STATE OF IDAHO
C. A. Benteleisen, Governor

IDAHO BUREAU OF MINES AND GEOLOGY
A. W. Fahrenwald, Director

GEOLOGY AND GOLDFIELDS OF THE ATLANTA DISTRICT
ELMORE COUNTY, IDAHO

By
Alfred L. Anderson

Prepared in cooperation with
the United States Geological Survey

University of Idaho
Moscow, Idaho
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This report describes a recently active gold and silver camp which from 1932 to 1935, inclusive, was the largest producer of gold in the state. Discovered in the early sixties, the district has experienced several mining booms, the latest through the activities of the St. Joseph Lead Company, and has produced ore valued at not less than $6,000,000 of which at least $2,500,000 was produced between 1931 and 1936. The district won early fame through the extraordinary richness of its silver ores, but the larger part of the wealth has been obtained from gold, especially since the late seventies.

Much of the ore mined in the early days was in the form of rich bonanzas, most of it within 200 feet of the surface. Some of it was rich enough to stand the shipment by pack-train and wagon to the railroad 250 miles away, and by rail to smelters in New Jersey and in Omaha. During the recent boom, the mill heads averaged slightly less than 0.5 ounce of gold per ton and from 1 to 2 ounces in silver.

The ore deposition was rather characteristic of epithermal and was accompanied by extensive silicification of the country rock. The ore deposits are faulted by an abundance of quartz, much of it very finely crystalline and in part associated with abundant minute crystals of arsenopyrite; also by scant amounts of pyrite and base-metal sulphides, and by localized bodies of complex silver sulphosalts and free gold in comb and drusy quartz. The deposits are also characterized by ore which has been extensively brecciated and much of which consists of quartz in breccias, in part breccias of country rock and in part breccias of early quartz. The ore minerals were introduced during one of the later stages of the process and were apparently deposited in openings fairly near the surface.

The deposits lie along a zone that extends through the Idaho batholith in a northeast-southwest direction. They occupy prominent shear and fracture zones apparently produced by horizontal shearing stresses. The principal fracture zone is occupied by the Atlanta lode, the largest and most productive in the district; the others are of smaller size and extend west-northwest at angles oblique to the main lode. The Atlanta lode has been traced for more than 2 miles and is from 40 to 120 feet wide, but the ore appears to be confined to shoots of exceptional porosity determined by variations in the strike of the lode itself. It contains six main shoots from 200 to 800 feet long, from about 400 to 800 feet high, and ranging from 4 to 6 feet - locally as much as 30 feet thick.

The minerals appear to have been deposited near the surface as the main ore shoots have been bottomed within 400 to 800 feet of the surface. Deeper development has not led to the discovery of other ore shoots, nor do the geologic conditions give much encouragement to the possibility of recurrence of commercial ore at greater depth. Although the deposits are within the Idaho batholith, they are probably not genetically related to it, nor to nearby dikes of granophyre of Miocene age, but are probably products of the early Tertiary metallization known to be widespread throughout the Rocky Mountain region.
INTRODUCTION

SCOPE OF THE REPORT

This report embodies the results of a geologic study carried on in the Atlanta district during the months of July and August, 1935. The district is one of the oldest and most famous in the state, but one of the least known, geologically. When the St. Joseph Lead Company started work in the district in 1931 and during the next four years made it the leading source of gold in the state, it naturally received widespread attention. There arose a demand for authentic geologic data on the character of the mineralization, its persistence with depth, and for other pertinent facts bearing on the occurrence of the ores and the possibility of long-continued production.

Although the investigation was to have been detailed and to have covered the entire region, most of it was centered on the famous Atlanta lode, the six major ore shoots of which have furnished the bulk of the district's production and have been the sites of three of its most famous mines. This lode was that worked by the St. Joseph Lead Company, and, with one exception, was the only one in the district accessible for study. Even study of it could not be as detailed as desired, for after several months of inactivity most of its stopes, drifts, and crosscuts were closed because of the extraordinary heaviness of the ground, and only its two main levels, the No. 6 and the No. 9, were reasonably accessible for study. Wherever conditions permitted, the Atlanta lode, as well as all others, were examined with as much detail as possible, both underground and on the surface. These observations were supplemented by such data as could be obtained from mine maps, assay records, and private mine reports. A detailed topographic map was made of the central part of the district and on it the lodes were plotted so that a concise picture of the distribution of the deposits and their relation to controlling structural features might be obtained. By this means a fairly comprehensive understanding of the geology and mineralization was obtained and has served as the present report.

