposed also on the east side of West Willow Creek just above the Equity mine. Another area of the same flow outcrops near Sunnyside and makes the lower slopes about Rat and Miners creeks and crosses to the west into Shallow Creek. A short distance beyond Shallow Creek it passes under other flows. This division of the volcanic series forms one or both walls of most of the lodes of the district. It is a normal rhyolite in composition. Its aphanitic groundmass incloses inconspicuous phenocrysts of glassy orthoclase and a very few of biotite and plagioclase. It is generally gray, pink, or red in color and has a prominent fluidal structure. Thin bands of dense dark-colored material alternate with irregular or lenslike bands of porous, lighter-colored material.

Overlying this fluidal rhyolite is a later rhyolite flow which has a thickness of over 1,000 feet where exposed east and southeast of Phoenix Park. On Mammoth Mountain, just south of the Mollie S. mine, are two small outcrops of this flow which in places are in faulted contact with the underlying rhyolite. Campbell Mountain is likewise capped by this flow. In the hanging wall of the Amethyst vein it is but a short distance below the surface. It outcrops just west of the Commodore mine and continues along the upper slopes of the hill into Windy Gulch. It occupies also the upper slopes on both sides of Miners Creek. This upper division of the lower rhyolite is commonly dark brick-red in color and has a dull bricklike luster. Fluidal structure is inconspicuous, but inclusions and irregular or lenslike blotches of a color and texture slightly different from the mass of the rock are characteristic. It is very similar in its mineral composition and texture to the underlying rhyolite.

Middle rhyolite.—In Windy Gulch below Bachelor are thin flows, breccia beds, and tuff overlying the lower rhyolite. The material of these deposits is a red soda rhyolite, which contains abundant crystals of glassy orthoclase and white microperthite and some quartz and biotite in a fine-textured groundmass. This soda rhyolite continues northward and forms the hanging wall of the Amethyst fault nearly to the Last Chance mine. It is here termed the middle rhyolite. On Rat Creek, just west of Bulldog Mountain, the lower rhyolite is overlain by several hundred feet of thin flows and breccia beds of hornblende andesite which are thought to occur at the same horizon as the soda rhyolite.

Above the hornblende andesite on the south slopes of Bulldog and McKenzie mountains there is a considerable thickness of rhyolite tuff and flow breccia. The rock is light pink in color, is characteristically porous, and contains prominent irregular fragments of pumice and of some other rocks. It contains a few crystals of orthoclase and biotite in a glassy or finely crystalline groundmass.

Upper rhyolite.—The two rhyolite flows of Bulldog Mountain are red in color and contain rather abundant phenocrysts of orthoclase, less plagioclase, and a little biotite in a fine spherulitic groundmass. Platy fluidal structure is everywhere developed. The upper flow has more abundant phenocrysts and contains much tridymite in the gas cavities. The flows have been recognized on both sides of Rat Creek, on Bulldog Mountain, and near Bachelor. A faulted block of these flows occurs east of Rat Creek and northeast of Sunnyside, and another small outcrop was found under the basaltic division in West Willow Creek, just above the mouth of Deerhorn Creek.

Basaltic division.—Overlying an eroded surface of the flows of Bulldog Mountain is a series of thin flows of basaltic rocks, with associated tuff and breccia. These rocks are commonly dark red or dark gray and are as a rule vesicular and amygdaloidal, especially in the upper portions of the flows. Everywhere they are somewhat altered and show few conspicuous crystals. The groundmass is fine grained to glassy and incloses phenocrysts of plagioclase, augite, altered olivine, and iron ore. Just east of the mouth of Deerhorn Creek, on West Willow Creek, there is some fine-textured thin-bedded basaltic tuff associated with the flows. The division is most prominently developed just north of Bulldog Mountain, where it attains a thickness of about 500 feet. Other small outcrops were found on the south slopes of McKenzie Mountain, at several places on upper Rat Creek, and on West Willow Creek just above the mouth of Deerhorn Creek.

Quartz latite.—Unconformably overlying the basaltic division is a series of closely related flows and tuff beds of quartz latite. At the base of these rocks north of Bulldog Mountain and on the lower slopes of Nelson Mountain is several hundred feet of fine-grained tuff. The tuff is overlain by several flows of quartz latite. These flows are confined to the northern part of the area covered by the map of Creede and vicinity. They form Nelson Mountain and the ridges on both sides of Rat Creek and extend north, east, and west beyond the area under consideration. The rock of these flows is characterized by rather abundant phenocrysts of plagioclase and some quartz, hornblende, augite, and orthoclase in a spherulitic groundmass.

Augite-quartz latite of McKenzie Mountain.—The youngest flow of the area is the augite-quartz latite which caps McKenzie Mountain. A small isolated body outcrops on the east side of Rat Creek east of Butte and is well exposed in the road cuts. Its base is very irregular, as it flowed over a rugged surface. The rock is red and is usually porous. It contains larger and more abundant phenocrysts than any of the other flows and consists of crystals of plagioclase, biotite, and green augite in a spherulitic or glassy groundmass.

Rhyolite flow near Equity mine.—On Deerhorn Creek above the Captive Inca mine and extending to the north and northeast beyond the Equity mine is a thick flow of rhyolite. Near the Equity mine it is in faulted contact with the lower rhyolite. At the ridge northeast of the Equity mine and north and east of the two faults it overlies the lower rhyolite, but its relation to the other rocks is not known. It occupies the position of the second rhyolite flow of the lower rhyolite and resembles that flow somewhat but is not believed to be a part of it. The rock is rather dense and has a greenish or reddish color. Flow structure is not prominent. It has a few phenocrysts of plagioclase, orthoclase, biotite, quartz, and altered augite in a fine spherulitic or granophyric groundmass.

Lake beds.—Miocene lake beds occupy the valley of the Rio Grande and extend up the north slopes to the mouths of the canyons at Sunnyside and Creede. The material of the lake beds is commonly well bedded and well sorted. In the lower part it is made up of rather large, irregular fragments of rhyolites similar to those of the lower rhyolite with a less amount of other rocks. Higher up the material is finer, more worn and rounded, and the top is a white shaly rhyolitic tuff. Within the lake beds, especially in their upper part, are abundant irregular or lenslike bodies of travertine. This material represents the deposits of springs, probably hot springs, partly in and partly about their vents, formed during the deposition of the lake beds. This travertine is light gray or brown, but much of it is stained with limonite. It contains numerous vugs and is commonly cellular. Chalcedony and coarsely crystalline calcite are abundant in the vugs and in veinlets.

On the Hayden map of this region the limestone of the lake beds was mapped as "Lower Carboniferous" and the tuff part was called Green River, but a careful study of the two has shown that they are intimately associated and of contemporaneous age. Fossil plants collected near Sevenmile Bridge and near Wasson have been determined by F. H. Knowlton as belonging to the well-known flora of Florissant, Colo., which he now considers to be of Miocene, probably upper Miocene age. These lake beds were deposited in a very rugged basin of the lower rhyolite, but their exact relation to the other rocks of the area is not known.

Intrusive rocks.—The intrusive rocks of the area include rhyolite porphyry (quartz porphyry), quartz monzonite porphyry, and basalt. Small intrusive masses of rhyolite porphyry have been observed in several of the mines and on the hill east of the Corsair mine. A dike of quartz monzonite porphyry occurs on the ridge just south of the Alpha mine and at some places forms one wall of the Alpha fault. Similar dikes are more prominent higher in the valley of Miners Creek, and one was found on Rat Creek about a mile above its mouth. A small dike of basalt is exposed about 2 miles above the mouth of Rat Creek.

Glacial deposits.—The upper parts of all the larger valleys have been glaciated and the terminal moraines of the old glaciers of Rat Creek and of both forks of Miners Creek are partly within the Creede area. The lower limit of glaciation can be easily recognized by the abrupt change in the character of the valleys, which are broad and U-shaped above that point but are sharp gorges below. The glacial deposits are easily recognized from the fragmental character of the rocks and the hummocky, undrained character of the surface. Much useless prospecting has been done in the glacial deposits, especially to the south and east of Deerhorn Creek. In such deposits surface indications are no criteria as to what is below, and at some places the bedrock is covered to a considerable depth.

Landslides.—Large landslide areas are rather abundant in the district. They are most likely to be found where a hard, resistant bed is underlain by softer beds, such as tuffs, and where the slopes are steep. Northwest of Bulldog Mountain a large landslide extends from a point about a hundred feet below the saddle to and across the bed of Rat Creek. It is joined by the débris of another landslide from the northeastern slope of McKenzie Mountain. Farther up Rat Creek are other large landslides. West of West Willow Creek, opposite the Captive Inca mine, is a large landslide which covers the slopes for 500 feet or more and extends along them for about a mile and a half. On the southwest slope of Nelson Mountain is another landslide, and considerable prospecting has been done in it.

Talus and alluvium.—Talus covers large portions of the lower slopes in nearly all parts of the area and obscures much of the geology. Small areas of alluvium occur in some of the valleys.

STRUCTURE.

The lavas in general dip gently to the north, but the lake beds south of Creede dip gently to the south. It is not known to what extent these structures are original or to what extent they represent actual tilting of the beds.

Complicated block faulting is the most important structural feature of the region. The location and mapping of the faults is made very difficult by the lack of good exposures in many critical places, the thickness and irregularities of the flows, their close similarity in appearance, and the lack of any good horizon marker. Any statements about the faulting are therefore subject to revision. The Amethyst fault is easily located from the Bachelor mine to the Park Regent mine, but beyond that point glacial drift and landslide débris cover it for over a mile, and the area beyond has not been carefully studied. The fault strikes west of north and dips in general from 50° to 75° SW. The footwall of the fault is of the lower flow of the lower rhyolite. For a short distance north of the Commodore mine the rhyolite breccia forms the hanging wall, but to the north the rocks which outcrop are higher in the section and flows of the upper rhyolite probably form the hanging wall.

At the Equity mine is a fault which trends about N. 75° W. and which throws up the lower rhyolite on the north side in contact with a more recent rhyolite flow to the south. The displacement is probably a thousand feet or more. Above the Equity mine, just east of West Willow Creek, is another great fault which strikes a little west of north; it is marked by a small bench or sag along its line. East of it is the lower rhyolite and west of it is part of the same great rhyolite flow which lies south and southeast of the Equity mine.

On Mammoth Mountain several faults, probably of small throw, strike from south of east to east of south and bring into contact the two flows of the lower rhyolite.

About half a mile northeast of Sunnyside is a block of rhyolite, similar to the flow capping Bulldog Mountain, which is probably bounded by faults. It is rudely triangular in shape and is nearly a mile in length and about a quarter of a mile in width. Its longest side is on the south and runs a little south of east, its shortest or northwestern side running about northeast and its other side about northwest.

Other faults are mentioned in connection with the description of the mines.

ORE DEPOSITS.

PRINCIPAL GEOLOGIC FEATURES.

The ore deposits are silver-lead fissure veins in rhyolite and fractured zones of silver ore in shattered rhyolite. The total production, except a few thousand dollars, has been obtained from the silver-lead fissure veins. These are strong fault fissures and are extensive both vertically and along the strike. They include the Amethyst, Holy Moses, Solomon, Alpha, Mammoth, and several smaller lodes. All of these strike in the northwest quadrant, and the majority dip west or southwest.

Brecciation and faulting have taken place on a large scale, as is indicated by slickensided surfaces with abundant movement striæ and at some places by a lack of correspondence of the rocks on the two sides of a vein. Some of the veins fill fissures along normal faults and at some places in the hanging-wall blocks there are subordinate fissures which join the principal faults in depth. Such relations are thought to show that the hanging wall was shattered as it was drawn downward by gravity along the footwall.

Some of the veins have been opened by movement since the ore was deposited. The results of such movement in the Amethyst vein are very pronounced. The ore itself is crossed by striated slickensided planes and locally the vein quartz with associated sulphides forms a friction breccia. The ore minerals include zinc blende, auriferous galena, pyrite, chalcopyrite, and their alteration products. The gangue minerals include quartz, much of it amethystine, with chlorite, barite, and fluorite. The several veins show considerable differences mineralogically. Hydrothermal metamorphism is not pronounced a few yards away from the veins, but along the most productive portion of the Amethyst vein considerable alteration has taken place. It is attended by silicification and the development of adularia and some sericite. Ribbon quartz and banded crusts are common, indicating deposition in open spaces. At some places near the veins, however, the intensely altered replaced rhyolite constitutes good ore. For reasons which will be mentioned in a subsequent paper, it is thought that these veins have been deposited by ascending thermal waters. As they cut rocks that are probably of Miocene age, the deposits are Miocene or later.

In some of the deposits secondary enrichment is pronounced. The rich secondary ores extend downward to great depths, owing to the high relief of the area and consequent ample head of the solutions and the open character of the veins, all of which facilitate a rapid downward circulation.

The fractured zones of silver ore in shattered rhyolite include the deposits of the Mollie S. and Monte Carlo mines. The fractures and joint planes of the rhyolite are filled with thin veinlets of green chrysoprase and other green copper minerals and locally carry very high values in silver. Argentite, cerargyrite, and native silver are plastered on the walls of the thin, narrow cracks. Iron sulphides are not abundant. The rhyolite along the veinlets is apparently fresh and glassy and is not greatly affected by hydrothermal metamorphism. Deeper exploration has not exposed any body of sulphide ores, and it is possible that the rich ores of this class are genetically related to the present topographic surface.

AMETHYST LODE.

GENERAL FEATURES.

The Amethyst lode is the most important deposit of the Creede district. Its total production is estimated at about $35,000,000 in silver, lead, gold, and zinc. It is developed for about 9,500 feet along the strike, and for the greater portion of this distance it has been exploited to depths of 1,000 to 1,400 feet below the surface. Its strike is in general about N. 22° W. At the north end it strikes nearly north and at the south end it strikes about southeast. It dips southwest at 50° to 65°, or locally at greater angles.

The country rock is the lower rhyolite, which here and there is intruded by small bodies of porphyry. In most places but not everywhere the lower division of this rhyolite forms the footwall and the upper division forms the hanging wall. In the upper levels the character of the rhyolite which forms the hanging wall and of that which forms the footwall is noticeably different, especially in the Amethyst mine.

At several places along the strike the vein splits to inclose horses of the country rock, and a number of small veins make off in the hanging wall of the main fissure. These strike approximately but not exactly with the main vein. Some of them are nearly vertical or dip westward at angles which are higher than the dip of the vein; consequently they join it in depth. Others dip eastward and make angles of 30° to 60° with the main footwall fissure. These smaller veins are very numerous in the hanging wall but are comparatively rare in the footwall of the vein. As they do not cross the main fissure and are not crossed by it, it is concluded that all the fissures are of approximately contemporaneous age.

The subordinate fissures are especially well developed in the Last Chance mine. On level 6 a zone 100 feet wide includes six nearly parallel fissures, each from 6 inches to 4 feet wide. All of them dip westward, but the footwall has the lowest dip and the fissures projected join it below. Above this level the ground between the six fissures was highly altered and mineralized, and the ore body for a width of 100 feet was stoped and smelted. The position of this ore body is shown by figure 11, a cross section of the vein in the Last Chance and New York mines. In the Commodore mine, 275 feet north of Discovery shaft, on the first level below tunnel 1, six parallel veins are developed and four of these carry workable ore. As

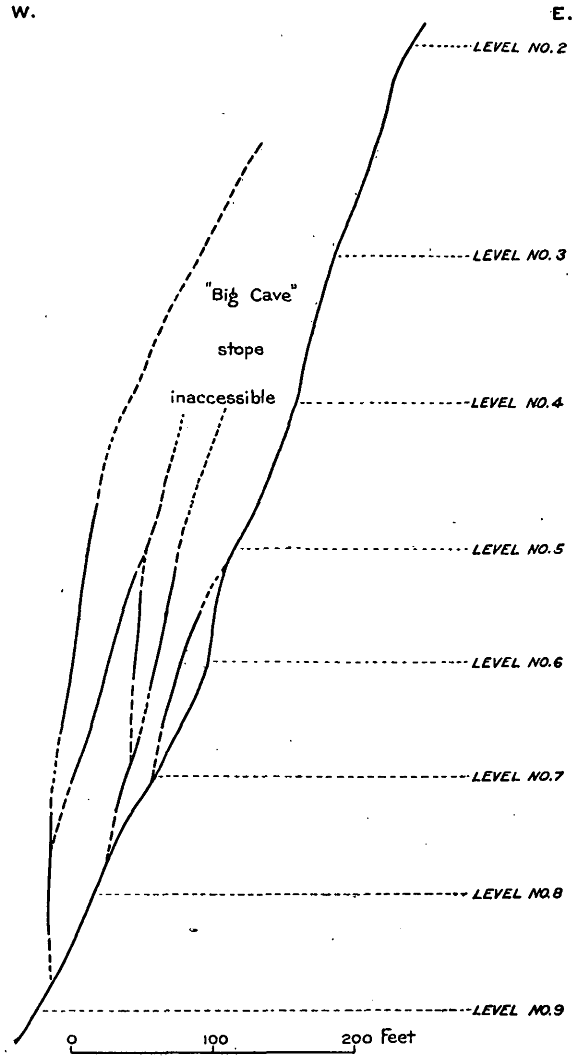


FIGURE 11.—Cross section of Amethyst vein in Last Chance and New York mines, Creede, Colo., showing the relation of the "Big Cave" stope to fractures of the hanging wall.

shown in the cross section, figure 12, these veins dip steeply into the footwall of the lode and join it about 100 feet below level 1. A large body of good ore was developed at the junction. In the Bachelor vein about 1,150 feet from the portal the vein is 16 feet wide, including a sheeted mineralized horse of country rock. The foot-wall dips about 70° S., and the wide body of ore extends downward 100 feet below level 4. Below this point the vein splits and both branches extend downward and carry ore. The vein is, as already stated, a normal fault, which implies a downthrow of the hanging wall. From the position of the minor fractures near the vein it is inferred that the hanging wall was extensively shattered as it moved downward.

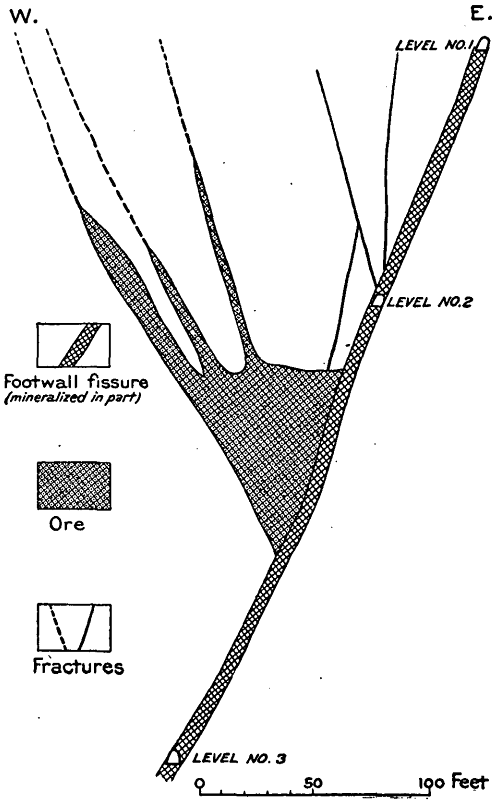


FIGURE 12.—Cross section on block 14, Commodore mine, Creede, Colo., showing fracturing in hanging-wall block.

Six mines on the Amethyst lode are credited with a production of $2,000,000 to $11,000,000 each. From south to north these are the Bachelor, Commodore, New York, Last Chance, Amethyst, and Happy Thought. North of the Happy Thought are the White Star and Park Regent, each of which has produced ore, but in much smaller quantities.

In the Wooster tunnel, which is the lowest and most extensive adit level, the lode is developed for a little less than 2 miles along its strike. At the face at the north end of the adit the vein is 3 or 4 feet wide and the ore is of comparatively low grade. The fissure is strongly developed, however, and shows no signs of playing out. On the surface about 1,000 feet above the north face of the main drainage adit the apex is concealed by débris. Some have maintained that the fault which the lode occupies passes northward approximately on its average strike to the Captive Inca mine, which is about 1½ miles north of the Park Regent, and thence to the Equity mine, which is about 1½ miles beyond the Captive Inca. The rhyolite flows are not sharply differentiated one from another, and in the absence of continuous exposures it is not possible with the data at present available to indicate the probable extension of the fault.

The apex of the lode is concealed also at its south end in the Bachelor mine. Near the point where encountered by the Wooster adit the lode makes a sharp turn and strikes about southeast. The face is not now exposed, but if the strike continues in the same direction its apex should be near the portal of the Wooster tunnel or a few paces north of it. Some shattered rhyolite is exposed at this point, but no strongly mineralized outcrop. Four hypotheses have been advanced respecting the southward extension of the lode. One is that it plays out in the Bachelor mine; a second that it continues southward to the Exchequer mine; a third that it continues southeast and joins the Mammoth vein; a fourth that it splits, one branch continuing to the Exchequer and another to the Mammoth.

The south face of the Amethyst vein is not accessible on the tunnel level. It is said that the vein is clearly defined at the face of the workings above the adit, where it carries some low-grade ore. The Exchequer tunnel is about half a mile south of this point. It passes through the lower division of the lower rhyolite. About 1,200 feet from the portal this tunnel encountered the upper division of the lower rhyolite, which is probably the hanging-wall rock, in the upper part of the Amethyst vein. The contact strikes about 20° east of north and dips 30° to 60° NW. There is much fracturing in the contact zone, but no clearly defined fault, and the two divisions are at some places tightly frozen to each other. In the upper division of the lower rhyolite there are three or four sheeted or fractured zones which strike northeast and dip northwest. These zones consist of broken rhyolite, cemented by barite but not highly altered by hydrothermal metamorphism. Here and there green copper stains impregnate the rock, and masses of quartz and galena carrying silver have been found. Much crosscutting and drifting has been done from the tunnel level, but thus far no body of workable ore has been encountered. Fragments of streaked purple rhyolite, like those which constitute the lower division, are found embedded in the upper division of the lower rhyolite and in the Exchequer mine appear to be confined to the horizon near the contact. These relations are interpreted to indicate that not much movement has taken place along the actual contact, though, as already stated, there is sheeting and brecciation in the upper division west of the contact.