ACKNOWLEDGMENTS

The work of the investigation was greatly expedited by the kind cooperation of those residing in the district. Special acknowledgment must be made to Mr. Frank H. Skeels, in charge of operations for the St. Joseph Lead Company, who gave freely of his time, provided maps of the underground workings, access to mine and mill records, and contributed his store of information on underground relations of ore bodies and ore. Appreciation is likewise extended to Mr. C. F. Phippen, who kindly gave access to maps and mine reports on the Monarch and Buffalo mines.

The writer also wishes to express his gratitude to Mr. Vernon E. Scheid, of the University of Idaho School of Mines faculty, who served as a most capable and efficient field assistant, and upon whom rested the main burden of the preparation of the topographic base map.

BIBLIOGRAPHY

The amount of published geologic data on the Atlanta district is surprisingly small and most of it is limited to the references cited in the bibliography which follows, although some information on the district was obtained from various annual reports of the State Inspector of Mines and from some of the volumes of Mineral Resources, issued in former years by the U. S. Geological Survey and since 1923 by the U. S. Bureau of Mines. These references are listed according to the year of publication.


Bell, R. N., Atlanta gold district; Eng. and Min. Jour., vol. 86, pp. 176-177, 1908.


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**GEORAPHIC FEATURES**

**LOCATION AND ACCESSIBILITY**

The Atlanta district (fig. 1) is in Elmore County about 60 miles by road north of Mountain Home, the county seat, and about 56 miles by air east-northeast of Boise, the state capital. Since it lies near the west margin of the Sawtooth Range and is separated from both Boise and Mountain Home by mountainous country stretching almost to the borders of the two cities, it is one of the most isolated mining districts in the state. It is near the headwaters of the Middle Fork of the Boise River and is referred to as the Middle Boise district in the annual reports of the State Inspector of Mines.

Until September, 1936, the only road to the district extended from Mountain Home, but another from Boise was completed during the latter part of the month giving the district an approach by two different routes. The road from Mountain Home is 80 miles long, part of it over mountain ridges, part of it along the South Fork of the Boise River. Between Rocky Bar and Atlanta it is blocked by snow for six months of the year, generally from December until late in June. During these months, the district has been cut off from the outside world, except by snowshoes and air plane. When the St. Joseph Lead Company began operations in 1831, a landing field was cleared along the Middle Fork of the Boise River a short distance from Atlanta. Since then, the district has had tri-weekly mail and passenger service from Boise from December until June. After the St. Joseph Lead Company had suspended mining operations, the plane service was changed to a bi-weekly schedule in December, 1936. The service was discontinued altogether in 1938. During the open season, the mail is brought in from Mountain Home by tri-weekly stage. Most of the food and mining supplies are trucked in during the open season although perishable foods are available throughout the year by stage in summer and plane in winter. The ore concentrates were stored during the closed season, but were trucked to Mountain Home during the summer and autumn. Mountain Home, on the main line of the Oregon Short Line (Union Pacific system), has been the source of freight and express for the district and shipping point for the concentrates, but
Figure 1. Index map showing location of Atlanta district.
all telegraphic and phone communications have been handled through Boise. The completion of the road from Boise at water grade along the Middle Fork of the Boise River has extended the trucking season and has made Atlanta accessible by road throughout the greater part of the year. This road is only a few miles longer than that from Mountain Home and has no steep grades. All mail now reaches Atlanta from Boise by the river road.

SURFACE FEATURES

The district lies far back in the mountainous area which is drained by the Boise River and its tributaries. Most of the mountainous area is unnamed, but the Sawtooth Range is included and the district is in the mountains at the west margin of the Range. (pl. 1). These mountains, as well as the Sawtooth Range, have been carved in a plateau-like surface which has been uplifted and in part faulted and tilted. The streams have cut deeply into this surface so that its original plateau-like character is indicated by the general accordance of the ridge levels. Locally, the mountains have been maturely to submaturely dissected to steep slopes; in places, further steepened by glacial sculpture. There is no well defined line separating the mountains on the west from the Sawtooth Range, except for the fact that the Sawtooth Range rises to higher levels than those on the west. (pl. 1)

The higher Sawtooths rise above 10,000 feet above sea level whereas those mountains on the west are mostly lower than 7,500 feet.