The theory that the Amethyst vein and the Mammoth vein are on the same fissure is attractive to some, as the Mammoth vein would be near the line of the strike of the Amethyst vein if the latter were projected across the talus slopes in the canyons of East Willow and West Willow creeks from its face in the Bachelor mine. The Mammoth vein carries barite and a little amethystine quartz, with small amounts of silver, gold, and lead, and, like the Amethyst vein, it occupies a fault fissure. Both strike in the northwest quadrant and dip toward the southwest at about the same angle. Between the southeast end of the Amethyst vein and the northwest end of the Mammoth vein, a distance of about $1\frac{1}{8}$ miles, the country is almost completely covered with talus, which accumulates in great quantities on the lower slopes of the canyons of the two forks of Willow Creek. Just west of the East Fork of Willow Creek, about midway between the ends of the two veins, on the Jo Jo claim, a tunnel is driven westward on a slickensided plane of movement. It follows this plane for about 150 feet along its strike, which is S. 83° W. for 60 feet and N. 80° W. for 90 feet. Beyond that point the workings are caved. Near the portal the slickensided footwall shows prominent striæ, dipping 85° W. on the plane of the vein, or 5° west of the direction of the steepest dip. From 6 inches to 2 feet of crushed rock lies above the slickensided surface. Both walls of the Jo Jo fissure are of the lower division of the lower rhyolite. Some quartz that is said to carry small quantities of silver is mingled with the crushed gouge, but no ore has been stoped. The hypothesis has been advanced that the Jo Jo fissure is on the fault which has been developed in the Mammoth workings to the southeast, but no conclusive correlation can be made from the data now available.

MINERALS OF THE LODE.

The minerals which constitute the unoxidized ore in the lower levels of the Amethyst vein include zinc blende, galena, pyrite, chalcopyrite, gold, barite, and amethystine and white quartz. In the country rock along the vein secondary quartz, chlorite, adularia, and some sericite are developed. A chlorite rich in iron appears to occur in the filled portion of the vein as well as in the country rock near it. At the outcrop, in the oxidized zone, and in the zone of partly oxidized sulphides numerous minerals have formed as a result of the weathering of the sulphide ores. These include limonite, hematite, pyrolusite, kaolin, jarosite, cerusite, smithsonite, anglesite, pyromorphite, cerargyrite, native silver, malachite, and jasper. Argentite has not been identified in the Amethyst ore but is present in other mines in the district and probably in the Amethyst ore also.

Barite is much more abundant in the upper levels and in the south end of the vein than in the lower levels at the north end. It is thus associated with the oxidized ore, although it may be residual in the oxidized zone. Fluorite was not identified in the ore of the Amethyst vein, though it was noted in ore from the Solomon vein.

OUTCROP.

The outcrop of the Amethyst vein is notably inconspicuous. The sheeting and crushing which are everywhere apparent along the lode have probably favored its disintegration, and it does not form a ridge at any place. At the portal of No. 1 adit on the Bachelor claim the rhyolite is sheeted and barite stringers fill the cracks, but sulphides are very sparingly developed. Southwest of this exposure the apex of the vein, as indicated by the underground developments, is along a ravine which marks the base of a lofty, nearly vertical cliff of rhyolite. Just above the portal of tunnel 4 of the Bachelor and Commodore mines, about 650 feet below tunnel 1, the vein outcrops as a sheeted knob of iron-stained rhyolite, cut by stringers of barite. No exposures are known southwest of this point. A knob of rhyolite, somewhat fractured, is exposed between the portal of the Wooster tunnel and the portal of No. 5 tunnel of the Commodore. Whether this is on or near the apex of the vein has not been determined.

About 1,700 feet north of the portal of tunnel 1 of the Bachelor mine there is a cave on the Commodore claim where the workings extended nearly to the surface, but according to reports the ore did not outcrop at this place. Iron-stained sheeted rhyolite is exposed also just west of the Last Chance shaft near the apex of the vein. About 600 feet north of this point, between the Last Chance shaft and the Amethyst vein, there is considerable evidence of mineralization, and according to report some good ore was taken from the outcrop of the vein. Near the Amethyst shaft the stopes were raised to the very surface and are still open along the outcrop. North of this point the country is covered with glacial débris, and there are no outcrops of the vein.

None of the outcrops that have been mentioned, except the one between the Amethyst and Last Chance shafts, would perhaps be considered particularly promising. At this place only has the ore been worked at the surface, and at most places along the lode the stopes do not extend within 200 feet of the apex. In view of the persistence and the great regularity of the workable ore in the deeper levels these relations may reasonably be interpreted as indicating a leaching of the oxidized zone.

ZONE OF RICH OXIDES.

The great bonanzas of the Amethyst vein were oxidized or partly oxidized ore. This ore consisted chiefly of lead carbonate with some lead sulphate, carrying high values in silver. The gangue of the ore is quartz and silicified rhyolite stained with iron and manganese oxides. Gold was of subordinate importance in the richer oxidized or partly oxidized ores, although some of this ore carried several hundred ounces of silver to the ton. Some of the silver is present as the chloride, cerargyrite, with which is associated the lead chlorphosphate, pyromorphite. Much native silver was present in the ore mined from the upper levels. It occurred as sheets and stringers in the oxidized ore and as little balls of silver wire nesting in open cavities. A common occurrence is a red jasper with flakes and sheets of the native metal. Some selected specimens of this jasper contain as much as 10 per cent of native silver. In cabinet specimens the sheets of silver exhibit a ribbon-like structure with combs of chalcedonic quartz and both are intergrown and contemporaneous. Under the microscope the jasper is seen to be made up of quartz and finely divided iron oxide. Native silver and jasper are confined to the oxidized ore and were not noted in the lowest levels of the mines.

SULPHIDE ORES.

In the lower levels, in general about 500 to 800 feet below the apex of the vein, sulphides of zinc and lead become increasingly conspicuous. These are more abundant in ore found at higher elevations in the north end than in the south end of the lode. There is no sharp line of contact between the oxidized and sulphide zone, but along fractures the oxidation extends downward here and there to the adit level. Partly oxidized ore is found in several of the mines 1,000 to 1,400 feet below the surface.

In the lower levels of the Happy Thought and Amethyst mines the sulphide ore is cut in places by seams of black manganese oxide, and the amount of gold in parts of such ore is conspicuously greater. The minerals of the sulphide ore include pyrite, sphalerite, galena, and a little chalcopyrite; probably some argentite is present also. The sulphur compounds of arsenic and antimony have not been noted.

SECONDARY ENRICHMENT.

In many deposits of copper, silver, and gold the ore near the surface is of relatively low grade and unworkable. At greater depths richer ore is encountered and at still greater depths such ore gives way to lower-grade sulphides. These relations are generally assumed to indicate that the metals have been dissolved out of the upper portion of the ore bodies and have been redeposited lower down. The leached portions of the deposits are in general highly oxidized. The richer portions are only partly oxidized, whereas the lower-grade ore in the deeper portions of the deposits shows comparatively little alteration. Briefly stated, many deposits may be divided into four zones—(1) an oxidized leached zone at or near the surface, (2) an oxidized or partly oxidized zone of richer ore below the leached zone, (3) a zone of rich sulphides below the rich oxidized ore, and (4) the lower-grade primary sulphide ore below the rich sulphides.[1]

These relations are indicated by the vertical distribution of the richer ore of the Amethyst vein. The horizon of the richest ore is in general from 200 to 800 feet below the surface, although such ore extended to the outcrop between the Amethyst and Last Chance shafts. The upper portion of the richer zone was highly oxidized, but a considerable number of nodules and masses of sulphide ore were present in the lower portion and the number of these increased in depth. The values in the oxidized ore are in silver, chiefly as the native metal and the chloride, and in lead, as the carbonate and sulphate. The proportion of gold to silver increased greatly below the thoroughly oxidized ore, suggesting a transfer of gold by descending waters. The lode is very strongly fractured and considerable oxidation has taken place along fractures and seams as deep as exploration has gone, or more than 1,200 feet below the surface. Limonite, set free by the oxidation of iron sulphides, and manganese oxide, liberated by the weathering of amethystine quartz, were deposited along some of these fractures. The great bulk of the ore in the lower levels carries from 6 to 20 ounces of silver to the ton, 5 to 15 per cent of lead, $1 to $2 to the ton in gold, and a variable percentage of zinc. Some of it is well within the limit of profitable exploitation, although it is considerably lower in grade than much of the more highly oxidized ore in the upper levels.

EXTENSION IN DEPTH.

As bearing on the possibility of profitable developments below the adit level, inquiry may be made respecting the position of this level in the zone of secondary enrichment. If the adit is below the bottom of the altered zone any ore bodies that may be encountered below the adit will be primary. If the adit is above the bottom of the zone of alteration, bodies of enriched ore may be expected. One would be bold indeed to prophesy in advance of development that such ore bodies will or will not be found, yet there is some evidence that bears directly on this point.

With respect to the distribution of silver it may be stated frankly that no bonanzas comparable to those which were worked in the upper levels of the mines have been developed within 100 feet of the adit level. Stopes have been raised at many places from the adit, but they are small compared with those higher in the vein and as already stated the ore in them is generally of lower grade. The evi-

[1] Emmons, S. F., Trans. Am. Inst. Min. Eng., vol. 30, 1900, p. 177.

dence of values alone, however, does not warrant the conclusion that the bottom of the zone of possible enrichment has been reached. The state of the ore with respect to alteration processes is important in this connection. At the southeast portion of the vein, in the Bachelor and Commodore mines, comparatively thorough oxidation extends to greater depths than in the mines on the lode farther north. At some places a considerable amount of oxidation has taken place in the Bachelor mine within 100 feet of the adit, and on the Commodore claim, which lies just north of the Bachelor, a stope called the Wire Silver stope was raised from level E, which is just above the Commodore tunnel. The bottom of this stope is about 225 feet above the Nelson drainage adit and about 1,200 feet below the surface. Although this stope was not accessible to the writers, the presence of wire silver in the ore is regarded as an indication of secondary alteration. A winze that was sunk below the adit in the Bachelor mine is now filled with water, but according to report some sulphide ore of shipping grade was developed.

The fracturing of the lode is very great and the secondary fracturing is complicated, the ore being much more permeable at some places than at others. On the whole, however, the circulation of water from the surface is exceptionally vigorous, owing to the highly fractured condition of the ore. These observations lead to the conclusion, therefore, that the adit level in the Bachelor and Commodore mines is probably not below the bottom of the zone which is marked by partial secondary alteration of the ore. Whether processes of enrichment have gone far enough to make exploration of this part of the lode profitable is a question which can not now be answered.

The northwest end of the lode, as already stated, is not so thoroughly oxidized in the lower levels as the southeast end. Nevertheless the sulphide ore in the lower levels of the Last Chance, Amethyst, and Happy Thought is crossed by numerous fractures in and along which limonite and manganese oxide have formed. Some of the ore which is cut by stringers of these oxides is low-grade concentrating ore. Locally, however, this ore carries considerable values, the increase being mainly gold. On level 12 in the Amethyst mine the ore 350 to 600 feet north of the shaft is composed of galena, zinc blende, pyrite, chalcopyrite, and other minerals and is said to carry about 11 per cent of lead, 6 to 8 ounces to the ton in silver, and about \$1.20 to \$3 to the ton in gold. In another stope about 800 feet north of the shaft and just below level 12 similar ore containing conspicuous veinlets of manganese oxide carries from \$5 to \$15 to the ton in gold. In the Happy Thought mine, 370 feet north of the bottom of the shaft, the sulphide ore only 20 feet above the adit level is cut by veinlets of manganese oxide. This ore is said to carry 8 per cent of lead, about \$1.80 to the ton in gold, and a little silver.

There is not much doubt that the gold of this ore has been increased somewhat by secondary processes, for the association of gold with manganese dioxide is significant of such processes.[1] For example, in the Happy Thought mine on the Amethyst vein between levels 7 and 8 a body of partly oxidized ore composed of galena, zinc blende, copper carbonates, cerusite, and anglesite carries a conspicuous amount of manganese dioxide, which coats the older sulphides and occurs in fractures cutting the partly oxidized ore. A considerable tonnage of this ore concentrated in the Humphrey mill yielded $20 in gold to the ton, and some of it ran as high as $100 to the ton. This figure is of significant magnitude, for the average content of gold in the Happy Thought ore is about $2 to the ton.

In reviewing these facts it is pertinent to inquire whether they warrant the expectation of any enrichment of gold below the adit level in the north end of the Amethyst vein. It has been shown that gold in these relations is found in stopes just above the adit level, but so far as is now known the enrichment of gold due to secondary deposition at this level is not great. The present methods of concentration, however, permit the recovery of lead, silver, zinc, and gold, and in much of the ore the gold values are rather subordinate. Silver is comparatively low in these levels, but so far as is indicated by the data available there is no reason to suppose that lead and zinc will be less abundant in the zone 200 feet below the adit than in the zone 200 feet above it, provided, of course, that the ore of the vein maintains an equal width.

In connection with the possibilities of profitable development below the adit level certain considerations other than the changes in the character of the ore in depth merit attention. The amount of water which issues from the portal of the adit is very great, and most of it is collected in that part of the adit which is driven on or near the vein. No notable quantity of water is added in the portion of the adit that crosscuts the country rock. In sinking a deep winze that was put down in the footwall in the Commodore mine pumping charges were high, and they would doubtless have been higher if the crosscuts had been run to the vein. Owing to the highly fractured condition of the vein, any project which contemplates deep exploration should provide for handling a considerable proportion of the water now draining from the adit. Some of this drainage could probably be kept out of lower workings, but extensive stoping below the adit would surely increase the flow.

The possibilities of tunnels below the Nelson adit have, of course, been considered. A crosscut driven north for 5,500 feet from a point near the mouth of Windy Gulch should encounter the lode at a depth

[1] Emmons, W. H., The agency of manganese in the superficial alteration and secondary enrichment of gold deposits in the United States: Trans. Am. Inst. Min. Eng., 1910, p. 767.

between 250 and 300 feet below the Nelson adit. This would not provide for dumping, however, and would necessitate a long extension of the track for disposal of waste. The expense of such an undertaking could be decreased by the development of cheap electric power, but the writers do not profess to know whether the possibilities of finding profitable ore below the adit level would warrant the necessary outlay of capital.

SOLOMON AND RIDGE GROUP OF MINES.

The Solomon and Ridge group of mines is on the west side of East Willow Creek canyon, about 2 miles north of Creede. The claims located on this group include the Holy Moses, Ridge, Ethel, Mexico, and Solomon. All these deposits are in the two divisions of the lower rhyolite. The principal deposit is an anastamosing fissure vein which strikes about N. 7° W. and dips 55° to 85° W.

Underground developments are almost continuous for about 3,300 feet along the strike of the lode. The most extensive developments are on the level of the Solomon tunnel, which is driven westward from the canyon of East Willow Creek at an elevation of about 9,300 feet. This level encounters the vein about 420 feet from the portal, and from the point of intersection a short drift is driven toward the south. About 75 feet to the north the vein splits, inclosing a narrow block of rhyolite. The two branches diverge along their strike and at a point 800 feet from the intersection they are 300 feet apart. The east branch is termed the Ethel vein and the west branch the Solomon vein. In the Ridge tunnel, which is about 90 feet above the Solomon adit, the east vein is termed the Ridge and the west vein the Mexico. The two branches probably join toward the north, but the point of intersection is not shown in the underground developments of the Solomon and Ridge mines. This point, estimated by projecting the two branches in the workings of the Ridge adit, is probably about 1,950 feet north of the south intersection. If this estimate is correct the horse of rhyolite inclosed between the Solomon vein and the Ethel branch is 1,950 feet long and has a maximum width of about 300 feet. Both veins dip as a rule from 55° to 75° W. but at some places are vertical or dip steeply to the east. North of the point which is assumed to be the north intersection the Solomon vein is developed for about 1,000 feet along the strike. At the north face this vein strikes north and dips 75° W. Above this point, at an elevation about 1,100 feet higher, the Holy Moses vein is developed from No. 1 adit level, where it strikes north and dips 56° to 66° W. Although the underground workings are not connected, it is thought that the Solomon and the Holy Moses veins are on the same lode. If this conclusion is correct the lode is approximately a mile long.

On the surface the Solomon and Ethel veins are exposed at several points on the Ridge ground. Brecciation and slickensiding of the walls are evidence of movement, but so far as may be judged from exposures the faulting has involved but one formation. The ores carry some sulphides at the outcrop. Owing to the low content of gold and silver in these veins, however, very little secondary concentration is apparent at or near the surface.

The ore of the Solomon and Ethel veins is composed of galena, blende, pyrite, and a little chalcopyrite in a gangue of green chlorite, talc, and quartz. A little fluorite is present in some of the ore. It carries a small amount of gold, but its silver content is very low. In some of the ore gold and silver together are below $1 a ton, the lead running as high as 35 per cent. Barite is not abundant in the ore of the vein now exposed, although a little was found in the Holy Moses workings, which are probably on the same vein. Amethystine quartz was not noted, nor is quartz conspicuous in any of the ore. Extensive crushing has taken place since the ore was formed; indeed, both the Solomon and Ethel veins at most places are zones of green gouge with abundant crystals of galena and zinc blende mixed with considerable crushed country rock. At some places the sulphides are powdered and mixed with a green mud resembling putty. There is probably considerable microscopic silica, but very little is visible in much of the ore.

The veins vary in width from 1 or 2 feet up to 15 feet. In the Ridge mine, about 250 feet north of the blind shaft on the lower tunnel level, 150 feet up in the stopes, the vein is 10 or 15 feet wide. It dips 72° W. and a smooth slickensided surface is near the footwall. This surface is polished and grooved by movement, and the grooves are inclined in the plane of the vein, dipping about 15° to the south of the line of steepest dip. The vein here consists of white and green mud, carrying many fragments of rhyolite, not highly altered. Here and there streaks of nearly pure zinc blende and galena are included in the crushed mass, and crystals or lumps of the powdered sulphides impregnate the mass. Locally seams of limonite cross the ore and some portions of the vein are oxidized. The sulphides predominate, however, although the ore is within 150 feet of the surface at this point. About 250 feet north of this point, on the adit level, 400 feet below the surface, oxidized ore was found at the north end of the workings.

Where exposed in the Solomon workings the vein is a great crushed zone, and a slickensided fissure runs nearly the whole distance through which the vein is developed. This fissure is in general on the hanging wall of the vein. About 2,000 feet from the portal of the Solomon adit a shaft has been put down about 400 feet. North of the shaft and about 3,150 feet from the portal of the adit, in a raise 70 feet above the tunnel level, 9 feet of concentrating ore is exposed. This consists of zinc blende, galena, some pyrite, and a little limonite and manganese dioxide. The gangue is crushed rhyolite and green chloritic gouge, much like that in parts of the Amethyst vein. The ore carries 30 per cent of zinc and lead, with 1 to 3 ounces of silver and $1 to $2 in gold to the ton.

About 80 feet above tunnel level and 1,100 feet below the surface the sulphides change abruptly to oxides. The ore there consists of cerusite, limonite, manganese dioxide, a little galena and zinc blende, and considerable pyrite. This ore carries about $2.50 to the ton in gold. Two feet above the partly oxidized ore no unaltered sulphides were noted. The occurrence of oxides along fissures and fractures far below the zone of complete oxidation is conspicuous, as it is also in the Amethyst vein.

ALPHA LODE.

The Corsair and Alpha mines are at Sunnyside, near the point of the ridge between Miners and Rat creeks, about 2 miles west of Creede. They are on the same lode and together have yielded about $600,000 in silver. Three adits are driven in the lode at different elevations on the southwest point of McKenzie Mountain. About 900 feet from the portal of the Corsair adit a winze equipped with steam haulage has been sunk to a depth reported to be about 155 feet. This is now submerged. On the surface a number of shallow inclines and pits are sunk on the outcrop, a few of them showing sheeted siliceous rhyolite stained with iron oxides. The vein, striking a little west of north, extends nearly along the crest of the ridge for about 600 feet to a point where it bends northwestward and strikes approximately parallel to Miners Creek. On the surface the dip is 50° to 65° NE.

The deposits are mainly in the lower rhyolite, which is intruded by dikes and irregular masses of quartz monzonite porphyry. The lode occupies a fault fissure, which may be followed along the southwest slope of McKenzie Mountain for 4,000 feet along the strike.

In the upper tunnel on the Alpha claim the vein is encountered about 100 feet from the portal. From that point it is followed northward in a drift 700 feet along the strike. It is a wide faulted zone, sheeted and highly crushed. For the greater part of this distance rhyolite forms the footwall and porphyry the hanging wall. At a point about 550 feet from the portal both walls are porphyry. Near this point the vein splits, and the zone of sheeting and crushing is about 75 feet wide. At the end of the upper tunnel short stopes from 1 to 5 feet wide have been raised on three veins which occupy the sheeted zones.

The workings on the upper tunnel of the Alpha are holed with the workings of the Corsair tunnel, which is driven on the vein at a level

75 feet lower. In the Corsair ground near the boundary between the two properties the vein is greatly fractured. The most persistent fissure strikes north for about 150 feet, then bends, and is followed northwest for 450 feet. For the greater part of this distance a warped slickenslided plane dipping about 53° NE. separates the rhyolite of the footwall from the porphyry of the hanging wall. The ore where stoped was nearly everywhere in the footwall of the fault and showed a preference for rhyolite rather than for porphyry.