The Atlanta district lies in a block of mountainous country in which the highest ridges rise to about 7,200 feet, more than 2,000 feet below the higher ridges of the Sawtooth Range immediately to the east. This block includes a small intermontane basin less than a mile in diameter, but large enough to contain the town of Atlanta and a landing field on the opposite side of the Middle Fork of the Boise River (pl. 1 and 2). The floor of the basin has an altitude of about 5,300 feet, and it is surrounded by ridges which rise much higher. The ridges rise rather abruptly to altitudes slightly above 7,000 feet, but that on the east rises almost precipitously to 9,000 feet (pl. 1), a part of the ridge culminating in Greylock Peak at 9,317 feet. The steep slope on the east side of the basin is a part of a prominent scarp-like slope which may be traced in a northwesterly direction for many miles and which serves as a natural boundary between the high Sawtooths and the lower mountains on the west.

The Middle Fork of the Boise River enters the basin from the higher Sawtooth Range through a broad, steeply-walled, U-shaped valley (pl. 1) that is joined in places by hanging valleys high on its sides. It meanders across the floor of the basin, and then passes into a narrow, rugged, V-shaped canyon on the west which it occupies most of the distance to Boise. The floor of this basin is not wholly smooth, but it shows low hillocks and mounds, identified as patches of glacial moraine, separated by smooth reaches of stratified outwash, the largest of which is utilized as a landing field.

The famous Atlanta Hill forms a part of the south rim of the basin. The upper part of this hill is roughly circular in outline and rises to an altitude of about 7,800 feet (fig. 2). It is surrounded on the north and northeast by the basin and Montezuma Gulch; on the west, south, and southeast by the Yuba River and its tributaries, Grouse and Flint creeks. The top of the hill is fairly broad, but its north side has been deeply incised by Quartz Creek which flows through Atlanta directly to the Boise River. From the higher slopes of the Sawtooths the hill looks almost exactly like a nearly circular cone, its top truncated and then breached on the north side by the deep gash occupied by Quartz Gulch (pl. 2).

Some authors have described the hill as a low mountain or hill encircled on all sides by higher mountains, although it is as high as those immediately beyond Grouse Creek and the Yuba River.
ATLANTA BASIN AND THE SAWTOOTH RANGE

View showing Atlanta Basin with the rocky, precipitous ridges of the Sawtooth Range in the background. Highest point on the left of the picture is Greylock Peak; the wooded slope on the right, Atlanta Hill. The U-shaped glaciated valley of the Middle Fork of the Boise River appears in the middle background, and bands of terminal moraine (covered by trees) at the mouth of the valley and across the floor of the basin. The steep, precipitous slope delineating the Sawtooth Range is in part a somewhat eroded fault scarp. The small town of Atlanta lies at the base of Atlanta Hill.
ATLANTA HILL

View of Atlanta Hill from the slope of Greylock Peak, showing its circular outline and flattened top and its resemblance to a breached cone. The town of Atlanta is at the mouth of Quartz Gulch in the center of the picture. The landing field lies at the foot of Greylock in the immediate foreground of the picture.

- B
Most of the streams tributary to the Boise River occupy deep, narrow valleys of steep gradient. Montezuma Gulch is an exception as it has a broad, rounded floor and lies along the base of the steep, scarp-like slope that marks the southwest margin of the Sawtooth Range (pl. 1). Its head is in a low saddle separating Atlanta Hill from the higher slopes of the Sawtooths, and is one of the striking local features (fig. 2).

POPULATION AND INDUSTRIES

The population of the district is wholly dependent upon its single industry, mining, and varies with the activity of this industry. The camp is deserted when the mines are quiet, but it is revived whenever work is renewed. During the recent boom, the town contained more than 200 families, but after the St. Joseph Lead Company suspended operations the outflux started, and during the summer of 1936 the families dwindled to less than 60, and by autumn to no more than 30. Some remained to continue work as lessees, others to await the next boom. During the last boom, 150 men were at work underground and there were as many more engaged in surface work and in the town's various enterprises. Another influx was under way in 1938 as a result of revived activity in mining.