The deposit where exposed is a replacement vein. Crustified structures such as are characteristically developed in simple fissure fillings are not conspicuous but were noted at some places. The ore contains much finely divided pyrite and nearly everywhere is heavily stained with iron oxide and a blue sulphate. According to report the values are mainly silver chloride. Barite is present but is not so abundant as on the Amethyst vein. Amethystine quartz is not abundant, but most of the quartz is a chertlike variety, probably a replacement of rhyolite. Argentite, stephanite, and stibnite have been reported from the lower levels, which are now inaccessible. None of the ore is suitable for concentration, and all has been shipped to smelters. That carrying below 30 ounces of silver to the ton is not profitable under present conditions. According to report the bulk of shipments carried between 40 and 70 ounces of silver to the ton, but some selected ore is reported to have carried over 1,100 ounces.

OTHER MINES AND PROSPECTS.

Besides the mines on the Amethyst, Alpha, Solomon-Ridge, and Mammoth lodes there are several other mines and prospects in the district, some of which have produced a few carloads of ore. Space does not permit more than brief mention of them in this preliminary paper.

Considerable development work has been done in the Monon mine, at Sunnyside, and in the Kreutzer Sonata, Paris, and Diamond King properties, on Miners Creek. Between Sunnyside and Bachelor are the Bethel, Little Gold Dust, Conejos, North Star, and Jack Pot lodes. North of the Park Regent mine are the Dolgooth, the Captive Inca, and the Equity. The Oxide claims are southeast of the Mammoth claim, probably on the extension of the Mammoth vein. The Jo Jo, between the Bachelor and the Mammoth veins, has already been mentioned. Several claims are located in the steep cliffs which form the west slopes of Mammoth Mountain. Of these the Mollie S., Eunice, and Homestake have produced some ore. The Monte Carlo mine is across the canyon of East Willow Creek, opposite the Mollie S., and the ore of the two mines has many features in common. Two or three prospects located near the head of West Willow Creek have not yet been visited.

A PRELIMINARY ACCOUNT OF THE ORE DEPOSITS OF THE LOON CREEK DISTRICT, IDAHO.

By Joseph B. Umpleby.

SITUATION AND HISTORY.

The Loon Creek district comprises an unorganized area of perhaps 75 square miles situated in the northwestern part of Custer County, Idaho. It is drained by the headwaters of Loon Creek, a tributary to the Middle Fork of Salmon River. The Parker Mountain district lies to the northeast, Sheep Mountain to the west, and the Yankee Fork district to the southeast. Mackay, Idaho, situated 110 miles southeast of Ivers, the principal local settlement, is the supply point for the region.

Placers which are variously estimated to have produced from $500,000 to $2,000,000 in gold were worked actively on Loon Creek during the decade closing with 1879. Most of the white men in the camp, attracted by other placer excitements, left the creek in the middle seventies, but 30 or 40 Chinamen remained. In 1879 all of these were massacred save one, who escaped on snowshoes At that time it was commonly supposed that Indians committed the deed, but now it is the prevalent opinion that white men were guilty. Since then comparatively little mining has been done on the creek, though all the promising ground is held as placer claims.

The principal property in the district at present is the Lost Packer mine, located by Clarence E. Eddie, a prospector, in July, 1902. Soon thereafter it was purchased by Ivers & Finlan, of Salt Lake, who began to develop it in the spring of 1904. A 100-ton smelter was completed in 1905, and although it has been necessary to haul coke 110 miles, development has been carried on with the returns from three short smelter runs—one in 1907, one in 1908, and one in 1911. Several other properties are situated in the district, but they are little developed and most of them have changed hands several times, successive holders becoming discouraged because of the difficulties of transportation. As a whole, the district is inadequately prospected and mining is in an initial state. Among the lode deposits those of gold-copper and silver-lead are most promising.

CONDITIONS AFFECTING MINING.

The district is a well-timbered and well-watered area of bold topographic forms. Sites suitable for the development of water power are numerous, though only Canyon Creek, a comparatively small stream, is now being utilized. The bold relief makes it possible to obtain a depth of 1,000 to 2,000 feet on most of the deposits without resorting to shafts. Suitable fluxes for local smelting are abundant in the district. Indeed, the only handicap to successful and economical mining operations is the expense of freighting supplies and especially coke from the Oregon Short Line terminus at Mackay, 110 miles distant. The route is difficult because of two high summits which must be crossed in addition to the 3-mile climb from Loon Creek to Ivers. The cost of haulage is 2½ cents a pound per round trip. When a load can be taken each way this is split into 1½ cents in and 1 cent out. The cost of coke is therefore the prime problem in local smelting, its average price laid down at Ivers being $46 a ton.

The various expenses charged against a ton of ore delivered as matte, f. o. b. Mackay, aggregate $20 to $22. It is this high cost which is serving as a damper on development in the Loon Creek and adjoining districts; the need of the region is railroad transportation. Only ores running $60 to $80 a ton have been smelted, but for every ton of this grade which has been developed there are estimated to be 2½ tons which will average $25.

GEOLOGY.

Physiography.—The Loon Creek district is a mountainous area varying in elevation from 5,000 to more than 9,500 feet. Loon Creek, a rapid stream averaging perhaps 30 feet in width, flows north through the area. Its most important tributaries are Mayfield and Cottonwood creeks from the east and Trail, Canyon, and Grouse creeks from the west. The area is a part of that broad region known as the Salmon River Mountains and preserves upon its highest parts the Eocene erosion surface from which those mountains were carved. These remnants constitute the most significant geologic datum plane in the region.

Sedimentary rocks.—The oldest rocks recognized in the district are mica schists and quartzites of Algonkian age, which outcrop over an irregular area of about 2 square miles in the central part of the district. In most directions they are cut off by late Cretaceous or early Eocene quartz diorite, but to the north they disappear beneath a capping of quartz latite. Throughout these ancient sediments few bedding planes are discernible, a strong schistosity striking west of north and dipping southwest being the dominant structural feature.

Overlying the Algonkian rocks in the south-central part of the area are beds of Paleozoic age. Although these beds are presumably separated from the underlying rocks by a pronounced structural unconformity, this relation was not observed in any of the exposures visited. As a rule areas of intrusive rock separate the two sedimentary terranes, but near the Lost Eagle mine they are in juxtaposition. This contact, however, is probably due to faulting. The Paleozoic series includes fine-grained quartzites and massive blue dolomitic limestones, both apparently nonfossiliferous. Nevertheless the similarity of the rocks to those at Gilmore, Lemhi County,[1] suggests that the quartzite is of Cambrian age, and that the massive blue dolomitic limestone is Ordovician. Their thicknesses were not determined. Higher beds of the Paleozoic probably outcrop in the extreme south-central part of the district, but this area was not visited.

Igneous rocks.—Igneous rocks of diversified types are widely distributed in the Loon Creek district. The oldest of these is a great batholithic mass of quartz diorite that extends into the district from the west. Outliers from it appear at several places east of the area of Algonkian schists, and about 3 miles farther east another broad area of the batholith, which is thought to underlie the entire district, is uncovered. The rock has a dark-gray color, due to the conspicuous amounts of biotite scattered through it. The feldspars are of medium size and about the composition of oligoclase. Orthoclase, though commonly present, is not an essential constituent. Quartz occurs as irregular grains and small interstitial fillings. Hornblende, nowhere abundant, and titanite and apatite are commonly present. This rock is thought to be a special phase of the great granitic intrusion which occupies an area of more than 20,000 square miles in central Idaho. This intrusion has been assigned, on what seems to be sound evidence, to the late Cretaceous or early Eocene.

Closely related to the quartz diorite are dikes of granite that is notably poor in ferromagnesian minerals. These are excellently shown in the Lost Packer mine, where they vary from narrow stringers to dikes 30 feet or more in width and usually follow the schistosity of the Algonkian rocks. Locally, however, they follow the vein fissure, which strikes west of north but at a much lower angle than the schistosity of the inclosing formation. It is thought that this rock is younger than the quartz diorite intrusion and that it is a differentiation from that mass. It is older than the ore deposits. When examined microscopically the granite dikes are seen to be made up of microcline, orthoclase, quartz, muscovite, a little plagioclase, and subordinate amounts of biotite. Apatite and zircon are the principal accessory minerals. Secondary pyrite is developed locally.

[1] Umpleby, J. B., Geology and ore deposits of Lemhi County, Idaho: Bull. U. S. Geol. Survey No. 528 (in press).

Subsequent in age to both the granite dikes and the veins are dikes and sills of granite porphyry and diorite porphyry. The relative age of these rocks has not been satisfactorily determined, although there is some evidence for thinking that the diorite is the older. Both rocks traverse the ore in several places and on the No. 3 level of the Lost Packer mine the two intersect, but the fine grained and extremely altered condition of the specimens from this point make it impossible to determine whether the older one should be correlated with the diorite porphyry or with the granite porphyry. Near the portal of No. 6 tunnel, however, the diorite porphyry presents a marginal facies similar to the older dike in No. 3 tunnel and from this it is thought that the granite porphyry is the younger. In the larger masses a phenocrystic development of quartz characterizes the granite porphyry, but this is lacking in the narrower dikes.

Eruptive quartz latites, probably still younger than the dikes and sills described above and certainly more recent than the veins, cap the summit above the Lost Packer mine. They are gray in color and are made up of phenocrysts of oligoclase, quartz, and biotite set in a microcrystalline groundmass which constitutes perhaps 60 per cent of the rock. Partial chemical analysis reveals 3.26 per cent of potassium oxide, which makes it necessary to class them as quartz latites instead of dacites as suggested by the microscopic description. It is thought that they are younger than the Eocene erosion surface.

Glaciation.—During the Pleistocene epoch alpine glaciers extended down the larger valleys to points about 7,000 feet above the sea—locally perhaps to 6,000 feet. Canyon Creek, which supplies water and hydroelectric power to Ivers, heads in three little lakes situated in the floor of a broad cirque in the north slope of Pinon Mountain and illustrates well the habits and limits of the local glaciation.

ORE DEPOSITS.

GENERAL FEATURES.

The Loon Creek district is noteworthy at present because of its gold deposits. These include lodes in which chalcopyrite and siderite carry most of the gold and placers along the streams in favorable places below them. From the lodes $350,000 has been derived, and from the placers possibly $1,000,000. The lode deposits have yielded $150,000 in copper along with the gold. Lodes of lead-silver have also been recognized in the district, but are inadequately developed. The ore found in them, however, is of excellent grade, being in many places clean galena carrying from 60 to 100 ounces of silver to the ton.

Excellent iron and lime fluxes are abundant along the contact between the Paleozoic limestone and the quartz diorite south of Ivers. These contain about 60 cents in gold and 1 ounce in silver to the ton—almost sufficient to pay for handling them. Whether or not they are contact-metamorphic deposits has not been established.

GOLD-PLACER DEPOSITS.

The Loon Creek Hydraulic Placer Co. owns six claims—in all, 470 acres—which extend from a point near the mouth of Canyon Creek to the Loon Creek Narrows, 4½ miles north. The average width is approximately 1,000 feet. A strip about 75 feet wide and 1 mile long, comprising the upper part of the central channel, was worked during the early seventies and is said to have produced a large amount of gold, occasional pans containing as much as $300. The gravels here were from 2 to 6 feet thick, but back of them are gravel terraces which were not explored during the early days. The present owners prospected these terraces during two seasons, making an average saving of 25 cents a cubic yard. A flume capable of delivering 80 second-feet of water to any point on the ground is partially completed and is part of a matured plan for hydraulicking the entire deposit. Heretofore water has been derived from two small streams—Grouse Creek and White Creek—but the present plans include the diversion of Loon Creek at a point well above the placers.

The auriferous gravels rest upon a floor of schist which as now explored presents a comparatively even surface. The gravel beds are rarely more than 15 or 20 feet thick, although locally attaining a depth of 30 or 40 feet. The individual pebbles are usually less than 6 inches in diameter, but locally bowlders up to 3 feet and rarely 6 feet in diameter are found at various distances from the base of the deposit. Being loosely cemented, the gravels fall apart readily when undermined by the giant. The gold is near bedrock, commonly in joints and shallow depressions in it, and as a rule is coarse, nuggets weighing more than an ounce being not uncommon and perhaps 50 per cent of the product averaging 25 cents a color or more. Its market value is $18 an ounce.

GOLD-COPPER DEPOSITS.

A description of the Lost Packer vein constitutes essentially a description of the known gold-copper deposits of the district. Other veins are recognized, but they are little developed and have produced only returns from test samples. Promising among these is the Effa ledge, which outcrops a few hundred feet west of the Lost Packer vein. The Sunset and South Packer groups also present some encouragement to the holders, although the small amount of development on them has not revealed commercial deposits.

The Lost Packer vein is a fissure filling inclosed in mica schist throughout most of its extent, though in places it traverses granite dikes. Later than the vein are a number of flat-lying dikes of granite porphyry and diorite porphyry, which vary in width from 5 to 80 feet, those about 30 feet across being most common. Ten of these dikes have been encountered and each one traverses the vein. The ore adjacent to them is usually crushed, and in places is separated from the intrusion by a gougelike layer as much as 3 inches thick. The most important effect of the dikes on the ore body, however, consists of offsets. In places there is a small lateral displacement of the vein as if the dike had entered along a fault plane, but usually the intrusion has acted simply as a wedge, prying apart portions of the vein formerly contiguous and leaving them opposite each other along a course at right angles to its surfaces. As the dikes roughly parallel the ore body in strike but dip westward at a much lower angle than it, there is a series of offsets to the east with increasing depth on the vein. (See fig. 13.)

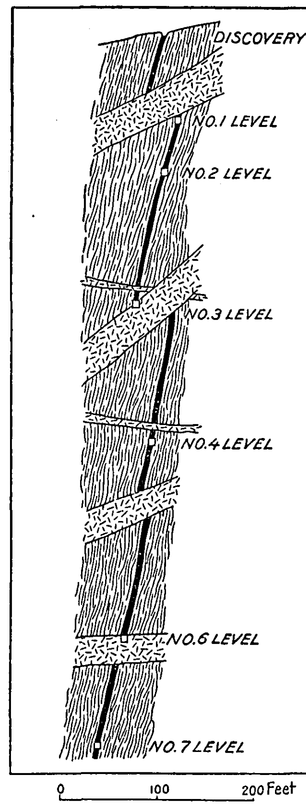


FIGURE 13.—Transverse section through Lost Packer vein, Loon Creek district, Idaho, looking north. Illustrates offsets in the vein caused by the intrusion of dikes.

The Lost Packer group of six claims and two fractions covers the known extent of the Lost Packer vein, which begins at Ivers and extends northward, successive portals being near the bed of the steep gulch which it approximately follows. The vein strikes north and south and dips 75° W. The development consists of 10 tunnels aggregating about 10,000 feet in length, which explore the deposit to a level 1,000 feet below its highest outcrop.

The vein varies in width from a fraction of an inch to 4 or 5 feet, averaging perhaps 20 inches. In most places it lies between well-defined walls which stand about 5 feet apart, the intervening material being gouge, sheeted schist, or ore. In many places all three appear in the same cross section, but even there the ore is usually a separate band, next to either the hanging wall or the footwall, more commonly the latter. In a few places small lenses of ore occur in the schist as far as 20 feet from the vein, but this is exceptional; usually the mineralization is confined to the fissure.

Three ore shoots, locally designated the north, south, and middle shoots, are recognized in the vein. These are connected on some levels by stringers, but as they are not of the same degree of importance and as they present somewhat different types of mineralization, they will be discussed separately. The north shoot is reached only by No. 4 and No. 3 tunnels. On the former it is 120 feet and on the latter 250 feet in length. Its average width is about 2 feet. The ore consists of coarse-textured milky to bluish-white quartz, with chalcopyrite and a little pyrrhotite and pyrite irregularly scattered through it, the chalcopyrite in places inclosing small crystals of the other minerals. On No. 3 level siderite is rare, but on the next level below it is equally abundant with chalcopyrite and presents a similarly irregular distribution. This ore body is comparatively lean, roughly sorted material running about $20 a ton—half an ounce of gold, 2 ounces of silver, and 3.5 per cent of copper.

The middle shoot is by far the most important in the mine. It lies 200 feet south of the north shoot and is developed from the seventh level to the quartz latite capping, 700 feet above. Like the two others, it has a general pitch to the south. The southern limit of ore is a fairly regular line, but the north boundary is not parallel to it. Thus the shoot is about 500 feet long on No. 2 level but narrows both above and below, so that its average length is about 300 feet.

In places this ore body stands in slight relief at the surface as a honeycombed quartz heavily stained by iron, together with a little manganese oxide and copper carbonate. Usually, however, it has little or no surface expression. Oxidation is unimportant in the deposit, primary ore predominating at a depth of 30 or 40 feet and being exclusively present below 70 or 80 feet. The ore averages about 20 inches in width, but locally is as much as 4 or 5 feet, wedging out on the ends of the shoot. This wedging out of the shoot seems to bear a definite relation to the tenor of the ore, for it has been commonly found that as the ore body narrows its assay value diminishes. Thus the ends of stopes temporarily abandoned are usually in ore running about $25 a ton, whereas the portion removed varies between $60 and $80 a ton. On No. 4 level the middle shoot is shorter than anywhere else in the mine and here also it contains a minimum amount of gold. Ore from levels both above and below ran 2 to 3 ounces of gold to the ton, but here less than 1 ounce was present.

The ore consists essentially of chalcopyrite distributed as bunches, small patches, irregular grains, and interstitial fillings in a gangue of coarse white quartz. The copper mineral constitutes about one-third of the total material mined. Siderite is present in small amounts but is not an important constituent. The chalcopyrite and quartz carry each about 3 ounces in gold to the ton, but less than half an ounce is present in the siderite.

The south shoot of ore differs markedly from the other two in the high percentage of siderite which it contains. It lies 500 feet south of the middle shoot and is developed from No. 10 level to its outcrop near the portal of No. 6 tunnel. This ore body varies in length from 75 to 150 feet and is about 20 inches wide. It consists of siderite and chalcopyrite in a gangue of coarsely crystallized quartz, in such proportions that the ore runs 26 per cent of iron and 4.5 per cent of copper. Gold and silver, averaging half an ounce and 3 ounces, respectively, are present. This shoot of ore is a valuable asset to the mine because it combines a fair amount of the precious metals and copper with an excess of iron, an element which must be added in the smelting of ores from the other shoots.

The three ore shoots worked in the Lost Packer mine have been described as separate units and as such they are mined, but in reality they are not distinct. All occur on the same fissure and on most levels stringers of low-grade ore connect them.

Considerable ore is blocked out in the mine and this will probably be materially increased during the present year. Returns from the last smelter run will be used to extend No. 7 tunnel beneath the north shoot and No. 10 tunnel beneath the middle shoot.

SILVER-LEAD DEPOSITS.

Silver-lead deposits have been found near the limestone area south of Ivers. The Lost Eagle claim and the Metcalf group are the principal properties, but neither is sufficiently developed to afford a satisfactory idea of the nature or extent of the ore bodies. Their occurrence, however, is thought to be of special significance and in order to emphasize this they will be described briefly. The Lost Eagle is situated on the divide between Canyon and Deer Creek cirques, at an elevation of 8,800 feet above the sea. It is inclosed in Algonkian schist though removed but a few hundred feet from an area of Paleozoic dolomitic limestone. The development consists of a shaft 50 feet deep and a short drift from it. The vein, which strikes N. 5° W. and dips 85° SW., is about 6 feet wide and is bordered by well-defined walls. Between them is crushed wall rock inclosing bands and interstitial areas of argentiferous galena, pyrite, and a little chalcopyrite in a quartz-siderite gangue.

The Metcalf property, situated about 1,000 feet northeast of the Lost Eagle shaft, contains an irregular vein partly developed for about 100 feet along its outcrop. The deposit is a fissure filling inclosed in granite near its contact with Paleozoic dolomitic limestone. The ore consists of argentiferous galena which fills the fissure almost exclusively and varies from a narrow stringer in most places to a body 3½ feet wide locally. The galena contains about 1 ounce of silver to the unit of lead.

In both of these deposits the amount of ore actually found is not of so much significance as its mode of occurrence. Both deposits are inclosed in rocks which are not nearly as favorable to the deposition of lead ore as limestone, even where that is impure; hence, in the opinion of the writer, the area of dolomitic limestone adjacent to them should be encouraging territory for the prospector. In the few places where time permitted an examination of the dolomitic limestone it was found to be rather intensely mineralized. The three iron mines which supply flux to the Ivers smelter illustrate this point. Each is a deposit of pyrite, now oxidized, which has replaced the dolomitic limestone.

SUMMARY OF CONCLUSIONS.

The more important points brought out in this preliminary report may be summarized as follows:

1. The Loon Creek district is a poorly prospected area of more than ordinary promise.
2. It is held back primarily by inadequate transportation, the nearest railroad point being 110 miles distant.
3. There are noteworthy gold placers in the area.
4. The principal gold-copper deposit has been explored to a depth of 1,000 feet, and throughout this extent the ore has ranged in value from $25 to $90 a ton, giving no evidence of impoverishment with increasing depth.
5. The area of dolomitic limestone near the head of Deer Creek is thought to be a promising field in which to prospect for lead-silver deposits.

GEOLOGY OF THE ST. JOE-CLEARWATER REGION, IDAHO.

By F. C. Calkins and E. L. Jones, jr.

INTRODUCTION.