POWER

There are two hydroelectric plants on the river, one above the town and the other below. The one above the town was equipped by the Bagdad Chase Mining Company thirty years ago and is part of the equipment of the Boise Rochester mine. The other is owned by the Atlanta Mines Company and was installed about the same time as the other to provide power for the Monarch mine and mill. Both were in operation during the recent mining activity, but during the winter months when the streams were deeply frozen it was necessary to supplement the hydroelectric power by that generated by Diesel engines. Electric current was available to townsmen as well as to the mines.

CLIMATE AND VEGETATION

Because of its location in the mountains and so high above sea level, the district has a heavy winter snowfall and considerable cold weather, but, on the other hand, has delightfully pleasant summers. Most of the precipitation is during the autumn, winter, and spring months, although showers are not uncommon during the summer. The growing season is too short to permit the raising of many produce except hay. The land available for cultivation is restricted to a few small patches in the Atlanta basin. Frost may occur in August, but is rare in July. The winter snow may exceed 5 feet in the lower part of the basin, but is much deeper on the higher slopes. Snowshoes or skis are essential to winter travel.

With the exception of the rocky slopes of the Sawtooths and the sides of the narrow rocky canyons, most of the district is or has been forested. Much of the timber, yellow pine and fir, in and adjacent to Atlanta - particularly on Atlanta Hill - has been cut, but ample timber for all mining needs remains nearby. The timber is much heavier on north than on south slopes, and is absent from the steeper, southward-facing slopes, except in protected gulches. The north slope of Atlanta Hill is choked by brush and second growth, but the south slope is open (pl. 2). Within the basin timber is confined to the poorly-drained patches of glacial moraine whereas sage brush covers the gravel reaches (pl. 1).
Figure 2. Topographic and geologic map of the Atlanta district showing Atlanta lode and other veins.

Broken contours and claim boundaries shown by dashed lines are approximate.
Datum is sea level.
The district is underlain by the granitic rock of the Idaho batholith and its affiliated aplites and pegmatites, and in a few places by small bodies of diorite and syenite and dikes of lamprophyre intrusive into the batholith. North of this district the batholith is cut by numerous dikes of Tertiary (Miocene) age, probably not related to the small bodies of diorite and syenite within the district itself. The only rocks of sedimentary origin are glacial deposits and stream gravels, which occur on the slopes and floor of Atlanta basin.

Erosion has extended to such depth that the older rock invaded by the Idaho batholith has been almost entirely stripped away and only minor remnants of the roof zone remain, most of it on the higher ridges.

The granitic rock of the batholith has been tremendously shattered and sheared during each of several periods of crustal disturbance. A zone of structural weakness was apparently initiated during the closing stages of consolidation of the batholith, and this has influenced nearly all subsequent deformation up to comparatively recent times. Not only did the zone of structural weakness have a marked influence on the localization and distribution of aplite and pegmatite dikes and seams related to the batholith itself, but also on subsequent mineralization and igneous activity.

ROCKS RELATED TO THE IDAHO BATHOLITH

Classification

Granitic rocks related locally to the Idaho batholith include some masses of slightly gneissic quartz diorite and granodiorite, which are recognized as marginal and somewhat older than the main mass of the batholith, and quartz monzonite which underlies most, if not all, of the district, and which is similar to the rock comprising the main body of the batholith through the central part of the state. These rocks have been extensively invaded by genetically related aplite dikes and by pegmatites.

The age of the Idaho batholith on the bases of evidence from nearby areas is probably late Jurassic or Cretaceous. /1

Quartz diorite and granodiorite

The quartz diorite and granodiorite do not outcrop on Atlanta Hill, but are found on the higher ridges on the east, less than half a mile away, and in the river canyon a short distance below Atlanta. Most of the boulders on the floor of Montezuma Gulch are composed of rock of this composition, and their abundance is evidence of a widespread distribution of the near-roof facies on the higher ridges.

Both rocks are much alike and are distinguished only by the fact that the granodiorite has slightly more potash feldspar, which may be recognized by its rather pale flesh color. Both rocks are generally characterized by a faint to pronounced gneissic banding and by a color somewhat darker than that of the quartz monzonite. Locally, the rocks have from 10 to 15 per cent of dark minerals, most

of it biotite, subordinate hornblende, and also numerous conspicuous yellowish-brown grains of titanite and greenish-yellow ones of epidote. The most abundant minerals are andesine (An₉₅) and quartz, the former composing from 35 to 60 per cent of the rock, the latter as much as 30 per cent. Potash feldspar, represented by microcline, forms from 2 to about 15 per cent in different specimens. The abundance of titanite and epidote is noteworthy for the titanite forms as much as 3 per cent of the rock; the epidote as much as 5 per cent. Other accessory minerals are ilmenite, magnetite, allanite, zoisite, zircon, apatite, rutile, chlorite, sericite, and calcite. The rock is medium-grained to moderately coarse, the biotite grains ranging from 0.5 to 2.0 millimeters, the plagioclase from 1 to 6, the quartz from 1 to 4, and the microcline up to 10 millimeters.

The rocks are of special petrologic interest because the relations of the minerals show that most of the quartz, microcline, titanite, allanite, epidote, a part of the biotite, and most of the accessory minerals were added to the rock after its consolidation. Apparently these post-consolidation additions have been accomplished through the action of hydrothermal solutions that emanate from deeper parts of the batholith. The addition of the above minerals has changed the original quartz-bearing diorite to a quartz diorite and granodiorite in the manner outlined by Currier for the rock in another part of the batholith.

Quartz monzonite

Most of the region is underlain by quartz monzonite, and that comprising Atlanta Hill is conspicuously porphyritic and is studded with flesh-colored microcline phenocrysts as much as 30 millimeters, exceptionally as much as 50 millimeters long. Otherwise, the rock is distinctly granitoid, light gray to white, and moderately coarse-grained. Generally it has about 5 per cent or less of biotite, which, along with the general absence of gneissic banding, sets it sharply apart from the darker, somewhat older marginal rock. Its principal minerals are oligoclase (An₂₀ to An₁₅), quartz, and microcline and orthoclase, and the minor accessories include zircon, apatite, magnetite, allanite, chlorite, sericite, rutile, calcite, and rarely titanite and epidote. Besides the biotite, the rock may also contain minor amounts of muscovite, which in places forms several per cent of the rock. Commonly, quartz forms 30 per cent or more of the rock, the oligoclase, 30 to 35 per cent, and microcline and orthoclase, 30 to 35 per cent. The biotite is usually partly or wholly altered to chlorite, magnetite, and rutile, and the biotite is more or less sericitized. The potash feldspar is generally slightly altered, but may be partly filled with included remnants of oligoclase or show shadow-like outlines of them. Quartz permeates the rock as vein and lobate masses, and appears in myrmekitic worms in the plagioclase grains bordered by potash feldspar.

This rock, like the marginal, shows evidence of a complicated origin, for the intricate relations of the minerals indicate that much of the quartz and potash feldspar, together with the muscovite and most of the accessory minerals, were added to the rock after its consolidation. Apparently, before the late modification the rock had the composition of a quartz-bearing diorite and granodiorite. Extensive and minute fracturing of the rock during late stages of its consolidation permitted the introduction of fluids rich in silica and potash, and containing minor amounts of other ingredients. These reacted with the rock and changed its composition to a more silicic and alkaline variety. The addition of considerable amounts of potash caused the formation of large crystals of microcline which has given the rock its marked porphyritic texture.

1/ Currier, L. W., A preliminary report on the geology and ore deposits of the eastern part of the Yellow Pine district, Idaho: Idaho Bur. Min. and Geology Pamphlet No. 43, pp. 8-12, 1936.
Numerous aplite dikes are scattered through the region, but are exceptionally concentrated on Atlanta Hill where they form one of the most conspicuous components of the bedrock. Most of the bodies are small and their thicknesses are measured in inches, less commonly in feet. The larger bodies generally crop out prominently along ridge crests and slopes, in places forming low ledges which may be traced for a score or several scores of feet. Float is abundant everywhere. The aplites are not confined wholly to the area of quartz monzonite, but also cut the quartz diorite and granodiorite masses as well. Contacts between the aplitic rock and the enclosing granitic wall rock are usually sharp, not gradational as in the case of the closely related pegmatites.

The color of the aplitic rock is lighter and the grain considerably finer than that of the normal granitic rock of the batholith. In the larger bodies, the rock is medium-grained and the grains are about half the size of those in the quartz monzonite or more calcic marginal facies. In the smaller seams and dikes the rock is fine-grained, the average grains about one millimeter in diameter. The fresh rock underground is somewhat pinkish in color, but that on the surface resembles fine-grained, more or less brownish sandstone.