The classification of lands of the Northern Pacific Railway Co.'s grant in the upper St. Joe and Clearwater basins, in northern Idaho, was commenced in the field season of 1910 by three parties of the Geological Survey. Owing to the shortness of the season and the difficulties encountered in this region, the classification was not completed in 1910. In 1911 the area remaining to be classified was examined by F. C. Calkins, with E. L. Jones, jr., as assistant, and was topographically mapped by J. E. Blackburn. The results of the geologic work performed in 1910 have been published in a paper by J. T. Pardee,[1] and the present report is intended to supplement that paper.

The tract examined in 1911, a map of which forms Plate II, has an area of about 250 square miles. It lies north of the forty-seventh parallel, in the northern part of Idaho and near its eastern boundary, which is formed by the watershed of the Bitterroot Mountains. The Cœur d'Alene lead-mining district is 20 or 30 miles away in a northwesterly direction.

GEOGRAPHY.

Relief.—The region is mostly occupied by flat-topped or gently sloping ridges, the remnants of what has been described[2] as representing an old erosion surface of low relief, into which the intricate drainage systems of St. Joe and Clearwater rivers have been entrenched. Some peaks attain elevations several hundred feet above the ridges on which they are situated, and among these the group known as the Three Sisters, on the divide between the forks of

[1] Geology and mineralization of the upper St. Joe River basin, Idaho: Bull. U. S. Geol. Survey No. 470, 1910, pp. 39-61.

[2] Lindgren, Waldemar, A geological reconnaissance across the Bitterroot Range and Clearwater Mountains in Montana and Idaho: Prof. Paper U. S. Geol. Survey No. 27, 1904, p. 59. Ransome, F. L., and Calkins, F. C., The geology and ore deposits of the Cœur d'Alene district, Idaho: Prof. Paper U. S. Geol. Survey No. 62, 1908, p. 75.

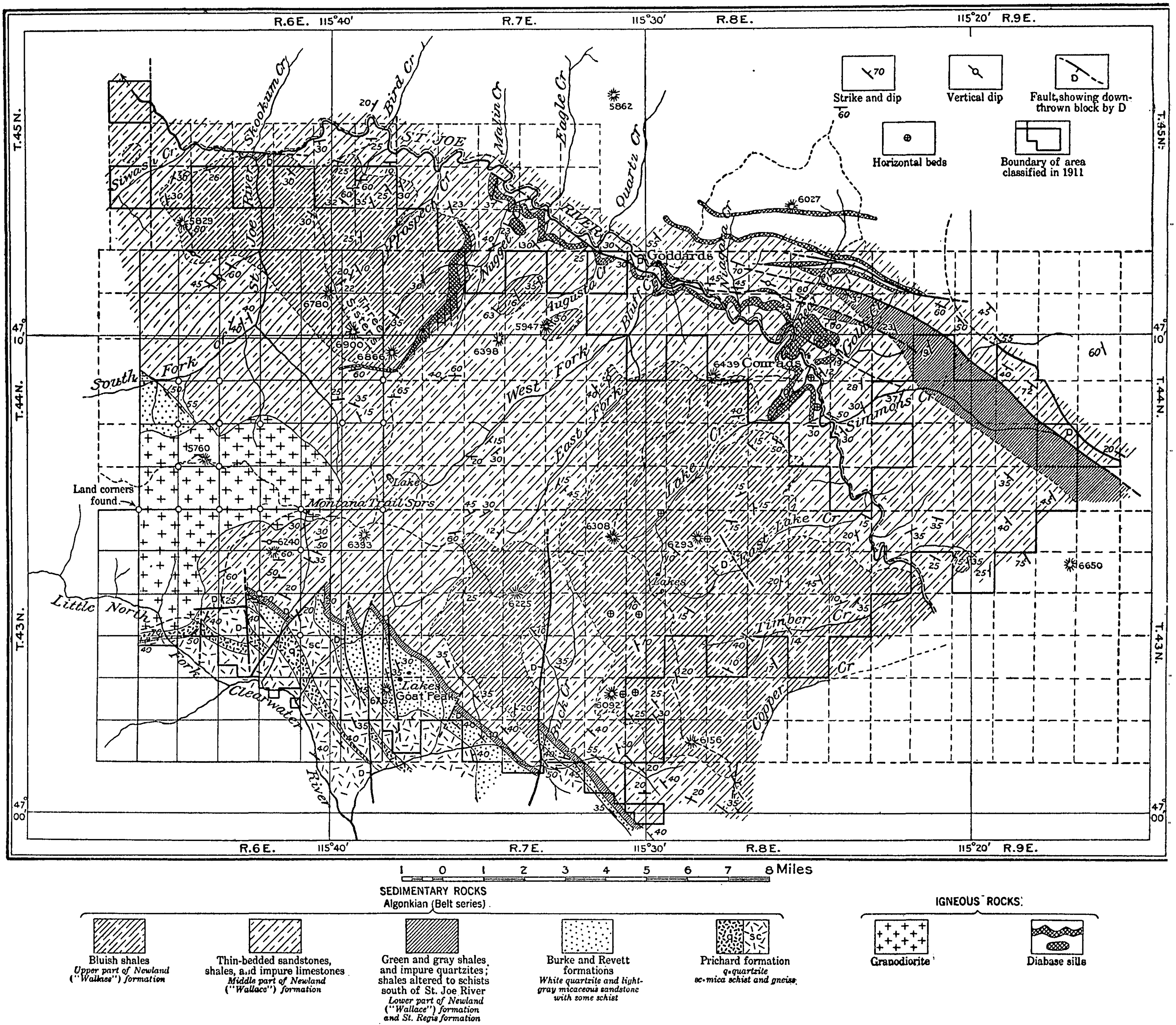
St. Joe River and Goat Peak, on an outlying ridge near the southern boundary of the area, is the most prominent. The Three Sisters are approximately 6,900 feet and Goat Peak is 6,760 feet in elevation. Average elevations on the main divide are about 6,000 feet; elevations on St. Joe River are 2,700 feet at the mouth of Skookum Creek and 3,300 feet at Conrads.

Drainage.—St. Joe River, with its principal tributaries, South Fork and Bluff, Lake, Simmons, Gold, and Bear creeks, drains two-thirds of the area under examination. The remaining southwestern part is drained by the headwaters of the Little North Fork of Clearwater River. The heavy vegetation, combined with abundant precipitation, conserves the water supply, so that all the streams maintain a large volume of water throughout the year.

Vegetation.—With the exception of steep southern slopes most of this region previous to the forest fires of 1910 was covered with a dense growth of coniferous trees and underbrush; but now nearly the whole area drained by St. Joe River south of the East Fork of Bluff Creek and by the Little North Fork of Clearwater River south and east of a stream flowing west from Goat Peak is burned over. The northwestern part of the area also suffered heavily from the fires of 1910. Many evidences of ancient fires and various stages of reforestation were noted in this region. Stumps of trees several feet in diameter were found standing in a forest of trees uniformly about a foot in diameter. Other areas are covered by a growth of trees but a few feet in height. The south and west slopes of the St. Joe-Clearwater divide, as well as the divide separating St. Joe River from the South Fork, are less susceptible to reforestation than the northern slopes, but they support a luxuriant growth of grass in many places, as well as numerous patches of huckleberry bushes and other shrubs.

The dense vegetation in large part conceals the rock outcrops and has greatly hindered the thorough prospecting of this region.

Trails.—A few trails suitable for pack animals are the only means of access to this region. It is usually entered by way of the trail leading up the St. Joe from Avery to Conrads. From Conrads a good trail leads northward to De Borgia, Mont., distant about 20 miles. The most frequently traveled route across the area south of the river runs in a general southwesterly direction from Conrads and ultimately reaches Clarkia. It joins others leading westward and southeastward along the St. Joe-Clearwater divide and northward over the Three Sisters to the St. Joe. The trails within the limits of the area mapped are in general fairly good, but the one that follows the divide west of the Montana Trail Springs is badly clogged with fallen timber, and the trail from the river to the Three Sisters is in places very steep.



GEOLOGIC MAP OF ST. JOE-CLEARWATER REGION, IDAHO.

GEOLOGY.

SEDIMENTARY ROCKS.

BELT SERIES (ALGONKIAN).

GENERAL STRATIGRAPHY.

The greater part of the area is occupied by Algonkian sedimentary rocks which represent formations exposed in the Cœur d'Alene mining district. In the 30 miles, more or less, that intervene between that district and the area examined in 1911 the lithologic features of the series are sufficiently constant to make general correlation possible. Detailed correlation, however, is made difficult by the fact that certain formations vary greatly in thickness within this distance and some exhibit variations in lithologic character which are accentuated by metamorphism.

The general character of the rocks, as well as of their variations, is shown in the following sections. In each column the descriptions of beds supposed to be equivalent are placed in the same horizontal position, and horizontal lines mark the limits of cartographic units.

Sections of Algonkian rocks (Belt series) in Idaho.

Cœur d'Alene district.	Vicinity of St. Joe River.	Vicinity of Clearwater River.
Striped Peak formation: Red and green shales and sandstones.	Removed by erosion............	Removed by erosion.
Newland (" *Wallace*") *formation* (total thickness 4,000 feet):[a] Bluish and greenish shales, partly calcareous.	Blue shales, mostly free from lime, partly altered to schists and hornstones. Thickness, 2,500 feet. Top removed by erosion.	Mica schists with garnet, cyanite, and scapolite. Top removed by erosion.
Interbedded calcareous shale, sandstone, and impure limestone.	Interbedded calcareous shale and sandstone; the shales partly altered to hornstone. Thickness, 2,000 feet.	Schist and hornstone containing scapolite interbedded with calcareous sandstone and quartzite. Thickness, 2,000 feet.
Green shales, calcareous in part..	Green shales, calcareous in part; locally altered to green hornstone containing scapolite. Thickness, 1,500 feet.	Mica schist, locally scapolite bearing, with some interbedded quartzite. Thickness, about 500 feet. Not readily separated from overlying beds.
Ravalli group: *St. Regis formation:* Purple and green shales and sandstones. Thickness, 1,000 feet.	Gray sandstones with interbedded shales. Little or no carbonate. Thickness, 1,000 feet. Base not exposed. Possibly includes part of Revett quartzite.	
Ravalli group: *Revett quartzite:* White thick-bedded quartzite. Thickness, 1,000 feet.	....	White thick-bedded quartzite. Thickness, 1,500± feet.
Ravalli group: *Burke formation:* Pale-tinted siliceous shale and flaggy quartzites. Thickness, 2,000 feet.	....	Flaggy sandstone and quartzite interbedded with mica schist. Thickness, 1,000± feet.
Prichard formation: Blue shale or slate with subordinate interbedded gray sandstone. Thickness, 8,000 feet. Base not exposed.	....	Mica schist, with subordinate quartzite. Thickness, 2,000± feet. Quartzite with subordinate schist. Thickness, 1,500 feet. Schist. Thickness, 2,000± feet. Base not exposed. Intruded by granodiorite gneiss.

[a] "Wallace" is the name originally applied to the formation in the Cœur d'Alene district. (See Prof. Paper U. S. Geol. Survey No. 62, 1908.)

LITHOLOGY AND VARIATIONS.

The rocks referred to the Prichard formation of the Cœur d'Alene district are exposed only in the vicinity of Clearwater River, where they have been subjected to intense metamorphism. They consist of mica schist and pure-white quartzite, with rocks of intermediate composition, comprising micaceous quartzites and siliceous schists. Garnet is commonly present in the schists and some of the less pure quartzites.

This assemblage of strata differs strikingly from the typical Prichard formation, inasmuch as it includes a thick and well-defined quartzitic member. This difference in the lowest part of the stratigraphic column is explainable according to one of two hypotheses, choice between which is not determined by the facts in hand. The quartzite member may be older than any beds exposed in the Cœur d'Alene district; in this case the Prichard must thin out toward the south. The alternative hypothesis is that some of the sandstones comprised in the Prichard of the type section may pass horizontally into quartzites that are much more purely siliceous.

Above the schists correlated with the Prichard and likewise exposed in the Clearwater basin are quartzitic rocks which correspond closely in character to the Burke and Revett formations but whose total thickness is somewhat less. These are mapped as a unit, but they comprise an upper and a lower division that are fairly distinct in good exposures. The upper division consists mostly of vitreous quartzite; the lower division consists chiefly of a peculiar soft-weathering light-gray micaceous sandstone, with which some flaggy quartzite and schist is interbedded.

Some of the most serious difficulties in the way of exact correlation pertain to the beds at the horizon, approximately, of the St. Regis formation. North of St. Joe River rocks are exposed which correspond closely to those of the typical St. Regis in most respects; they consist partly of light-gray impure quartzite, in beds a foot or less in thickness, in which ripple marks and other features indicating deposition in shallow water are conspicuous, and partly of greenish-gray shale. The sole respect in which these rocks differ from those of the St. Regis of the type localities is in the absence of the purple color which, in the Cœur d'Alene district, was regarded as the diagnostic feature of the formation. It is possible that the destruction of this color has been one of the effects of the slight igneous metamorphism that prevails where these rocks are exposed. Owing to the absence of this distinctive feature, the rocks in question can not readily be separated from the overlying beds, which constitute the lower part of the Newland ("Wallace") formation, for they grade into these and do not essentially differ from them except in being more sandy. For this reason the beds representing the lower part of the Newland are mapped with those representing the St. Regis north of St. Joe River.

The lower part of the Newland formation, as exposed in the basin of Simmons Creek, presents much the same appearance that it has in the Cœur d'Alene district. It consists chiefly of gray-green fine-grained argillite but includes a little greenish-white sandstone in thin beds. Metamorphism of rather slight intensity has given the argillite a perceptibly crystalline appearance and has caused the formation of round whitish grains of scapolite, which are somewhat less abundant and conspicuous than in the overlying portion of the Newland formation.

In the Clearwater basin the division corresponding to the Revett and the lower part of the Newland ("Wallace") is so thin and ill defined that it would hardly deserve to rank as a stratigraphic unit if that area were considered by itself; but it is distinguished on the map for the sake of consistency. The beds that here intervene between those that correspond in lithologic character to the Revett and the middle part of the Newland, respectively, are only about 500 feet in thickness, compared with 2,500 feet north of St. Joe River. They consist in general of gray or brown, rather siliceous mica schist and micaceous quartzite. A little scapolite which occurs in certain beds of schist indicates the presence of a small amount of lime. If the purplish and greenish tints that distinguish equivalents of these beds in the Cœur d'Alene district were originally present here, they have been obliterated by metamorphism, so that these rocks present no marked contrast to those that overlie them.

The beds representing the middle part of the Newland ("Wallace") formation maintain, apart from the effects of metamorphism, a fairly uniform character throughout the region. They are not exposed in a wholly unmetamorphosed condition in any part of the area classified in 1911, but they are little altered in some parts of the area examined that lie a short distance north of the river. They consist essentially of alternating thin beds of calcareous argillite and sandstone. The argillite is mostly dark blue, but that in the lower part of this stratigraphic division is greenish; the sandstone is gray or white, and, although most of it is calcareous, it comprises some quartzite free from lime and similar to the Revett quartzite. The rocks in part of the stratigraphic series differ from their equivalents in the Cœur d'Alene district chiefly in being somewhat less limy and in containing a larger proportion of sandy beds.

The effect of metamorphism is clearly manifested, in nearly the whole of the area mapped, by the argillaceous layers. These become altered, for the most part, to chocolate-colored biotitic hornstones of fine texture, in which roundish grains of scapolite whose average diameter is about that of buckshot are abundant. On weathered surfaces the scapolite grains are white, in strong contrast with their dark matrix, from which they project in relief.

In general these rocks are easily weathered and not well exposed, except on the steep slopes of cirques or canyons.

One of the most striking differences between the stratigraphy of the Cœur d'Alene district and that of the area here described consists in the great development in the latter area of the rocks representing the upper part of the Newland ("Wallace") formation, which are apparently several times thicker than in the Cœur d'Alene district and constitute a well-defined stratigraphic unit. Locally, indeed, a thin conglomerate with sandstone pebbles is found near their base, which makes it appear possible that their great variation in thickness is due to unconformity and overlap.

This division is remarkably homogeneous and consists almost wholly of material that in an unaltered state is a regularly banded shale in which dark-blue layers about half an inch thick alternate with thinner light-green layers. These beds, in contrast to those of the middle part of the Newland, are almost free from lime and are comparatively resistant to erosion, so that good exposures of them are common.

Metamorphism, where of slight extent, gives these rocks a brownish cast owing to the development of biotite. Where the metamorphism is more advanced it results in the formation of garnetiferous schists, which form the country rock of the Three Sisters. Over extensive areas metamorphism is still more strongly manifested by the development of brown staurolite crystals, largely in the form of cross twins, which attain lengths of 2 or 3 inches, and of pale-blue cyanite crystals whose maximum length is still greater. These minerals are conspicuous along the St. Joe-Clearwater divide. Where the metamorphism is extreme the schists take on a coarse crinkly texture and resemble those of the strata correlated with the Prichard.

IGNEOUS ROCKS.

KINDS AND SEQUENCE.

The Algonkian sediments have been invaded by the following intrusive rocks, named in order of age: Diabase (partly altered to amphibolite), granodiorite (altered to gneiss), pegmatite, a second granodiorite with apophyses of granodiorite porphyry, quartz porphyry, and diabase porphyry. In addition to these there are dioritic dikes whose relation to the other intrusives is not known, and a breccia, possibly of volcanic origin, which occurs in small quantity.

CHARACTER AND OCCURRENCE.

Diabase sills of remarkable persistence occur at several horizons within this region. The principal one, named by Pardee the "Wishards sill," is intruded in the quartzites of the middle division of the Newland formation. This sill has been traced by Pardee along the Bitterroot divide for a distance of 15 miles. In the vicinity of Wishards Peak it leaves the divide and, through a series of faults, is finally thrown south of St. Joe River, where for many miles it forms a prominent bluff.

Another sill of some importance occurs near the base of the upper division of the Newland. It is best exposed on Nugget Creek, where the outcrop forms a striking bench. This sill is very persistent, although its thickness is much less in other areas. Occurrences of metamorphosed diabase stratigraphically lower than those previously noted consist of amphibolite found in the quartzites on Goat Peak and also near the Little North Fork of Clearwater River in close proximity to the granite gneiss.

The diabase is greenish black in color, spotted with white feldspar laths. The texture varies from fine grained to coarsely granitoid. The principal original constituents are labradorite, augite that is purplish in thin section, interstitial quartz and alkali feldspar, and numerous grains of ilmenite.

Metamorphism of the diabase has altered most of the augite to hornblende, has formed in places large garnet crystals, and in the intrusions intercalated with the Prichard formation has produced a decided schistose structure.

Granite gneiss is found in the southwestern part of the area intercalated with mica schists, amphibolites, and quartzites of the Prichard formation. The gneiss is a gray medium-grained rock, in which biotite, hornblende, feldspar, and quartz can be recognized. The chief feldspar is oligoclase. The gneiss is much older than the granodiorite, as the latter is intruded into the former and has suffered but little deformation.

Pegmatite intrusions, presumably related to the gneiss, are numerous within this region, especially in the southwestern part, where they form conspicuous dikes and sheets, commonly 5 or 10 feet thick, in the older metamorphosed rocks. Gradations were noted from coarse-grained pegmatites consisting of feldspar, mica, and quartz to those consisting essentially of quartz.

The unsheared granodiorite occurs on either side of the St. Joe-Clearwater divide in the western part of this area and is a continuation of that in T. 43 N., R. 5 E., mapped by Mr. Calkins in 1910. The rock is of medium-granular texture and consists of the same minerals that were noted in the gneiss. This rock resembles that of the great batholith[1] of central Idaho, which, however, is described as quartz monzonite. In the rock of the St. Joe region plagioclase is so abundant as to make granodiorite seem the more appropriate name.

Apophyses of granodiorite porphyry are abundant on the borders of the granodiorite batholith. In the vicinity of the forks of the South Fork of St. Joe River a great number of these dikes are intruded between steeply dipping beds of the Newland formation; in other localities they occupy fissures and have also been noted cutting across diabase sills.

Porphyritic, nearly white dike rocks, in which phenocrysts of glassy quartz are prominent, are closely related to the granodiorite porphyry dikes and are similar in distribution but are less abundant.

Narrow dikes of a fine-grained rock consisting chiefly of needles of hornblende and plagioclase feldspars are of sparse distribution. They closely resemble the dike rocks found in the Cœur d'Alene district.

A fine-grained black diabase porphyry containing large glassy feldspar phenocrysts occurs in the Clearwater region. Dikes of this character probably represent the latest stage of igneous activity.

The breccia possibly of volcanic origin occurs in a few very small areas north and south of the river near Conrads, apparently overlying slates of the upper Newland ("Wallace") and diabase. It consists chiefly of fragments of a gray porphyritic rock, with phenocrysts of plagioclase, quartz, and biotite in a fine-grained gray groundmass.

METAMORPHISM.

Metamorphism of the sediments is apparent everywhere, but it is much more intense in some parts of the region than in others. It is least toward the northwest but is gradually more and more marked toward the southwest, where it reaches its extreme stage. The change brought about in the sediments is so great that were it not that gradual transitions can be observed in traversing from the northeast to the southwest and that the stratigraphic sequence can be held fairly well in hand, the determination of formations would be difficult.

The metamorphism is due in part to the nearness of the great Idaho batholith and in part to dynamic stresses acting under a heavy load of sediments. Minor metamorphic effects are displayed in the vicinity of the diabase sills and on the borders of the granodiorite mass, but such effects are largely overshadowed by those due to the agencies just mentioned.

One of the most noteworthy metamorphic effects has been the widespread formation of scapolite in the calcareous rocks of the middle

[1] Lindgren, Waldemar, op. cit., p. 63.

division of the Newland ("Wallace"). The chlorine which this mineral contains was probably given off by the metamorphosing magma, for scapolite is wholly absent from the contact zones of other instrusions that cut the Newland formation in the Cœur d'Alene district and near St. Joe River.