Most of the aplites are composed of about equal amounts of quartz, sodic oligoclase (An<sub>12</sub>) and microcline, and have less than 5 per cent of biotite, which in most bodies has been converted to muscovite. The rock also has minor amounts of titanite, garnet, zircon, apatite, allanite, magnetite, sericite, chlorite, rutile, leucocline, zoisite, and calcite. As the oligoclase and microcline are about equally abundant, the rock may generally be classed as a quartz monzonite aplite, although in some the oligoclase is considerably more abundant and the rock then has the composition of granodiorite aplite.

The mineral relations are essentially those in the quartz monzonite and other more coarsely crystalline facies of the batholith. They indicate that the rock has been very much modified since its early consolidation and that most of the quartz and microcline, and many of the accessories have been late additions. The rock differs from the normal quartz monzonite only in its somewhat less calcic composition, reflected in a more sodic plagioclase, less biotite, and more quartz, and in the finer grain. It also contains more muscovite and sericite, apparently as the result of more extensive attack by late-stage hydrothermal solutions. Its texture indicates rapid cooling, but its composition indicates that it is related to the magma of the Idaho batholith, evidently to a deeper part which had become less calcic through continued crystal fractionation.

In some bodies, the microcline grains tend to increase in size and form crystals such as characterizes the pegmatites, and as these increase in abundance the rock approaches pegmatite.

Pegmatite

Although not as abundant as the aplites, the pegmatite dikes are also numerous on Atlanta Hill. The dikes are less than a foot thick and, therefore, smaller than the closely affiliated aplites. Some of the pegmatites cross the aplite dikes, but may occur in and along the aplites as though the fracture which had guided the intrusion of the aplite had been reopened and had then controlled the position of the pegmatite. In every occurrence the pegmatite appears to be younger than the aplite.

The contact between the pegmatite dikes and the quartz monzonite and aplite walls is poorly defined and gradational. Usually the pegmatite appears to have permeated into and partly replaced the confining walls.
Much of the pegmatite is coarsely granitic in texture, less generally graphic, but individual minerals are usually less than an inch long. However, the rock is much more coarsely grained than the quartz monzonite. The fresh rock from the underground exposures is distinctly pinkish because of the color of its abundant microcline, but the somewhat weathered surface of the rock is white or light gray. Much of the highly feldspathic pegmatite is composed largely of microcline, but quartz is always present, abundant in places; and generally there is considerable sodic oligoclase and albite and more or less biotite, muscovite, garnet, zircon, magnetite, apatite, sericite, chlorite, and pyrite. Some of the plagioclase has been inherited from the invaded country rock and occurs as remnant grains and shadow-like inclusions in the microcline. That indigenous to the pegmatite is more sodic than that in the older rocks. Some of the quartz, like the plagioclase, has also been inherited from the confining country rock, but most of it has been introduced later and has penetrated into and through the microcline as well as the plagioclase. Garnet, zircon, apatite, magnetite, and pyrite were introduced with the quartz.

These pegmatites clearly show a replacement origin and have apparently been formed from solutions of later age, of greater fluidity, and probably from deeper sources than those which produced the aplites.

TERTIARY INTRUSIVE ROCKS

Classification and relations

Although intrusive dikes of known Tertiary (Miocene) age have not been positively identified on Atlanta Hill, they are abundantly concentrated along the north side of Atlanta basin, less than a mile away, and are described in this report as a matter of record. They appear to be members of a belt which crosses the Boise River several miles below Atlanta and which extends in an east-northeasterly direction along the north side of the river up and over Greylock Peak. The limits of this belt have not been determined, but it has been traced for more than 10 miles and is known from traverses to be not less than 3 miles across. The dikes are particularly conspicuous along James Creek and Queens River, and for several miles up Queens River. Because of their superior resistance to erosion, they stand out as large reefs in the canyon walls, projecting above the granitic rock of the batholith. They are equally as conspicuous along the precipitous slopes of Greylock Peak. Most of the dikes are from 50 to 300 feet thick and several hundred to several thousand feet long. Their trend, oblique to that of the belt as a whole, is within a few degrees of east. Their dip is steeply north to vertical. Their size, abundance, and structural relations can be fully appreciated only if seen in the field or if plotted on a detailed geologic map.