STRUCTURE.

FOLDS.

The principal structural feature of this region is a broad synclinal fold which extends roughly from the northwestern part to the southeastern part. At the northwestern part, as indicated by the plotted dips and strikes on the accompanying map (Pl. II), the syncline ends in a canoe-shaped form opposite the Packsaddle syncline,[1] on the north side of St. Joe River. The axes of these two major folds are approximately parallel and strike west-northwest. In general the strikes of the rocks are northwest and southeast, but variations are numerous, especially within the synclinal trough; the numerous variations in strike indicate a series of minor folds as well as dislocations of the strata.

The major fold controls in large part the distribution of the rocks in this region. Upper Newland ("Wallace") rocks lie within the trough of this fold. Southwest from the central part of the syncline older formations follow in succession to the Prichard, and to the northwest the area of Newland rocks is greatly increased by the occurrence of several faults and the lower formations are not exposed.

FAULTS.

Numerous faults complicate the structure of this region. They are most numerous in the southwestern part of the area and along St. Joe River. Although no definite rule as to direction of strike or throw of the faults can be given, yet those in the southwestern part generally strike north and south, with downthrow on the west, and those along the river strike west-northwest, with downthrow on the north. Most of the faults have steep dips which make it probable that they are normal, although this has not been proved for many of them. The two series of parallel faults correspond closely in direction with two systems of the Cœur d'Alene district.[2]

The west-northwest faults, as previously stated, have greatly increased the areal distribution of the Newland rocks north of St. Joe River. A prominent fault of this series extends from a point near the mouth of Bluff Creek to a point opposite the mouth of Malin Creek. In a number of places this fault cuts off large blocks of the prominent diabase sill on the south side of the river.

[1] Pardee, J. T., op. cit., p. 40.

[2] Ransome, F. L., and Calkins, F. C., op. cit., p. 62.

The principal development of north-south faults occurs near Goat Peak, where they have greatly broadened the outcrop of the quartzite from which the peak has been formed. The diabase sill on Nugget Creek is broken into numerous blocks by a series of northward-trending faults.

The displacements of these faults are difficult to estimate, but probably the one having the greatest amount is that near the mouth of Buck Creek, where rocks of the upper Newland are brought adjacent to quartzites of the Ravalli group. The throw here is at least 2,500 feet. Probably the majority of the faults mapped represents displacements of 1,000 feet or more. Numerous faults of small displacement and others of greater throw doubtless exist, but except where condition are favorable for their detection they are overlooked.

MINERALIZATION.

DISSEMINATED MINERALS.

The minerals associated with ores in the Cœur d'Alene district[1] are widely distributed in this region. Siderite, or more generally its oxidation product, limonite, commonly occurs in the sandy quartzites of the middle Newland ("Wallace") and in the greenish shales of the lower Newland and the St. Regis. Magnetite and pyrite occur sparingly in the shales of the lower Newland and the St. Regis.

VEINS.

CHARACTER AND DISTRIBUTION.

The veins of the region may roughly be classed as follows:

1. Veins consisting almost wholly of quartz but locally containing a little feldspar and mica.
2. Veins consisting chiefly of quartz but containing much chlorite and more or less calcite.
3. Veins composed of carbonates and quartz in nearly equal quantity.

In general, these veins are of small size—rarely more than a foot or two in thickness—and their prevailing strike is more nearly east-west than north-south.

The veins of the first class are the most numerous and widely distributed; they occur in all parts of the region but are more abundant in the southern than in the northern part. They are present in all formations but are apparently most abundant in the rocks of the upper part of the Newland formation. The chloritic veins are occasionally found in the upper Newland south of St. Joe River, but they are most abundant in the Newland and the St. Regis formation north

[1] Ransome, F. L., and Calkins, F. C., op. cit., pp. 95, 97, 138.

of the river, and were most frequently noted about Simmons Creek basin. The veins containing carbonate are comparatively scarce and were found only in the middle Newland north of the river.

Numerous assays on veins of all these classes showed small amounts of gold and traces of silver. A few assays for copper gave negative results.

ORIGIN.

The necessarily superficial nature of the present study of these veins could hardly afford a secure basis for speculation as to their origin. The most interesting problem, perhaps, that arises in this connection concerns the relation of mineralization to intrusion. That this relation, in some places at least, is a close one is suggested by the fact that small quantities of gold are found in quartz that appears to be a part of highly siliceous pegmatite, or so intimately associated with pegmatite that it seems likely to have a close genetic relationship with that rock. It is certain, at least, that all gradations may be found between typical pegmatites and quartz veins containing little or no feldspar, and some of the facts indicate that the pegmatite quartz is locally auriferous.

There is nothing to suggest at first sight a magmatic origin for the chloritic veins or those rich in carbonates. These contain no feldspar and occur at relatively great distances from large intrusions. On the other hand, it is not improbable that they are more or less remotely related to the intrusions which have almost everywhere metamorphosed the country rock.

DEVELOPMENT.

The region has been very little prospected, the small amount of development noted being confined largely to the more accessible localities. The prospects along St. Joe River in the vicinity of Goddards, Conrads, and the mouth of Bird Creek have been described by Pardee [1] in the previous report on this region. South of the St. Joe to the Clearwater divide but one prospect of any importance is known to exist.

Conrad's mine is located on the St. Joe-Clearwater divide several miles southeast of the limits of the area under classification. No work has apparently been done there within recent years. Copper is said to occur in this mine.

On the ridge a short distance northwest of the Three Sisters Mr. Stevens, a prospector, has uncovered narrow iron-stained quartz veins in two shallow pits. An assay of the quartz gives values of $11 in gold and 2 ounces of silver to the ton.

[1] Pardee, J. T., op. cit., p. 48.

Placer mining was attempted at one time on a rather extensive scale within this region, but evidently no work of this character has been done for many years. Old placer workings were noted on Gold and Simmons creeks. At the former locality old blazed trees evidently mark the corners of claims, and piles of bowlders along the creek indicate former work. The stream has been dammed by beavers in the sluiced creek bed and a willow swamp now occupies the site of former placer mining. An old trail leads from the Bitterroot divide to the headwaters of Simmons Creek, on which old cabins, forges, and large piles of washed bowlders furnish ample evidence of former work.

It is said that colors of gold can be obtained along St. Joe River as far down as the mouth of Bird Creek. Rumors of the occurrence of gold on the headwaters of the Little North Fork of Clearwater River and streams flowing northward to the St. Joe are apparently verified by the results obtained from the quartz-vein assays. On the headwaters of Bluff Creek old blazes and squared posts may mark the position of old placer locations.

NOTES ON THE ANTELOPE DISTRICT, NEVADA.

By F. C. Schrader.

LOCATION.

The Antelope district is in Nye County, south-central Nevada, about 30 miles east-southeast of Goldfield, the nearest supply point, on the Las Vegas & Tonopah Railroad, with which it is connected by a good wagon and automobile road, and 25 miles from Ralston siding, the road to which is nearly all gently down grade or level. The nearest mining camps,[1] all of which are small, are Wellington and Jamestown, about 6 miles distant on the southwest; Wilson's on the southeast; Trappmans, 2 miles south of Wilson's; Cactus Springs, 9 miles to the northwest; and Gold Crater, 11 miles to the southwest. (See Pl. III.)

HISTORY AND PRESENT CONDITIONS.

The district is named from a group of springs, which have long been marked on Government maps. The largest of the springs flows about 500 gallons of cool palatable water daily, and, together with two wells recently sunk on the downstream side, furnishes the main supply of water for the camp. Ample water for milling can probably be obtained at very reasonable depths.

Several isolated prospects within a few miles of the springs have been intermittently developed in the last decade, almost from the time the region was visited by the wave of prospectors that followed in the wake of the Tonopah boom.

Gold was first discovered here in 1903 by the Bailey Brothers, of Cactus Spring, on the Antelope ground, which they still hold and develop, about a mile southwest of the main spring. In 1906 the Jordan brothers made locations about the same distance to the south, including the ground of the recent strike, and they too have annually done considerably more than the required development work. The strike of high-grade ore which recently attracted attention to the district and gave the camp its present impetus was made

[1] Mineral Resources U. S. for 1907, pt. 1, U. S. Geol. Survey, 1908, Pl. I.

by Jordan & Reilly on the Antelope View ground early in November, 1911, and soon afterwards there were 150 men in camp prospecting and making locations. By the close of the year a $15,000 five-day option had been taken on the Antelope View claim by George Wingfield, of the Goldfield Consolidated Mines Co., who prosecuted the work of sinking a shaft continuously with good results, but as he wished a brief extension of time, which it is said the owners would grant only at a very large price, he relinquished the option.

The present paper is based on a two days' visit to the camp by the writer early in January, 1912, when about 100 men were at work on nearly as many prospects developing their own ground. To these men and to James H. Parks, of Goldfield, the writer is indebted for information and assistance in making his examination.

At this time the district had been organized and named, two town sites were being developed, half a dozen frame buildings had been erected, and supplies and machinery were being freighted in and some ore hauled out. A stage-line service with Goldfield every other day was in operation and teams and automobiles were coming and going daily. The welfare of the camp was being cared for by committees appointed by miners' meetings.

The Antelope View ground and the Western Union claim adjoining it on the south had been nearly all leased in small blocks 100 by 600 feet extending across the claim and vein, with the perhaps oversanguine expectation that the rich ore of the Discovery shaft would be found extending continuously throughout the length of the claims. On each of these blocks the lessees were sinking in quest of rich ore, mostly on the main vein, and some of them were obtaining encouraging results.

Including the earlier work several tunnels and incline shafts about 150 feet in extent and many prospect pits had been opened in the camp, but the development was still in the oxidized zone, so that only ores oxidized by surface waters had been encountered.

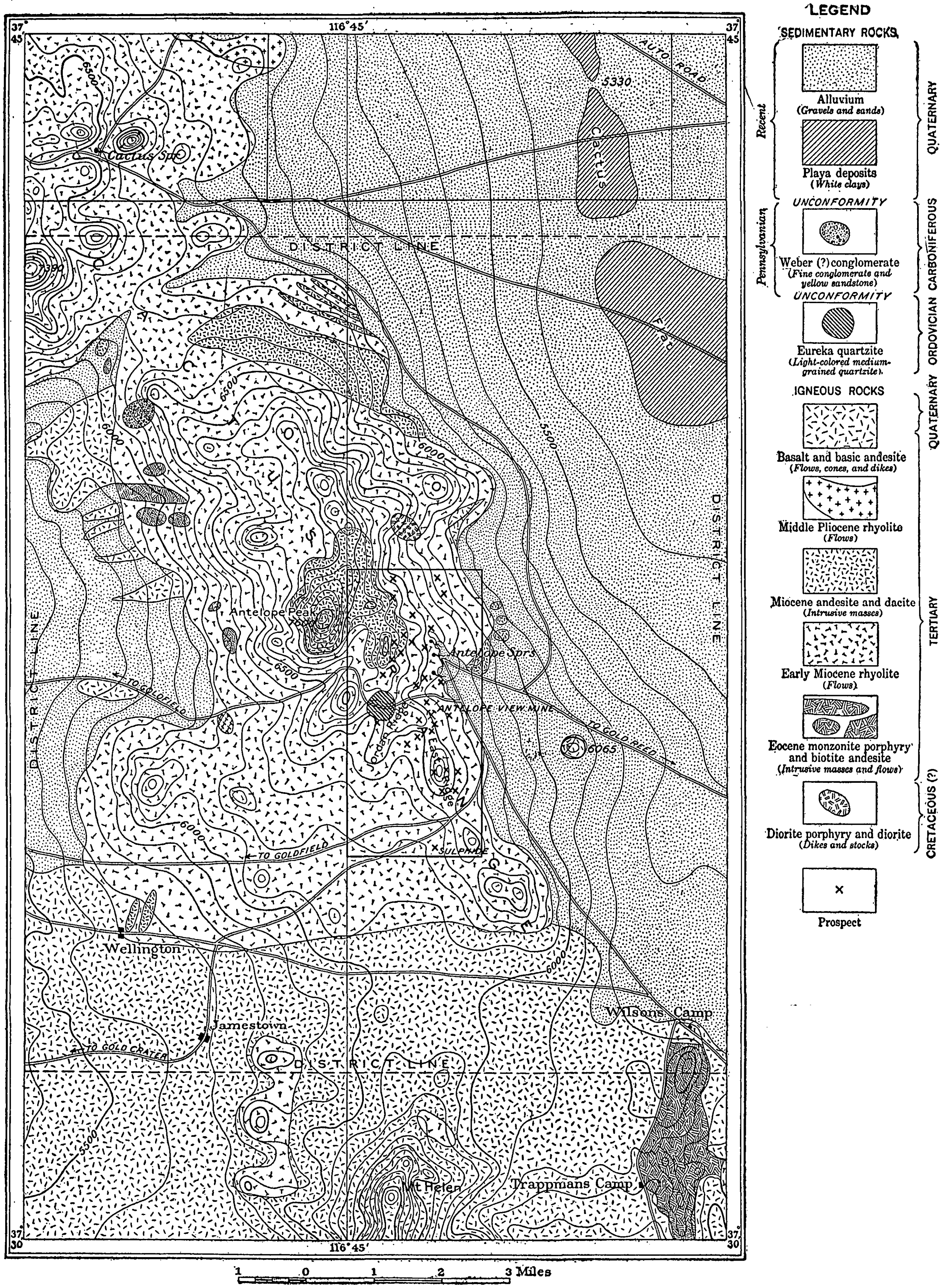
According to latest accounts received early in April the outlook for the camp is encouraging. Good ore has been found at several places and the installation of a mill is contemplated.

TOPOGRAPHY.

The relief of the region is characteristic of the Great Basin province, which comprises nearly all of Nevada and portions of adjacent States. The dominant features of this province, as shown by earlier publications,[1] are parallel north-south minor mountain ranges—the "desert ranges"—separated by detritus-filled valleys.

The district is situated in the southern part of one of these ranges, the Cactus Range, which trends northwesterly, and has a length of

[1] U. S. Geol. Expl. 40th Par.; Bull. U. S. Geol. Survey No. 208, Pl. I; No. 303, Pl. I; No. 308, Pl. I.



GEOLOGIC RECONNAISSANCE MAP OF ANTELOPE DISTRICT, NEVADA.

about 20 miles, a width of about 10 miles, and an average height of crest of about 7,000 feet. The range rises about 1,500 feet above Cactus Valley on the east, 2,000 feet above Stonewall Valley on the west, and culminates at 7,600 feet in Antelope Peak on the south.

The prospects to which attention was chiefly directed at the time of visit were contained essentially in a north-south rectangular area about 4 miles long and 2 miles wide, near the center of the region shown on the map (Pl. III). It is with this area that this paper chiefly deals, and for convenience it will in a general way be referred to as the district or camp. The "official" district, as laid out at a miners' meeting January 3, 1912, and named the Antelope Springs mining district, is a much larger area, and contains about 120 square miles. It extends from the main spring 6 miles north, 6 miles south, 4 miles east, and 6 miles west. Its boundaries on the east and on the west coincide respectively with those on figure 1, where also its south limits are marked by the east-west broken line passing about a mile south of Wilsons and its north limits by a similar line about a mile south of Cactus Spring.

The area here treated lies mainly on the easterly slope of the range, and extends from 6,000 to 7,000 feet in elevation. The topography is in part rough but not rugged. Its general character is fairly well expressed on the Survey map of the Kawich quadrangle, from which figure 14 is adapted, and also on Plate I of Bulletins 303 and 308. The principal features are several north-south monoclinal or hogback ridges, of which East Ridge and Jordan Ridge (see Pl. III and fig. 14), situated diagonally to the axis of the range, are examples, and their intervening small valleys or open gulches. The collected drainage issues mainly by means of a broad, open wash through a long, gentle débris-covered slope eastward into Cactus Valley.

GEOLOGY.

Most of the older rocks in the desert ranges are faulted Paleozoic and Mesozoic sediments cut by many intrusive dikes and bodies of porphyry and flooded by lavas.[1] According to Ball,[2] who has written the best report on the general geology of the southwestern part of Nevada, the succession of formations exposed in the Cactus Range from the base up is as follows: "Pogonip limestone, Eureka quartzite, Weber conglomerate, granite, diorite porphyry, hornblende-biotite latite, earlier rhyolite, biotite andesite, augite andesite, later tuffs (?), later rhyolite (?), and basalt."

The range, however, is composed of predominantly Tertiary volcanic rocks, and the covering or country rock as shown on Ball's

[1] U. S. Geol. Expl. 40th Par.; Bull. U. S. Geol. Survey No. 208, Pl. I; No. 303, Pl. I; No. 308, Pl. I.

[2] Ball, S. H., A geological reconnaissance in southwestern Nevada and eastern California: Bull. U. S. Geol. Survey No. 308, 1907, p. 89.

map, from which the geology of Plate III is adapted,[1] is almost wholly rhyolite, regarded as of early Miocene age. This rock contains the ore deposits of the camp.

The rhyolite forms almost all of the higher part of the range, occupying a belt 5½ miles wide. On the south, in the latitude of Wellington, it is abruptly terminated by a large area of early Quaternary and late Tertiary flows of basalt and basic andesite, small bodies of which also flank the rhyolite in other parts of the range.

Locally capping the rhyolite unconformably as flows and likewise intruding it are andesite and dacite, which occur also in the northwestern part of the district and near by form the upper part of Antelope Peak. They too are referred to early or middle Miocene age.[2]

In the western part of the district, where the rhyolite is bared by erosion, occurs a small area of quartzite, regarded by Ball as the Eureka quartzite of Ordovician age. "This is a fine to medium

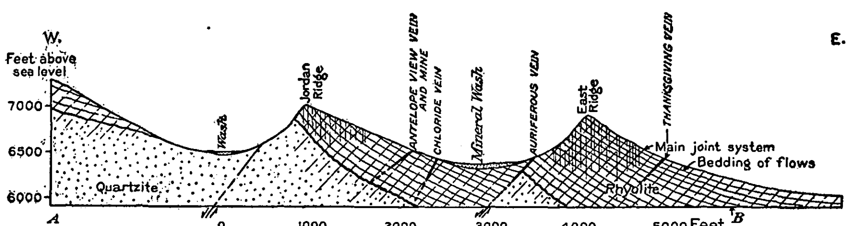


FIGURE 14.—Section through Jordan Ridge and East Ridge, Antelope district, Nevada, showing rock structure and some of the principal mineral veins along line *A-B*, figure 15.

grained quartzite of white, yellow, or red color, and is cut by small stringers of white quartz. It lies unconformably below the surrounding rhyolite."[3] Its presence in the Antelope camp is of importance only in indicating in a general way the probable thickness of the overlying rhyolite in which the mineral deposits occur.

The rhyolite is a porphyritic lava or igneous rock with a glassy base and has about the same chemical composition as granite. It occurs mostly in heavy flows which have been domed and transversely faulted into the series of monoclinal ridges above described. The flows dip mainly 20°–60° E., and the fault scarps formed by their broken upturned edges face to the west. (See fig. 14.) The flows are crosscut by a prominent system of sheeting which dips 30°–60° W., about parallel with the fault planes. This sheeting is probably contemporaneous in origin with the faults and was induced by the same forces. It is important in that its fissures and cracks contain or are associated with the mineral deposits. Locally, as in

[1] At the time of visit the writer did not know that the district was covered by this map.
[2] Ball, S. H., op. cit., p. 94.
[3] Idem, p. 90.

Jordan Ridge, the cracks contain also many small nonworkable veins or ledges and stringers of quartz. The rocks, in places at least, as best shown in East Ridge, are also thinly sliced by a close vertical sheeting amounting almost to cleavage, and in places dikes or bodies of younger but similar rhyolite seem to be intruded along the faults.

The rhyolite is mostly light greenish gray or white, but varies from flow to flow and locally is red, purple, dark brown, or blackish. It is considerably altered, especially near the veins. Much of it is heavily stained with iron and manganese and some contains disseminated pyrite scarcely visible to the naked eye. Some of this pyrite is probably cupriferous and is the source of the copper stain found in part of the ore.

The rock is normally medium grained, with moderate-sized or small phenocrysts of orthoclase and quartz freely disseminated through the lithoidal groundmass, and much of it shows banding or fluxion structure. Some portions, however, are silicified, dense, and flinty, and others are kaolinized and altered to a white chalklike mass. As pointed out by Ball,[1] it is chiefly in association with these silicified and kaolinized areas that mineralization has taken place.

Microscopically the rhyolite is seen to be composed essentially of a turbid brownish glassy groundmass which has flow structure, which varies from cryptocrystalline to microcrystalline in texture, and in which are phenocrysts (or their casts) of orthoclase, quartz, biotite, plagioclase, and hornblende. The phenocrysts are medium or small in size and are usually abundant and uniformly distributed. Some of them are fractured by flow.

Hematite as black phenocrysts and as ferriferous grains and dust-clouded areas in the groundmass is present and is probably secondary. Apatite is sparingly present as an accessory.

The rock as a whole is highly altered. The groundmass is in part devitrified and silicified or replaced by secondary quartz and orthoclase, mostly fine but varying greatly in size of grain, containing quartz blebs. Alunite in grains and aggregates is scattered through the groundmass.

The phenocrysts are mostly changed to or replaced by secondary products, the orthoclase to kaolin, chalcedonic quartz, secondary orthoclase, sericite, and alunite; the biotite to green chlorite and muscovite. Much of the quartz is deeply embayed by magmatic corrosion and some is slightly smoky or has a pale wine-red color. Veinlets of fine-grained chalcedonic silica and secondary orthoclase fill cracks in both the groundmass and the phenocrysts.

Alunite occurs chiefly as a replacement of orthoclase in a variable zone on the surface of the phenocrysts and along the fracture walls,

[1] Ball, S. H., op. cit., p. 43.

while here and there secondary quartz and orthoclase replace the remainder of the crystal. Some crystals are traversed by a reticulating network of fractures. The alunite occurs also in veins traversing the phenocrysts and in grains and elongated forms in the groundmass. Calcite is sparingly present in most slides, and with acid the rock in general gives a slight lime reaction.

Exceptions to the above general descriptions are (*a*) the purple cap rock in the crest of East Ridge, which is relatively fresh, profusely banded, and probably younger than the flows containing the deposits; (*b*) a pale-greenish flow underlying the cap rock of East Ridge, which contains very little quartz and which seems to stand close to trachyte; and (*c*) the purple rock occupying most of the west slope of this ridge, which, though rich in quartz, contains relatively considerable acidic plagioclase (oligoclase near oligoclase-andesine), whence the rock is close to dacite. Dacite is also reported to be the country rock in the northeastern part of the district, on the Spendel claim group, where it is probably an outlier of the Antelope Peak area.

ORE DEPOSITS.

The deposits of the camp are veins containing ores of silver and gold. Their occurrence is in a general way similar to that of like deposits in the Tertiary volcanic rocks of the West. They are found in or associated with veins and fissures contained in the rhyolite which has been described. The veins are about 20 in number. The relative position of the principal veins is shown in figure 15 and the distribution of the principal prospects in Plate III. They occur mostly at elevations of about 6,500 feet. The general strike of the veins is N. 12° E., about parallel with the principal jointing system above described, but some of them depart from this direction, both to the east and especially to the west. The dip is about 40° W., into the range, but varies from 30° to 60°. Of the steeper dips the Chloride vein (fig. 14) is an example. In several places the dip was observed to flatten in depth, and the tendency to flatten seems to be general. The veins are fairly persistent, several having a known extent of 2,000 feet or more, while for some a much greater length is claimed. Branching and intersection seem to be common.

The veins are exposed principally in the southern and northern parts of the district. If present through the considerable stretch of intervening ground, they are mostly covered by alluvial wash and débris from the mountains.

The veins vary from 1 to 20 feet or more in width, 8 feet being perhaps a fair average. As for the most part they weather evenly with the country rock, the croppings are generally not prominent.

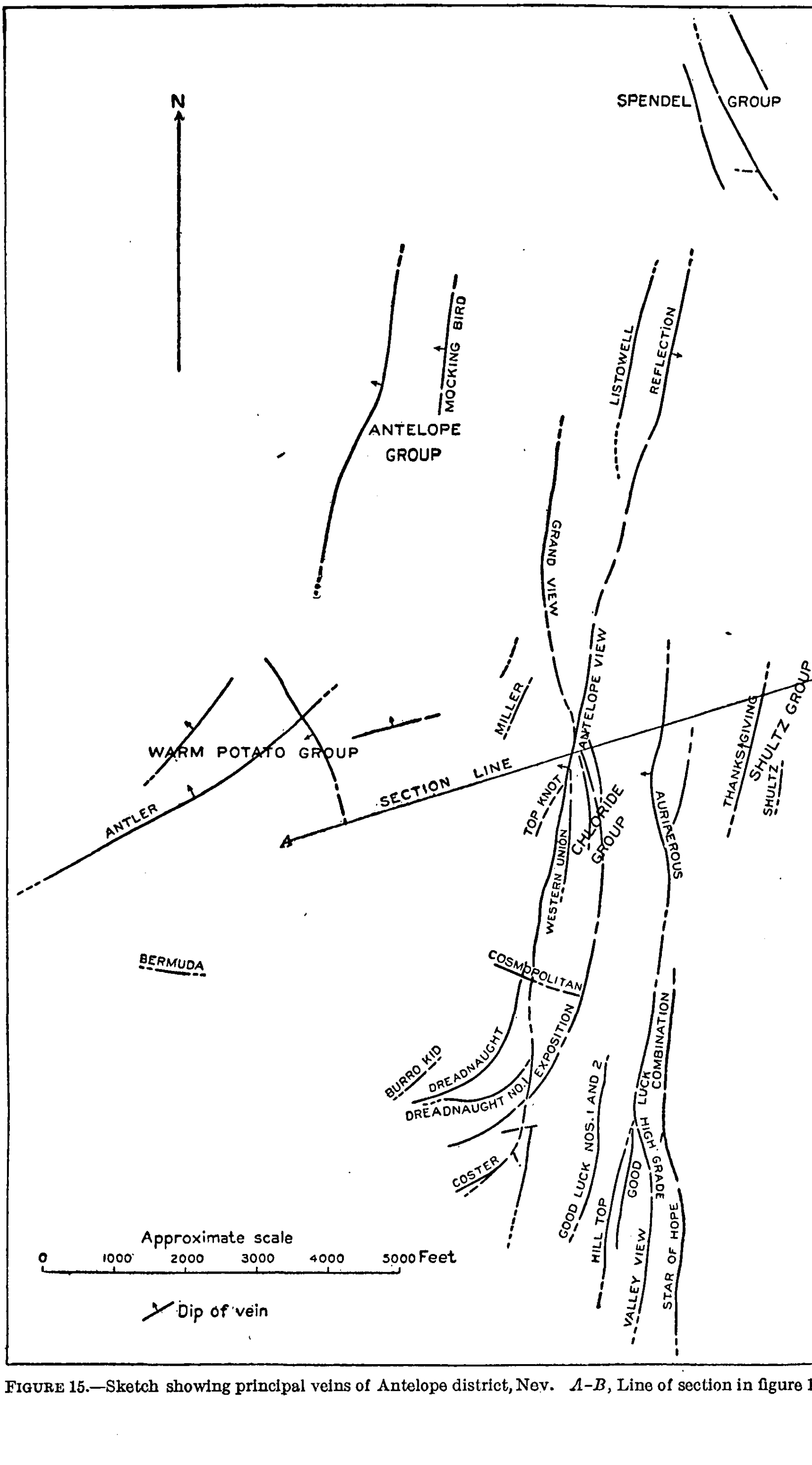


FIGURE 15.—Sketch showing principal veins of Antelope district, Nev. *A–B*, Line of section in figure 14.

However, there are some good-looking croppings, consisting chiefly of iron and manganese stained quartz and silicified rhyolite, in the southern part of the district on the Chloride and Auriferous groups, in the western part on the Antelope group, and to the north on the Reflection and Listowell claims.

The Auriferous croppings have considerable gossan that pans well in gold. Quartz samples from the Exposition shaft show hematite with specularite and some pyrolusite, and quartz ore from the Chloride shaft, near the southwest corner of the Antelope View, contains considerable chrysocolla.

The gangue is quartz and faulted, crushed, and altered rhyolite. The rhyolite is in part silicified, in part completely kaolinized to a white chalklike mass of so-called talc, and in part affected by all stages of alteration between these extremes. The chalklike material is largely kaolin, with some alunite. The portions most resembling talc in the hand specimen are found under the microscope to consist principally of sericite, a filmy white or colorless mica derived by alteration from the orthoclase. Even the portion of the gangue which at first appears to be normal vein quartz is found on examination to be mainly altered and silicified rhyolite replaced by quartz. Some of it has a finely honeycombed or porous texture, which seems in part due to cavities of disseminated pyrite dissolved out of the rhyolite. The quartz is also drusy, with small, very irregular cavities, containing acute solid angles and jagged walls studded with pyramidal quartz crystals and filmed with hyalite. Adularia is sparingly associated with the quartz as a gangue mineral.

In the northwestern part of the district, on the Antelope group, was observed some platy quartz, pseudomorphic after calcite or other spar, indicating that the present gangue has in part replaced an earlier gangue mineral, but this phase of replacement seems to be very subordinate.

In general, much of the gangue is more or less heavily stained with iron and manganese, and, as shown by slickensides and displacements, there has also been considerable postvein movement.

The valuable ore minerals are chiefly the silver chloride, cerargyrite or horn silver, and the sulphide, argentite. They occur mainly in the form of dark-green or gray-green specks, bodies, and films widely distributed through the gangue, and with them and the iron oxide is associated the gold. Some of the bodies are cuboidal and apparently fill casts of dissolved pyrite crystals. The film form is best developed on slickensides in the chalky kaolinized masses.

About four-fifths of the valuable content of the ore is in silver and one-fifth in gold. In places occur bodies several inches in diameter of yellowish and gray-green horn silver that are very rich. Macroscopic free gold is not common, especially in the main vein, but in a cellular quartz specimen collected at about 60 feet down the hill slope from the Antelope View mine the pocket lens shows the dark silver ore bodies to be peppered with small beads and specks of gold. The light color of much of this gold denotes that it is in alloy with native silver.

Associated with the ore in many places is considerable iron oxide, mostly limonite, which so permeates and stains large bodies several feet in diameter that the mass resembles partly decomposed iron ore. Much of the ore of this type, as well as of the porous honeycombed siliceous ore, pans well in gold.

In places the ore minerals, by metasomatic replacement, impregnate to a considerable degree the surrounding altered wall rock, which is locally kaolinized or silicified for distances of 60 feet or more back from the vein. In contracted parts of fissures and in small fissures and joint cracks showing little or no distinct vein the ores appear along the planes of division.

MINES AND PROSPECTS.

ANTELOPE VIEW MINE.

The Antelope View mine, where the recent strike was made, is near the south-central part of the district, about a mile south of the spring, in the east base of Jordan Ridge. (See Pl. III, figs. 14 and 15.) At the time of visit it was opened by a 150-foot crosscut tunnel and a 23-foot inclined shaft sunk on the vein. The shaft was sunk mainly under the Wingfield option, already described.

The vein strikes N. 12° E. and dips 35° W. into the hill. The country rock is the rhyolite which has been described. Locally the hanging wall only is known as rhyolite, the footwall, because of its numerous kaolinized feldspar phenocrysts, being called "birdseye porphyry." The supposed difference is due to weathering, however, for the microscope shows the rock in the two walls to be the same.

The shaft is about 50 feet above the edge of Mineral Wash on the east and 35 feet above the tunnel. The vein here has a width of about 10 feet. It is opened in one of the best-mineralized spots of the camp and near by seems to be joined by one or more spurs or feeders coming in from the Chloride group on the southeast (fig. 15). As exposed in the shaft, it consists principally of crushed and blocky silicified and kaolinized rhyolite, partly iron stained, with quartz in irregular bodies, bands, stringers, and veinlets.

Practically all the material excavated from the shaft (about 30 tons) is ore. It is reported to average about $200 to the ton, and contains some rich bunches. At the time of visit 2 tons of the ore had been shipped, 14 tons was sacked ready for shipment, and about an equal amount lay on the dump.

The bottom of the shaft at this time contained several angular blocks of relatively little altered rhyolite which seemed in part to displace or crowd out the vein. Later reports,[1] however, state that at the depth of 50 feet the vein was widening and the ore had improved in grade.

Early in April the shaft had attained a reported depth of 85 feet. At that depth the vein is about 3 feet wide, and some samples taken across its width assayed $600.

The tunnel, which also has produced some ore, is driven on the footwall side in crushed and partly altered rhyolite. Its dump material is more or less iron stained and much of the rock has a parallel elongated or semirodded structure, the rods consisting mainly of chalk kaolinization products, apparently derived from the feldspars.

On several of the leases to the north and the south, on the Western Union claim, and on the Hilltop, adjoining the Western Union on the west, where the vein is split or is represented by three veins, some shallow openings show good-looking prospects that yield fair assays of ore minerals, principally horn silver, but not yet in workable amount. In fact, the lease openings, some of them 20 feet or more deep, seem to indicate that the rich ore found in the Discovery shaft does not extend continuously along the vein, as was expected.

CHLORIDE GROUP.

Six hundred feet south-southeast of the Antelope View mine, near the southwest corner of the Chloride claim, a vein which seems to be a spur or feeder to the Antelope View vein, is opened by a 40-foot 60° inclined shaft. The dump shows the vein material to be principally crushed quartz, and it is reported to carry only low values.

On the Clifford lease, about 100 feet to the east of the above-mentioned shaft, in the west edge of Mineral Wash, is another ledge which at the time of visit was being opened with good results, its material panning well in gold. A few hundred feet north of this locality a 3-foot hole that was being sunk, apparently on the same deposit, exposed a 10-foot vein, which, together with its iron and manganese stained croppings, ranks among the best indications seen in the camp.

AURIFEROUS GROUP.

Easterly across Mineral Wash about 1,300 feet from the Antelope View mine is the Auriferous vein, on the claim group of this name, shown in figure 15. It is opened by a 30-foot inclined shaft. The croppings here show a vein width of about 12 feet. The vein is reported to have a known extent of about 2,000 feet and to contain

[1] Jordan, P. T., letter of Feb. 22, 1912.

considerable $14 ore, and it pans well in gold. About one-fourth mile south of the shaft the vein is opened by a 120-foot crosscut tunnel.

GOOD LUCK GROUP.

South of the Auriferous group, on the Good Luck group, two claim lengths in extent, is a vein reported to be opened by a 65-foot shaft and a 45-foot tunnel. The vein is said to be 4 feet in width and yields assays of $18 to $75 to the ton in silver and gold.

STAR OF HOPE GROUP.

East of the Good Luck group, with the High Grade claim intervening, is the Star of Hope vein, about two claim lengths in extent, opened principally by a 150-foot tunnel. This vein has a reported width of about 4 feet and considerable portions of it carry ore containing about $6 in gold and $9 in silver to the ton.

ANTELOPE GROUP.

On the Antelope group, owned by the Bailey Brothers, in the northwestern part of the district, the principal upper or western vein lies at about 6,800 to 6,900 feet elevation, being about 100 feet higher on the north than on the south. It is situated similarly to the Antelope View vein, shown in figure 15, but on a steeper upper slope. It also is in rhyolite, which is pale greenish and is possibly a dike, and it seems to be associated with the contact of this rock with the "intrusive" andesite-dacite area of Antelope Peak on the west. It is opened at eight or ten points by a series of pits and inclined shafts, mostly earlier work, extending through a distance of about half a mile.

On the south, where opened by a 40-foot 40° inclined shaft, the vein has a width of about 14 feet and contains some greenish quartz which traverses the rhyolite in stringers and veinlets, locally forming a sort of stockwork.

Toward the north end of the vein the principal opening is a 150-foot 35° inclined shaft, which is in iron-stained crushed and in part altered and silicified rhyolite, some of which is also brecciated and cemented with infiltrated quartz.

The eastern or Mocking Bird vein, situated about 100 feet lower than the upper vein, is opened principally by a 120-foot 30° inclined shaft. The walls consist of rhyolite that is less crushed and more massive, coarse, and blocky than that on the upper vein. They are also in part silicified. The dump contains a little ore, but so far as learned there has been no production.

REFLECTION GROUP.

The vein on the Reflection group, in the northern part of the district, extends about 2,000 feet northward from the vicinity of the spring, which seems to be connected with it in origin. It is about

12 feet in width and apparently forms an exception to the general westerly dip of the veins in that it seems to dip 40° E., but the openings on it are too shallow to determine this point conclusively. Portions of the vein look well, as do also portions of the Listowell vein, nearly paralleling it about 500 feet distant on the west. In places the croppings on the Listowell are prominent and are pitted with cavities representing dissolved-out pyrite.

SULPHIDE PROSPECT.

The prospect commonly known as the Sulphide, or Trappmans new camp, which represents earlier work than that of the recent strike, is located at the south border of the district, on the upper west slope of the range. It is opened principally by a 120-foot shaft, the lower part of which is in the sulphide zone. A gasoline hoist used in sinking the shaft has been removed, it is said, on account of the large amount of water in the shaft and the relatively low grade of the ore.

CONCLUSIONS AND SUGGESTIONS FOR PROSPECTING.

Although no deep sinking has yet been done in this camp, present developments and the geologic and mineralogic conditions indicate that the region probably contains a reasonable amount of fair-grade ore. From the general nature of the deposits, the relatively unfavorable character of the underlying rock, and the tendency of the veins to flatten in dip as they go down and to follow the bedding of the flows, it is inferred that the deposits are practically confined to the rhyolite covering and as a rule do not penetrate the underlying quartzite. The thickness of the rhyolite probably nowhere much exceeds 500 or 600 feet and in most places it is considerably less.

The view held by many that rhyolite is a particularly unfavorable formation for the occurrence of mineral is without good foundation. This is shown by the Jarbidge, De Lamar, and other camps. Besides, the rhyolite of this district is known to be among the productive rocks of the Southwest.[1]

In prospecting, as pointed out by Ball, attention should be given to the quartz veins and fissures in the kaolinized and silicified areas of the rhyolite, to the contact of the rhyolite with the underlying intruded rock, especially if it is limestone, and also especially to the contact of the rhyolite with the younger intrusive andesite and dacite, as in the Antelope Peak area on the northwest, and to the andesite and dacite themselves.

[1] Ball, S. H., A geologic reconnaissance in southwestern Nevada and eastern California: Bull. U. S. Geol. Survey No. 308, 1907, p. 49.

NOTES ON THE NORTHERN LA SAL MOUNTAINS, GRAND COUNTY, UTAH.

By JAMES M. HILL.

FIELD WORK AND ACKNOWLEDGMENTS.

This report is based on a reconnaissance of the north end of the northern group of the La Sal Mountains, Utah, including the Miners Basin and Wilson Mesa districts. The field work was undertaken in the middle of June, 1911. A later date would have been preferable, as these mountains are from 11,000 to 12,500 feet above sea level and the snow lies in drifts from 10 to 20 feet deep in the more sheltered places until the beginning of July, blocking the trails and mine workings. Few of the prospects could be entered. So far as could be learned the miners at the basins (numbering about 20 to 30 men) depart with the approach of winter and rarely return before the first of July.

The writer is indebted to the few men who were in the mountains at the time of his visit for numerous courtesies, and in particular to Mr. M. I. Fowler, of Basin and Salt Lake, who gave generously of his time and by his knowledge of the region aided the field work materially. Mr. L. M. Prindle, of this Survey, who has visited these mountains, has generously supplied much information from his notes and made many helpful suggestions during the preparation of this report.

LOCATION.

The La Sal Mountains are shown on the La Sal topographic sheet of the United States Geological Survey at about latitude 38° 30′ north, longitude 109° 15′ west. The northern group of these mountains is in the extreme southeast corner of Grand County, near the Colorado line. The region is most easily reached from Cisco, on the main line of the Rio Grande Western Railway. A daily stage runs from Cisco to Castleton, a distance of 38 miles. The latter town lies in Castle Valley, at the northwest base of the mountains, and roads of varying degrees of poorness radiate from it to the lower parts of the basins and to Wilson Mesa and Moab. Moab, the county seat, is about 14 miles west-southwest of Castleton in an air line, but the road between the two towns is over 20 miles long. A daily stage runs between Moab and Thompsons, on the Rio Grande Western, about 30 miles north-northwest of Moab.

PREVIOUS WORK.

The first known mention of the Sierra La Sal is in the report, published in 1876, of the exploring expedition headed by Capt. J. N. Macomb, of the United States Engineers, in 1859, from Santa Fe to the junction of Grand and Green rivers. Macomb's party visited the Sierra Abajo, or Blue Mountains, south of the La Sal Mountains, studied their character, and from long-range observations concluded that the two ranges were of similar character, being formed by eruptive trachyte which has domed the sedimentary beds.

In 1875 Peale and Holmes[1] studied the Sierra La Sal, making a topographic map and drawing several sections across the mountains. Peale describes the mountains as consisting of three groups of eruptive trachyte porphyry with low sedimentary saddles between. The northern group shows beds of red sandstones, slates, and shales of Cretaceous and Triassic age, dipping away from the mass in all directions, steeply near the mountains and at low angles a short distance from them. The eruptive rock is described as a light-gray feldspathic trachyte with crystals of feldspar and hornblende, giving it a porphyritic appearance. The specimens were lost, but were said to be similar to the rock of Mount Marcellina, in Colorado. Peale places the age of the eruption as post-Cretaceous and preglacial. The present form of the mountains he ascribes to extensive erosion, in part glacial. This erosion has removed the sedimentary beds, which may have at one time completely covered the group, except on some peaks on the north and northeast flanks of the mountains.

Endlich,[2] in reviewing the "acidic volcanic eruptives" of Colorado, summarizes Peale's report and classes the rock of the La Sal Mountains as porphyritic trachyte, a group of eruptive rocks which he describes as including those that are isolated in their topographic character and geognostic position and show all the typical characteristics of trachyte.

Peale[3] in 1877 reviews the work of the Hayden Survey since 1873, and concludes that many mountain masses in Colorado and Utah show the same general characteristics, namely, they are isolated, they are of eruptive origin, they show general resemblance in their rocks, and they occur in areas of sedimentary rocks. He notes that in all of them the igneous material came up through fissures in the lower sedimentary strata with or without tilting the beds until it reached the Cretaceous shales, where the magma spread out in dikes and

[1] Peale, A. C., On the Grand River district: Ninth Ann. Rept. U. S. Geol. and Geog. Survey Terr., for 1875, 1877, pp. 59-62, 80-92, 95-98.

[2] Endlich, F. M., On the erupted rocks of Colorado: Tenth Ann. Rept. U. S. Geol. and Geog. Survey Terr., for 1876, 1878, pp. 232, 239.

[3] Peale, A. C., On a peculiar type of eruptive mountains in Colorado: Bull. U. S. Geol. and Geog. Survey Terr., vol. 3, 1877, pp. 551-564.

sheets, in some places doming the superimposed beds. He states that there is considerable difference between individual rock specimens but concludes that they all belong to one class of acidic feldspathic rocks.