These dikes are surprisingly alike and show little change in color, texture, and composition. Most of them appear to be composed of pink granophyre, but a few at least have the composition of granite porphyry and dacite porphyry, and other varieties might be found on detailed field study and mapping.

This dike zone is similar to others in south-central Idaho, such as those described in the Casto quadrangle and in Boise Basin, and the rock varieties are much the same. In the Casto quadrangle, the pink granophyre dikes and related varieties have intruded the lower part of the Challis volcanics (upper Oligocene or lower Miocene), and their age is regarded as Miocene.

Pink granophyre

The pink granophyres are pale pinkish, or have grayish or brownish tones, but weather buff in the outcrop. The rocks are porphyritic and contain from 10 to 20 per cent of phenocrysts divided more or less equally between quartz, orthoclase, and sodic plagioclase enclosed in and corroded by an aphanitic groundmass of micropegmatite. The biotite which is also included among the phenocrysts, with its grains usually partly altered to chlorite or sericite, forms no more than several per cent of the rock. The size of the phenocrysts differs in the rock from one dike to another. Rounded and corroded quartz grains are from 1 to 2 millimeters in diameter, rarely from 1 to 4. They occur as scattered individuals or in clusters. The feldspar phenocrysts are from 1 to 6 millimeters long, but most commonly less than 3 millimeters. Those composed of orthoclase are generally larger than those composed of sodic plagioclase. Both kinds are somewhat sericitized and the precise composition of the plagioclase is difficult to determine. The groundmass varies in detail. It commonly shows a typical micrographic intergrowth, but in some dikes it consists of radial aggregates in well-defined spherulites visible only with the microscope. Some of the spherulites are separated by clear grains of quartz and orthoclase. Other minerals include widely scattered crystals of magnetite, zircon, and rarely apatite.

Granite porphyry

Like the granophyre, the granite porphyry is pinkish, but it contains about 25 per cent of phenocrysts of orthoclase and sodic plagioclase; these include scattered chloritized grains of biotite in a fine-grained, microgranular groundmass of orthoclase and quartz. In addition, there are scattered small grains of magnetite, apatite, zoisite, and rutile. The orthoclase phenocrysts are as much as 20 millimeters long and those of sodic plagioclase and biotite from 2 to 4 millimeters. The plagioclase is considerably sericitized, but appears to be a sodic oligoclase. The phenocrysts of orthoclase, as well as that in the groundmass, are also slightly sericitized. The quartz is confined to the groundmass and occurs only as scattered anhedra, much subordinate to the orthoclase. The rock is practically identical to the pink granophyre, except for its granular groundmass and lower quartz content.

Dacite porphyry

The dacite porphyry is a grayish rock of pinkish tone which contains about 10 per cent of white plagioclase, greenish chloritized biotite and hornblende phenocrysts from 2 to 3 millimeters long in a fine-grained—almost aphanitic—groundmass, composed of sodic plagioclase laths, a minor amount of quartz, and some chloritized and epidotized biotite and hornblende. The rock is considerably altered so that the twinning in much of the feldspar has been obscured by secondary products. The dark minerals are represented by epidote and chlorite pseudomorphs.

INTRUSIVE ROCKS OF INDETERMINATE AGE

Classification and relations

Minor masses of intrusive rock, which apparently have no structural or genetic relations to the series of Miocene dikes, have also been found in the batholith in and near Atlanta Hill. These are dark-colored, more or less evenly-grained rocks, which occur as dikes of considerable length but variable thickness, although mainly less than 10 feet. Most of them are found east of Montezuma Gulch and in upper Flint Gulch, and have the composition of diorite, although one had to be classified as syenite. Lamprophyre (dioritic) dikes are also included, but they were positively identified only in mine workings along the Atlanta lode.
These intrusives have many features in common and are probably related genetically. They do not fit into the Miocene rock series, nor do they possess features which might link them with the Idaho batholith. Somewhat similar diorite has been described in the Edwardsburg district and is regarded there as Tertiary [1], but, although the dikes are included with Miocene types, the particular part of the Tertiary is not stated. These in the Atlanta district do not appear to have the same trend as the granophyric dikes, nor do they appear to conform with Miocene structural features. They are probably older, and, therefore, might have been intruded during the early part of the Tertiary at the time when igneous activity was more or less general over the Rocky Mountain region. The lamprophyre offers the only significant relation. It occurs in and along the Atlanta lode and is post-ore. Its alteration and other relations suggest that it is not much younger than the ore deposit.