In 1880 Gilbert[1] published his report on the Henry Mountains of Utah, which is a classic for the laccolithic type of which the Sierra La Sal is an example. This report is exhaustive and can not well be summarized in a short paper like the present one. C. E. Dutton examined his specimens microscopically, and classes them as porphyritic trachyte. He notes large crystals of feldspar and hornblende in a "compact uniform paste through which hornblende is disseminated."

In 1894 Cross[2] summarized the available knowledge of laccolithic mountains, giving brief descriptions of the principal groups and discussing the chemical and mineralogic character of the rocks, which he considered derivatives of a similar magma. He describes the rocks as typical porphyries. The phenocrysts were formed in the magma before eruption, but probably continued to grow afterward. The most typical phenocryst is plagioclase with hornblende and biotite subordinate. Hypersthene and augite are present in some types. The ferromagnesian minerals vary in amounts rather than in kind in the various specimens. The groundmass is generally gray, with few ferromagnesian minerals, but consists essentially of feldspar (usually orthoclase) and quartz.

The rock of Mount Marcellina, in Colorado, with which Peale correlates the La Sal Mountain eruptive, Cross calls a porphyritic diorite, "consisting essentially of plagioclase, orthoclase, hornblende, biotite, and quartz." It is a fine-grained grayish rock in which the dark minerals are subordinate and the phenocrysts small, ranging from 1 to 3 millimeters in diameter.

Several of the typical rocks of the La Sal Mountains, collected by L. M. Prindle in 1901, have been analyzed by the survey and brief descriptions of them published,[3] as follows:

Analyses of rocks from the La Sal Mountains.

Petrographic descriptions by L. M. Prindle. Analyses by W. F. Hillebrand, record No. 2032.

A. Monzonite porphyry, 2 miles west of Mount Peale. *Akerose.* Contains phenocrysts of plagioclase, partly resorbed hornblende, and pyroxene in a groundmass of partly striated feldspar. It may contain also orthoclase and quartz. P. R. C. 1306.

B. Ægirite granite porphyry, about 1.5 miles south of Mount Waas. *Omeose-liparose.* Contains quartz, feldspar, pyroxene, and iron ore. The pyroxene is probably for the most part ægirite. P. R. C. 1304.

[1] Gilbert, G. K., Geology of the Henry Mountains: U. S. Geog. and Geol. Survey Rocky Mtn. Region, 1880.

[2] Cross, Whitman, The laccolithic mountain groups of Colorado, Utah, and Arizona: Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, pp. 165-241.

[3] Clarke, F. W., Analyses of rocks and minerals: Bull. U. S. Geol. Survey No. 419, 1910, pp. 120-121.

C. Syenite-aplite porphyry resembling grorudite. About 2 miles south of Mount Waas. *Liparose.* Contains potash and soda-lime feldspars, quartz, pyroxene, titanite, and iron ore. In the groundmass are needles which are probably ægirite. P. R. C. 1301.

D. Syenite porphyry resembling sölvsbergite. About 1 mile northwest of Mount Waas. *Phlegrose near nordmarkose.* Contains potash and soda-lime feldspars, quartz, pyroxene, and iron ore. Needles of ægirite (?) in the groundmass. P. R. C. 1303.

E. Pulaskite, 1 mile west of Mount Waas. *Nordmarkose.* Contains potash feldspar, pyroxene, biotite, apatite, titanite, and iron ore. P. R. C. 1305.

F. Noselite syenite porphyry, dike on northwest shoulder of Mount Waas. *Miaskose.* Contains feldspar, pyroxene, sodalite or noselite, apatite, titanite, and iron ore. The pyroxene appears to be mostly ægirine-augite and the feldspar mainly potash feldspar. P. R. C. 1302.

	A	B	C	D	E	F
SiO_2	61.21	73.27	70.02	68.96	62.64	58.99
Al_2O_3	17.10	13.29	14.38	15.42	17.36	19.01
Fe_2O_3	2.72	1.16	1.17	1.99	2.79	1.74
FeO	1.88	.13	.13	.16	.63	.59
MgO	1.47	.07	.61	.22	.53	.27
CaO	4.83	.21	.66	.25	1.70	2.02
Na_2O	5.66	3.44	5.48	6.59	7.00	9.11
K_2O	3.00	7.53	5.87	5.48	4.97	5.07
H_2O at 105°	.34	.23	.27	.22	.43	.38
H_2O above 105°	.68	.43	.44	.30	.53	1.24
TiO_2	.51	.10	.10	.12	.43	.21
ZrO_2	.02	.02	.01	.04	.02	.07
CO_2	None.	.02	.38	.13	.54	None.
P_2O_5	.24	Trace.	Trace.	Trace.	.12	.04
SO_3	None.	.07	.19	None.	.06	.96
Cl	.04	.01	.03	.01	.03	.15
MnO	.15	.03	.02	.07	.04	.08
BaO	.13	.10	.13	Trace.	.10	.02
SrO	.07	None?	.06	None.	.07	.02
Li_2O	Trace?	Trace?	Trace.	Trace.	None.	Trace.
	100.05	100.11	99.95	99.96	99.99	99.97

S absent from all.

In 1904 Boutwell[1] visited the vanadium deposits in the vicinity of Richardson, near the north end of the La Sal Mountains. His description of the sedimentary beds is fairly complete, but he made no attempt at correlation with similar formations elsewhere. As these deposits were not accessible in 1911 a brief summary of his observations is given for the benefit of those who have not seen his report.

A zone of deformation enters the Richardson amphitheater near the mouth of Fisher Creek and crosses it in a southwesterly direction. Along this zone the sedimentary beds are upturned, brecciated, and probably faulted. Mineralization has occurred through the replacement of crushed sandstone for a distance not greater than 4 feet from the main fracture. The yellow, green, and blue vanadium minerals are usually found in "thin patches 1 to 10 inches in diameter upon the walls of sandstone blocks," being more abundant near the main fissure. Small oval masses of yellow earthy carnotite up to 1 inch in diameter are also found in certain beds of gray sandstone, particularly on the hanging wall. The vanadium minerals are the more abundant and important.

[1] Boutwell, J. M., Vanadium and uranium in Utah: Bull. U. S. Geol. Survey No. 260, 1904, pp. 200-210.

In 1905 Cross and Howe[1] published a paper correlating the subdivisions of the "Red Beds" of Colorado and suggesting their continuance farther west. During the summer of 1905 Cross studied in greater detail the stratigraphy of southeastern Utah. His report[2] not only gives his own results but reviews and correlates all the previous work in this region and includes a very complete bibliography on this problem. The formations discussed by him are shown in the subjoined table, together with their chief characteristics and their distribution in the Grand River region.

Sedimentary formations exposed in Grand River region.

[After Whitman Cross.]

	Powell.	Peale.	Holmes.	San Juan folios, United States Geological Survey.		Character in Grand River region.
Cretaceous.				Mancos.		Dark shales; very small exposures left.
	Henry's Fork.	Dakota or Upper Dakota.	Upper Dakota.	Dakota.		Light-colored sandstones and shales, thin bedded. Partly eroded, leaving uncertain thickness.
Jurassic.	Flaming Gorge.	Lower Dakota.	Lower Dakota.	Gunnison.	McElmo.	Soft variegated, light-colored sandstone with much green, red, and white shale and marl. Probably thin in the vicinity of Mesa.
		Jurassic.			La Plata.	Light-pink, orange, or reddish sandstones showing marked cross-bedding. Two massive beds separated by thin-bedded sandstones. The total thickness at good exposures is about 625 feet.
	White Cliff.	Triassic.	Triassic.			
Triassic.	Vermilion Cliff.			Dolores.		Massive dark-red sandstone, cliff-making above, 100 to 200 feet of thin-bedded sandstones and shales below, with beds of limestone conglomerate containing saurian fossils.
Carboniferous.	Shinarump group. (All assigned to Triassic.)	Permian, Permo-Carboniferous, or Upper Carboniferous.		Permian?	Cutler.	Red, purple, and green thin-bedded arenaceous shales, locally gypsiferous. From 600 to 800 feet thick as exposed along Grand River between Moab and Castle Valley, but estimated to be between 1,500 and 2,000 feet in maximum thickness.
	Aubrey.	Middle Upper Carboniferous.		Pennsylvanian.	Hermosa.	Blue fossiliferous limestone and thin light-colored sandstones. At Moab about 475 feet thick.

TOPOGRAPHY.

The La Sal Mountains are in the Colorado Plateau region, which is marked by long mesas cut by abrupt canyons from 2,000 to 2,500 feet in depth with steep cliffs 500 to 600 feet high. Above this relatively level plateau, which has a general elevation of 8,000 feet, the northern

[1] Cross, Whitman, and Howe, Ernest, Red Beds of southwestern Colorado and their correlation: Bull. Geol. Soc. America, vol. 16, 1905, pp. 447–498.

[2] Cross, Whitman, Stratigraphic results of a reconnaissance in western Colorado and eastern Utah: Jour. Geology, vol. 15, 1907, pp. 634–679.

group of the mountains rises abruptly to an extreme height of 12,586 feet at Mount Waas. The group trends north-northwest and south-southeast and is about 8 miles long by 5 miles across. Rising as it does some 4,000 feet in 2½ miles, the slopes are necessarily steep, in places precipitous.

The mesas from a distance give the impression of having a very gradual, even slope away from the mountains. In detail they are more like broad, uneven steps. The horizontal portions are separated by wavy cliffs or by steep talus slopes with low cliffs at the top. The rises are not everywhere the same, but vary from a few feet to a hundred feet in height. The mesas are usually narrower near the mountains and broaden as they approach the rivers. This is particularly noticeable of Wilson Mesa. The long, narrow, flat-topped ridge between Castle Valley and Rock Creek shows the reverse condition.

The main drainage from the mountains is radial, and the permanent streams are in the bottoms of deep canyons. On the east and northeast sides the streams flow into Dolores River, which joins the Grand about 20 miles north of Mount Waas. On the other sides the drainage is directly into Grand River by way of Fisher Valley at the north, Castle Valley in the center, and Mill Creek at the south.

There are no permanent streams on the mesas, but broad, shallow drainage lines with flat gradients parallel to the longer dimensions of the mesas are prevalent. The grade is so small that in several places dams 2 to 4 feet high pond water over several acres. The water on Wilson Mesa is taken from Mill Creek, though melting snows and infrequent showers account for at least a part of that stored in the reservoirs.

GEOLOGY.

SEDIMENTARY ROCKS.

The sedimentary series, outlined in the table on page 103, in the region of Castle Valley and Wilson Mesa, is as follows: The floor of the west end of Castle Valley is cut into the red shales and sandstones of the Permian. Some gypsiferous sandstones occurring at the top of the series can be clearly seen in the low hogbacks at the north side of the valley. Between these beds and the massive red sandstone (Vermilion Cliff) which forms the "Castle" at the lower end of the valley there is a series of alternating shale, sandstones, and conglomerate of red color about 550 feet thick, which probably represents the basal portion of the Dolores formation. The Vermilion Cliff sandstone, the equivalent of the upper part of the Dolores formation, is the rim rock of the west end of the valley and underlies the lowest western part of the Wilson Mesa. The middle mesa, extending westward from Mesa post office about 1 mile, is underlain by light-reddish sandstones which are probably referable to the White Cliff sandstone, regarded as the appropriate equivalent of the La Plata sandstone. The upper mesa, extending eastward from the ridge east of Mesa post office to the mountains, consists of thin-bedded light-colored sandstones mapped by Hayden[1] as upper Dakota, and in Cross's correlation called Dakota. At the base of the sandstones exposed in a creek bed southeast of Mesa post office there are some soft green and white shales that may represent the McElmo formation. The Mancos shale is exposed close to the mountains about 4 miles west of Mesa post office.

The correlation given above is based on the similarity of the sedimentary series exposed here to the formations as described in the published reports on the "Red Beds." The writer did not have the opportunity to study the section described by Cross or to correlate the series from any known point to the immediate vicinity of Wilson Mesa.

DETRITAL MATERIAL.

In some localities on Wilson Mesa there are deposits of unconsolidated auriferous gravels for whose character and distribution it is rather difficult to account. These gravels will be discussed under the heading "Economic geology." Extending eastward from the intrusive dome in the center of Castle Valley to the base of the mountains there is a ridge separating the valley into two parts. This ridge consists of relatively fine material near the dome showing some rough stratification, but of coarse, unstratified cobbles and sands near the mountains. It is cemented by a white calcareous material at the east end and contains some gypsum cement in some places near the center. The cobbles were derived in part from the sandstones, but by far the most abundant fragments are similar to the rocks of the laccolithic mountains. In appearance this conglomerate somewhat resembles the Gila conglomerate of the desert country of southwestern Arizona.

In the heads of the basins in the high mountains there are small glacial moraines. These are very short and low, but they have typical moraine topography. Few of them extend below 10,000 feet and none reach the lower parts of the basins. The best example is in Miners Basin, where the town of Basin is built on a small flat just above the terminal.

Rock streams or rock glaciers are developed in most of the cirques. Three small examples are to be seen in Miners Basin, two in Bachelor Basin, and two in Beaver Basin. Those in the last two localities were partly covered by snow in June, 1911. On the south side of Miners Basin, about a quarter of a mile southeast of Basin post

[1] Hayden, F. V., U. S. Geog. and Geol. Survey Terr., Atlas Sheet XIV.

office, is what at first glance appears to be a talus slide. However, it has rude concentric ridges at the lower end, which rises at a steep angle about 50 feet above the valley floor and appears to be advancing into a grove of pine trees. Its sides in the lower part are marked by steep V-shaped depressions between the rock glacier and the talus slopes of the valley. The heads are clearly talus slopes. Time was not available for detailed study of these glacier-like slides. The theory advanced by Capps [1] that such forms are actually moving, owing to the movement of interstitial ice filling, seems to the writer not to fit the conditions in the La Sal Mountains as well as the landslide theory which Howe [2] applied to apparently similar forms in the San Juan Mountains.

The most recent formation is the relatively insignificant deposit of fine gravels along the streams, in the mountains, and on the mesas. The west-central part of Castle Valley is covered by gravel, apparently of the same origin as the conglomerate ridge, and silts from the wash of the present stream. The gravels cover the broad, flat bottom to considerable depths. At least 20 feet is shown in stream cuts, and it is reported that wells 100 to 150 feet in depth penetrate no other formation. The silts are relatively thin and patchy in distribution.

INTRUSIVE ROCKS.

The core of this group of the La Sal Mountains is composed of a series of rocks probably all derived from the same magma. The earliest and by far the most widely distributed rock is a light-gray, fine to medium grained porphyry, with distinct phenocrysts of plagioclase and hornblende, and smaller ones of pale-green augite. Normally this rock shows no quartz, but here and there blebs are noted up to one-eighth inch in diameter. Orthoclase feldspar phenocrysts are seen in some specimens, but this mineral is usually more abundant in the groundmass, a large proportion of which is made up of finely granular plagioclase. The normal rock is a monzonite porphyry, but with more abundant quartz it approaches quartz monzonite porphyry. The monzonite porphyry forms the main intrusive mass indicated on the map (fig. 16) and also the knob northwest of Castleton.

Cutting the monzonite porphyry are at least two, and possibly three, sets of dikes, whose general direction is about north-northeast to south-southwest. They vary from a few feet to 100 feet in width, but are relatively short.

The most common of these dikes is a rock with a fine-grained gray feldspathic groundmass containing conspicuous tabular phenocrysts

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[1] Capps, S. R., Rock glaciers in Alaska: Jour. Geology, vol. 18, 1910, pp. 359–375.

[2] Howe, Ernest, Landslides in the San Juan Mountains, Colorado: Prof. Paper U. S. Geol. Survey No. 67, 1909.

of plagioclase and orthoclase up to half an inch or more in diameter. The proportion of ferromagnesian minerals is small. This rock has been classed by Prindle as syenite porphyry. It weathers gray to yellow and is, as a rule, not iron stained except near veins.

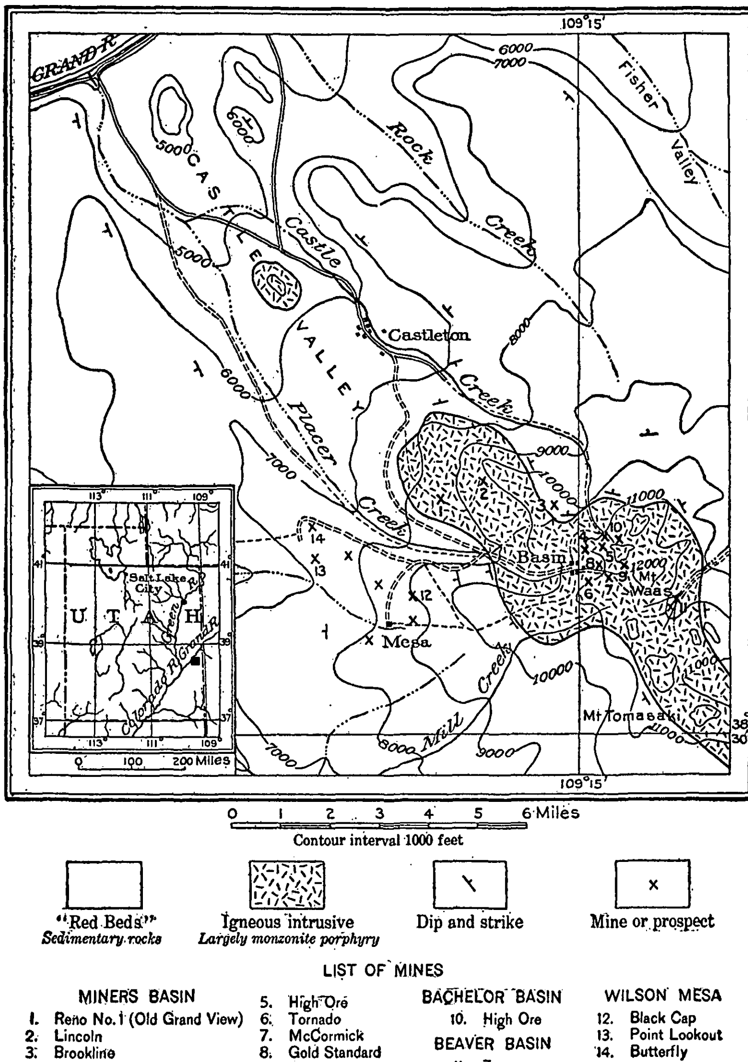

FIGURE 16.—Sketch map of the northern group of the La Sal Mountains, Grand County, Utah. Adapted from La Sal topographic sheet, U. S. Geol. Survey. Black square on index map indicates location of area.

A second type of porphyry dike rock Prindle has called noselite syenite porphyry. It occurs in a few dikes up to 20 feet in thickness in the monzonite porphyry and the syenite porphyry. It is composed of very large zonally banded orthoclase crystals up to 1½ inches across set in a medium-grained porphyritic groundmass. The groundmass constitutes less than one-third of the rock and contains megascopic crystals of orthoclase, pyroxene (ægirite-augite and ægirite), and noselite in a feltlike mass composed of orthoclase without crystal outlines and ægirite needles. The orthoclase crystals are rounded and in places weather out of the groundmass as nearly perfect crystals. The groundmass becomes pitted and of a brownish-yellow color upon weathering.

The third dike rock, quartz monzonite porphyry, was found at only one locality, about half a mile west of Basin post office, and the croppings were largely covered by slide rock. The material is all intensely altered, leaving a yellowish-white pitted groundmass showing scattered plagioclase feldspars with abundant quartz blebs and prismatic crystals of altered white orthoclase from one-eighth to three-fourths of an inch in longest dimension. It may be that this is simply a very siliceous phase of the monzonite porphyry, though its high orthoclase content makes it appear to be a distinct type.

So far as noted, the sedimentary beds adjacent to the intrusive rocks contain no contact-metamorphic minerals, and in the descriptions of these mountains cited above no mention is made of contact metamorphism. Cross[1] makes the following statement in this regard:

> One interesting difference between these magmas [the laccolithic] and the closely allied ones of the Elk Mountain diorites has already been alluded to. Not only are the sediments adjoining the laccolithic masses unattacked by heat, but they seldom exhibit any development of secondary minerals as contact phenomena.

The age of the formation of the laccolith can not be given definitely. The Mancos shale is involved in the doming, so the intrusion is at least later than Upper Cretaceous. Cross in the paper above cited places the age as Tertiary. This estimate is based on the hypothesis that a load of probably several thousand feet of sediments, above those now exposed, was present at the time of the intrusion. This great thickness is thought essential to account for the uniform conditions of cooling through a great vertical range shown by the porphyries of the several laccolithic groups.

STRUCTURE.

The "Red Beds" at first sight appear to be in an absolutely horizontal position along Grand River but on closer inspection are seen to lie in broad, flat anticlines, with a few faults of small displacement.

A pronounced anticlinal axis with a northwest-southeast trend runs through Salt Wash, northwest of Grand River and south of Thompsons, on the Rio Grande Western Railway, continuing through Castle Valley, and apparently is again seen southeast of the La Sal

[1] Cross, Whitman, The laccolithic mountain groups of Colorado, Utah, and Arizona: Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, p. 230.

Mountains in the Paradox Valley, Colorado. Salt Wash is a broad, flat valley surrounded by low hogbacks which approach one another at each end, the beds dipping northeast on the north side and southwest at the south. It is an excellent example of a broad, low dome.

Castle Valley has an average width of 2 miles and is 9 miles long from Grand River to the base of the La Sal Mountains. It has a flat floor, except for a round porphyry butte near the center and the conglomerate ridge already mentioned joining it to the mountains and dividing the valley into two parts. The sides are nearly vertical cliffs about 1,500 feet high. They are composed of "Red Beds" strata and dip away from the axis of the valley at angles of 5°. To the northwest they converge and just east of Grand River a fault of about 100 feet displacement is clearly shown in the butte which stands in the center of the valley. The broader southeast end of the valley is blocked by the intrusive mass of the La Sal Mountains. The sedimentary beds on the north side are bent toward the intrusive mass about three-fourths of a mile from it, then are sharply upturned over the porphyry core. Castle Creek follows this sharp syncline. On the south wall of the valley the sedimentary rocks dip southwest at very steep angles for one-fourth of a mile or less from the intrusive and at that distance flatten out rather abruptly to the general level of the beds underlying Wilson Mesa.

On the north side of the mountains the sedimentary beds come up to an elevation of 10,750 feet, overlying a ridge of porphyry that runs northwest from the central core. East of Beaver Basin the beds dip about 45° E. and form the east wall of the basin.

ECONOMIC GEOLOGY.

Two classes of deposits are worked in the vicinity of Basin and Mesa. In the mountains there are several quartz mining prospects and at least one locality where placer gold has been recovered. On Wilson Mesa there has been recently some little excitement over the discovery of gold-bearing gravels.

HISTORY.

So far as can be learned, the earliest discoveries of minerals in this area were made about 1886, the first location being made in 1888 on the ridge between Bachelor and Miners basins, on what is now the High Ore claim. Practically no mining was done in these mountains until 1896, when a party of prospectors did some work that resulted in the discovery of the Tornado deposit in 1897. The district has never attracted much attention, on account of its distance from the railroad and the inclement winters. Shortly after the discovery of the Tornado, a small stamp mill was installed in Miners Basin. It has five 600-pound stamps, driven by a Pelton wheel, generating

6 horsepower. A 5 by 9 foot copper amalgamation plate and two Frue vanners were used for saving the gold. After about 100 tons of ore had been run through the mill it was closed and has not been operated since.

In 1907 it was first noted that the gravels on Wilson Mesa carried gold. For two years these gravels were washed by crude methods, and in 1910 a little excitement was created in Salt Lake and Grand Junction over the richness of the deposits. That their nature was not understood is clearly shown by placer and lode locations which cover the same ground.

There has been practically no production from the quartz mines, and it is probable that $5,000 would cover the entire output from both quartz and placer mining in the region.

QUARTZ PROSPECTS.

GENERAL FEATURES.

There has been very little work done on the mineral deposits of the La Sal Mountains. The greatest depth reached is perhaps 150 feet below the surface, and 95 per cent of the shafts and tunnels are not more than 50 feet below the grass roots. The general procedure seems to have been to locate a mineralized zone on the hill slope and then go into the valley bottom and start a long crosscut to reach it in depth. As yet few of these crosscuts have reached the desired goal. It is evident that from the exposures available under these conditions only a superficial knowledge of the nature and character of the deposits is possible.

The general direction of the lodes seems to be northwest and southeast to east and west, with one or two east-northeast fractures. The northwest-southeast trend corresponds in a general way to the longer axis of the intrusive mass, as is shown in figure 16.

There are two rather distinct types of deposits—one characterized by glassy quartz with copper, silver, and gold, and the other with apparently the same kind of quartz, but containing largely gold in a pyritic carrier. The deposits of the former type are usually simple, relatively narrow quartz veins that have affected the walls to a much less degree than the second type. The gold-pyrite deposits appear to be stockworks or zones of minute branching, interlacing quartz-filled fissures. In the deposits of this type the wall rock is altered and impregnated with pyrite, forming masses of low-grade ore as much as 20 feet across. These two types, though more or less distinct, merge into each other and in places the gold-pyrite deposits show copper minerals. Veins characterized by carbonate gangue were seen in two places and carry both pyrite and chalcopyrite.

The ores so far developed are largely oxidized, but remnants of chalcopyrite and pyrite are found surrounded and cut by masses of limonite, malachite, and chrysocolla. These three oxides are more or less mixed, the iron being much more abundant than the copper minerals, forming a low-grade copper-pitch ore. Very minor amounts of bornite and chalcocite occur in Beaver Basin, but were not noted elsewhere. Azurite is rather uncommon. Glassy, coarsely crystalline quartz is by far the most abundant gangue mineral. It is usually rather smoky but may be clear. Calcite and siderite are seen in some veins, and associated with them in one place is a very minor amount of fluorite. Barite with limonite was noted in one deposit in sandstone near the monzonite porphyry. The association of glassy quartz with much copper-bearing limonite in small stringers is commonly seen in the brownish float of the mountains.

The lodes are later than all the porphyries except possibly the very siliceous quartz monzonite mass half a mile west of Basin. It seems possible that they may be the final product of the intrusion. The interpretation of the origin of these deposits, however, can be attempted only after much more development has uncovered the primary ores of the region, so that more detailed study of them is possible.

MINERS BASIN.

The Reno claim (No. 1, fig. 16) crosses a high ridge overlooking the southern part of Castle Valley. A shear zone about 6 to 8 feet in width cuts this point, bearing N. 60° W. and standing almost vertical. The development consists of several pits and caved tunnels on both sides of the ridge. The country rock is monzonite porphyry and the ore seen on the dumps is largely the same rock cut by stringers of quartz with abundant limonite and some malachite and chrysocolla, surrounding kernels of chalcopyrite. The principal body of ore is on the east side of the ridge, and has an elliptical cross section. All the ore is oxidized with the exception of the kernels of chalcopyrite noted.

The Lincoln prospect (No. 2, fig. 16) is on a 12-foot zone of somewhat silicified monzonite porphyry, showing on joints and narrow fractures a coating of calcite and siderite. The monzonite contains a little disseminated pyrite, largely altered to limonite. The short tunnel does not extend below the zone of oxidation.

The Brookline prospect (No. 3, fig. 16) is in a saddle of the ridge called Horse Mountain, north of Pinhook Gulch. This ridge is capped by white sandstones dipping north at steep angles. Monzonite porphyry outcrops about 400 feet below it in Pinhook Gulch and about one-fourth of a mile east and west on the top of the ridge A 50-foot shaft sunk in apparently unaltered sandstone disclosed a small body of iron-stained barite and a little limonite deposited along an open watercourse running N. 30° W. A minor amount of limonite (?) is seen coating fragments of sandstone.

On the Skylark claim (No. 4, fig. 16) there are two tunnels, the lower about 205 feet and the upper about 35 feet long. They expose a vein varying from knife-blade thickness to 2 feet. This vein cuts both monzonite porphyry and a dike of syenite porphyry. It strikes N. 52° E. and stands nearly vertical. In its wider portions there is an abundance of glassy dark quartz with drusy cavities. Some of these druses are coated with greenish-blue chrysocolla, much of it dull and earthy. Masses of limonite, usually copper bearing, which are probably the alteration products of cupriferous pyrite or chalcopyrite, occur in the quartz. Narrow quartz stringers make off into the porphyry, which contains some disseminated pyrite near them.

The upper workings of the High Ore claim (No. 5, fig. 16) are located on the divide between Miners and Bachelor basins. They consist of shallow shafts in a body of very siliceous oxidized copper ore said to have carried about $157 to the ton in copper, gold, and silver.

The Tornado property (No. 6, fig. 16) has been worked to more advantage than any of the other properties in the basin. Two zones of fracturing intersect near the main workings; one, the Tornado vein, strikes N. 80° E., and the other, the Indiana, strikes N. 40° E. Along these zones there are numerous branching fractures filled with dark glassy drusy quartz up to three-fourths of an inch in width. Near the junction of the two systems the interlacing seams are more abundant. Pyrite has been deposited both with the quartz and disseminated in the altered monzonite porphyry wall rock. The Indiana zone averages about 10 feet in width and the Tornado from 15 to 20 feet. The former is opened by two short tunnels and the latter near its junction with the Indiana by a tunnel and a 50-foot shaft. A crosscut tunnel, now 270 feet long, has been started for the intersection but has not yet reached it. All the altered pyrite-impregnated monzonite porphyry cut by quartz stringers is classed as ore, with a reported average value of $15 to $20 a ton in gold. It is all oxidized, and only a few pyrite crystals remain unchanged to limonite. The material pans well, but it is said that the iron concentrates, made at the mill, ran $28 to the ton in gold.

The McCormick prospects (No. 7, fig. 16) are only slightly developed. The Gold Coin No. 1 is on a 10 to 15 foot zone of altered monzonite cut by interlacing quartz stringers and containing some disseminated pyrite, now altered to limonite. Copper carbonates are seen in some joints and a little chalcopyrite in process of alteration is noted. One other prospect is on a vein at the contact of syenite and coarse noselite syenite. This vein is not very well defined and is nowhere over 21 inches wide. The vein material is calcite, siderite, and a little fine quartz, partly filling the fracture, which in a few places shows stains of copper carbonate.

The Gold Standard tunnel (No. 8, fig. 16) is about one-eighth of a mile east of Basin post office. It is a crosscut tunnel and could not be entered. On the dump some serpentine was noted on what appeared to be a fault. Pyrite-impregnated monzonite cut by quartz stringers, similar to the Tornado ore, was also seen, as well as calcite-siderite vein matter like that of the McCormick vein. A small amount of very black compact earthy material on the dump contains manganese and iron with some copper. It is probably a mixture of limonite and pyrolusite.

The Dewey group of claims (No. 9, fig. 16) is located at the extreme east end of Miners Basin, just under Green Mountain. The monzonite porphyry is cut by a series of nearly parallel fractures bearing N. 45° W. A 225-foot crosscut tunnel exposed near its face an open fracture in which drusy quartz crystals are coated with chrysocolla. Fifty feet farther out toward the mouth a 12 to 18 inch vein of glassy quartz shows some limonite and copper carbonates with a little calcite. This material is said to average about $20 to the ton in gold, silver, and copper from assays. On the surface this vein is largely calcite with some fluorite and minor quartz and siderite. The tunnel does not reach the sulphides, though in some of the limonite ore there were kernels of pyrite and chalcopyrite.

There are several other small prospects in Miners Basin, most of them on zones of pyrite-impregnated monzonite porphyry similar to the Tornado ore.

BACHELOR BASIN.

Only one mine in Bachelor Basin could be visited, as snow covered all the prospects. The High Ore tunnel (No. 10, fig. 16) cuts two veins. One striking east and west is cut about 50 feet from the mouth of the tunnel. It is distinctly a vertical fissure filling from 6 to 18 inches wide, consisting partly of glassy quartz with many drusy cavities. Chalcopyrite, largely altered to copper-pitch ore, was deposited with the quartz, and copper carbonates are prevalent as coatings in the druses. A little earthy fluorite of a light lilac color is found in some specimens. The other vein strikes about N. 32° E. It is followed for about 100 feet, the drift then running north of it for about 250 feet, to a point where a crosscut has been turned south, intersecting the vein at 50 feet. This vein is very narrow and consists of sugary quartz in altered monzonite porphyry. The mineralization seems to be largely pyritic, though some copper stains were noted near the junction with the other vein. It is oxidized throughout. Seven tons of the ore from the siliceous north vein was shipped and is said to have brought $54 a ton in copper, silver, and gold.

BEAVER BASIN.

In Beaver Basin the workings were entirely covered by a snowslide, except for one end of the dump of a crosscut tunnel of the Zero group (No. 11, fig. 16). The material on this dump is largely monzonite porphyry, showing some serpentine developed along shear planes. A small quantity of ore on the dump consists of glassy quartz with minor amounts of bornite, chalcocite, limonite, and malachite. It is said that the tunnel runs southeastward along a zone of altered porphyry, about 12 feet wide, containing many joints coated with serpentine, and that the ore occurs in small seams between this altered zone and unaltered monzonite. The values are said to be largely in copper and silver, with very little gold.

PLACER MINES.

WILSON MESA.

Geology and mining conditions.—The flat mesas south of Castle Valley are covered by a coating of gold-bearing gravel. This deposit is usually very thin, being indicated by scattered bowlders and pebbles or by small flattened mounds of like material here and there on the sandstone bedrock. In a few places it attains greater thicknesses. Some of the larger deposits stand as low rounded knobs, but most of them seem to occupy reentrants in cliffs. The latter was apparently the position at the Point Lookout placer. A combination of the two forms is seen at the Black Cap workings. A third and much rarer occurrence is along what appears to be an old channel which runs northwestward from the Black Cap.

The gravels are the same throughout, consisting of subangular cobbles of igneous material similar to that seen in the La Sal Mountains to the east, with a relatively small proportion of sandstone fragments. They range in size from one-fourth of an inch to 2½ feet, with an average size of about 10 to 12 inches. Fragments of monzonite porphyry cut by quartz stringers are fairly abundant and magnetite cobbles up to 4 or 5 inches in diameter are not at all rare. There seems to be a slight decrease in size of the bowlders at the western edge of the deposits, but it is not everywhere the same and is rather doubtful. There is practically no stratification of these gravels except along the present drainage lines in reworked material.

The gold, said to be worth from $19 to $20 an ounce, occurs in small wires or flakes, and none of that seen appeared to be much waterworn. It is distributed throughout the thickness of the deposits, which are said to be of about the same grade from the surface to bedrock. Besides the gold that can be recovered by washing, it has been found that the "ribbon rock" (the monzonite porphyry cut by quartz stringers) contains a fairly large portion of the gold value of the gravels. Some of the miners assert that for every ounce saved by sluicing 10 ounces is lost in the ribbon rock which goes over the dump.

There is no natural water supply on Wilson Mesa. A ditch originally built for irrigation is said to supply about 12 cubic feet a second from the beginning of the thaw in April to the last of July, when the greater part of the snow has disappeared from the mountains. From then until October the supply is about 8 cubic feet a second, and it is further diminished during the winter. The water is all taken from Mill Creek, and considerable trouble has been experienced in obtaining enough for sluicing, as the town of Moab also takes its supply from this source and has a prior right to the water.

Prospects.—The Black Cap placer (No. 12, fig. 16) is located in the cliff between the middle and upper mesas. The gravels here form a low knoll, and are also found below the general rim-rock level in what appears to be a cleft or reentrant from the face of the cliff. The maximum thickness above the true rim rock is about 50 feet, with possibly as much more below at one place.

Hydraulicking into sluice boxes located in the reentrant has opened a pear-shaped cut about 40 feet in maximum width by 60 feet long, with a face 40 feet high. The location is ideal for this sort of work, as there is plenty of ground for a dump much below the level of the gravels. It is said that some difficulty was experienced with the larger bowlders and that considerable gold was lost in the ribbon rock.

At the Point Lookout placer (No. 13, fig. 16) the gravels clearly occur in a reentrant at the rim of a canyon leading into Mill Creek. This locality is also in the rim of the middle mesa, just above the lower mesa. A very thin veneer of gravels covers an area of 2 or 3 acres, with one deeper deposit just at the rim.

A shaft sunk in the deep deposit has gone down about 20 feet through gravel that contains a large amount of magnetite, usually as small pebbles, though some cobbles as large as 8 inches in diameter were noted. Very little water can be had here. The surface has been partly sluiced into a vibrating screen which allows only the finest material to pass. The fines were put through riffles and finally over a small amalgamation plate. Practically all the free gold was saved, but it was found that the tailings carried gold in the quartz ribbon rock.

At the Butterfly placer (No. 14, fig. 16) a low ridge running from the middle to the lower mesa is covered with gravel to varying depths, a knoll at the lower west end showing the greatest thickness. The main irrigating ditch referred to above passes this place and the gravels were handled by road scrapers, being carried upon a platform through which they fell into sluice boxes. The method was very cheap and it is said that with a team and scraper two men could make $16 a day.

Figure 16 shows prospects just northwest of No. 12 and east of No. 13. At the latter locality two shafts about 100 feet apart have been sunk; one to a depth of 40 feet is all in gravel, and the other, 10 feet deep, entirely in sandstone bedrock. This is on the relatively flat middle mesa, but in a depression that at present is a watercourse and seems to have been a channel at the time of the deposition of the gravels. Little work has been done on the prospect nearer No. 12, a low gravel knoll. The prospect southwest of Mesa post office is also a low knoll of gravel with bedrock outcropping just east of it. This is apparently a remnant behind a ledge of sandstone. The prospect just east of Mesa is a continuation of the Black Cap deposit. It is a relatively thin layer of gravels except in a few shallow reentrants.

Origin of the gravel.—The material composing the gravels of Wilson Mesa is at least nine-tenths igneous. It occurs on flat-lying undisturbed sandstones which nowhere show any igneous rock in place. All the porphyry types represented in the main laccolithic mass of the La Sal Mountains are represented by pebbles or bowlders in these gravels. Pebbles of monzonite porphyry cut by stringers of glassy quartz containing limonite, which resemble the ore of the Tornado and other places, are frequently seen. These, owing no doubt to their original altered condition, are softer and more weathered than the previously unaltered rocks. It can hardly be questioned that the gravels were very largely derived from the La Sal Mountains. Their present distribution is probably due largely to erosion since their deposition. In sheltered places such as reentrants the gravels have not been removed, but they have been largely eroded from the flat-topped mesas except for the remnants left in old channels or between the present drainage lines.

The method of deposition of the gravel on this mesa is open to question. That its deposition is not related to the most recent glaciation is clearly shown by the fact that the last glaciers were very small, rarely reaching below an elevation of 10,000 feet and never issuing beyond the high mountain valley. The material is subangular, no rounded pebbles being noted; it is fairly coarse for the most part, with only a little sand; and it is so far as seen unstratified. Two hypotheses are suggested by its character. Both torrential floods and glaciers form such deposits. That one or the other of these agencies brought the material to its present resting place is fairly sure. In either event it is quite certain that the gravels were deposited at a time when the La Sal Mountains were higher than they now are, and either explanation presupposes a very much greater precipitation than there is at present in this region. It seems probable that the gravels were deposited prior to the establishment of the present drainage system, for deposits of this class are found only on flat-topped mesas, and if ever present have been entirely removed from the places now occupied by canyons. Similar gravels that were not visited are reported on the mesas north of the mountains.

If these gravels are glacier-borne deposits they must surely afford some evidence of this mode of transportation. The writer at the time of his visit did not fully realize the difficulty of proving this point, so did not spend sufficient time to collect conclusive evidence. One bowlder of sandstone 10 feet in diameter on the upper mesa about half a mile east of Mesa post office showed marks that were thought to be striæ.

Wallace W. Atwood, of the United States Geological Survey, who is making a study of the somewhat similarly disposed gravels in the San Juan region, has come to the conclusion that they are the result of glaciation very much older than that which produced any of the Pleistocene drift heretofore found in the Rocky Mountains, and from his description of these deposits at the meeting of the American Association for the Advancement of Science held in Washington in December, 1911, the writer is inclined to attribute to a similar agency the deposition of the gravels of Wilson Mesa.

The question is, however, still far from solution, and more detailed study of the mesa will be necessary before a final statement can be made as to what brought the gravels to their present position.

MINERS BASIN.

The town of Basin is located on a flat just above a very small, indistinct terminal moraine of the last glacial epoch. This moraine is composed entirely of angular igneous material, none of which has traveled over a mile and much of it a very inconsiderable distance. The moraine lies on the top of a débris-filled V-shaped valley. Both the glacial material and the débris contain a little fine free gold. The amount of material is, however, very small and hard to handle on account of the large angular talus blocks included in it.

OTHER MINERAL RESOURCES.

About a mile north of Mesa post office a tunnel starts in at the base of the cliffs to the upper mesa. On the dump there is some manganese ore which is a replacement of slightly calcareous sandstone. Pyrolusite has replaced the lime and coated the quartz grains. Some of the ore is nearly pure manganese oxide. The tunnel is caved, but it is said that there is 10 feet of material similar to that seen on the dump.

The vanadium prospect near Richardson, just beyond the northwest corner of the area shown on figure 16, was not being worked. Boutwell's description of this prospect is summarized on page 102.

About 9 miles east of Dewey, the halfway station on the Cisco-Castleton road at Grand River, a copper-silver mine entirely in sandstone, with no igneous rock in the vicinity, is said to be producing some ore. The property was not visited, but the writer had an opportunity to see some of the ore. It consists of chalcocite deposited in small seams cutting white sandstone and also disseminated in the adjacent walls. Along the borders of these seams a thin zone of malachite is usually present, and this mineral, together with azurite, stains the sandstone near the fissure. The mine is now being worked for its silver, which occurs in native form and as silver chloride. The development is rather shallow. The vein is said to strike a few degrees north of west and to be traceable for more than a mile.

Emmons [1] has described an apparently similar deposit on the east side of the La Sal Mountains in Montrose County, Colo.

In June, 1911, several oil men were prospecting in Fisher Valley, where there are said to be some oil seeps. The east end of this valley is at the extreme northeast corner of the area represented on figure 16.

FUTURE OF THE DISTRICT.

The quartz prospects in the northern La Sal Mountains do not at present give much hope for a large mining camp. They are few in number and the values are low even at the surface, where many gold-bearing deposits are enriched. The veins, so far as could be seen, are very small and contain much barren quartz. The high freight charges to the railroad at Cisco ($25 a ton in and $12 to $15 out) are an additional handicap.

The Wilson Mesa placers apparently are of minor extent. There is not a large amount of gravel and all the values in it can not be saved by sluicing. As has been said, part of the values are carried in the tailings. These values are in free gold carried in the quartz stringers in fragments of monzonite porphyry. To save all the gold will require some sort of crushing of these bowlders. There is so much material that surely carries nothing of value that it would hardly seem advisable to install expensive crushing and amalgamating machinery unless it were found practical to sort the ore from the waste by hand. There is a very meager and uncertain supply of water available for placer operations. Unless some company controls practically all the gravel deposits on the mesa and is assured of a certain permanent supply of water such operations would hardly be a profitable venture. There is, however, a fair amount of free gold that might be procured at a profit if the deposits are worked in a small way.

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These publications, except those to which a price is affixed, may be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.; the monographs from either the Director or the Superintendent of Documents. The publications marked "Exhausted" are not available for distribution but may be seen at the larger libraries of the country.

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