**Diorite**

The diorite is a dark gray, fine-grained rock, the mineral grains of which are about 0.5 millimeters in diameter. It weathers brownish and is somewhat more resistant to erosion than the granitic rock of the batholith. The general trend of the dike is commonly reflected in the topography.

The rock is ordinarily composed of zoned andesine (about 50 per cent), hornblende (about 30 per cent), minor amounts of biotite (5 per cent), quartz (5 per cent), and orthoclase (as much as 10 per cent). Other minerals—present in very small quantities—include apatite, magnetite, and zircon. The hornblende forms greenish-brown, lath-and-rod-shaped crystals, and the apatite, scattered rods and needles. The orthoclase is dusted with sericite, but the plagioclase crystals are clear and the hornblende and biotite show only incipient stages of alteration to chlorite. The weathered biotite crystals are very conspicuous and give the rock the appearance of having more biotite than it actually contains.

**Syenite**

The syenite is a dark greenish-gray to greenish-black, fine-grained rock almost identical to the diorite in general appearance. Its greenish color is apparently the result of weathering. It differs from the diorite, however, in being composed mostly of orthoclase and hornblende, and contains only minor amounts of quartz, sodic plagioclase, magnetite, titanite, apatite, and zircon. The hornblende forms greenish, rod-like crystals similar to those in the diorite. The syenite differs from the diorite in the greater abundance of orthoclase and the presence of considerable epidote and chlorite produced as a result of more extensive weathering.

**Lamprophyre**

The lamprophyre is a dark gray to greenish-black rock, inconspicuously porphyritic, and contains from 10 to 20 per cent of faintly outlined dark phenocrysts in a groundmass which is aphanitic where the body is narrow and fine-grained where moderately thick. As revealed in thin section, the phenocrysts consist of completely altered olivine crystals comprising as much as 10 per cent of the rock and hornblende crystals also altered and, in places, nearly as abundant. The olivine is recognized by its perfect crystal outline and cleavage, the latter accentuated by lines of magnetite crystals; otherwise, it consists of pseudomorphous calcite and chlorite. The hornblende is altered more or less completely to chlorite and calcite.

The groundmass consists of highly zoned plagioclase laths ranging from andesine to labradorite in composition, numerous crystals of magnetite and needles of apatite, and abundant chlorite and calcite, which either show the outlines of former hornblende and biotite grains or contain included remnants of them. A little orthoclase and quartz are also present. The extensive alteration appears to be a primary feature of the rock and is not related to the general mineralization, for the dikes cut the lode and are therefore younger than the ore. In places, the dikes are cut by numerous veins of pure calcite.

From the kinds of minerals present, the lamprophyre is to be classed as a dioritic variety. Dikes of the rock are exposed in many places in the underground workings along the Atlanta lode. As they commonly appear in masses, which pass diagonally across the shear zone into the walls, they probably are members of a system.

QUATERNARY ROCKS

Classification

The Quaternary rocks are the only ones of sedimentary origin in the region. They include glacial and snowslide deposits and those of the present streams. The Pleistocene glacial deposits appear to be of two ages, separated from each other by an interval of time sufficient to permit as much as 1,500 feet of downcutting by the Boise River. The snowslide deposits have been accumulating from Pleistocene time to the present day.

Glacial deposits

Older deposits

The older glacial deposits are found on the north side of the Middle Fork of the Boise River at altitudes of 1,500 to 2,000 feet above the present level of the river. These deposits cap the ridges which encircle Atlanta basin on the north and are strewn as a thin veneer over the surface of the ground for some distance below. They are composed of unassorted boulders and gravels which show a wide range in size. Some of the boulders are angular and subangular, but a considerable proportion are rounded and waterworn. The boulders are largely pink granophyre and other dike rocks, including aplite. Apparently, the deposits are so old that all granitic boulders have been destroyed by weathering and only the more resistant materials like the pink granophyre have survived.

Older glacial deposits are not unknown in south-central Idaho, for Ross has described old glacial till on ridge summits as much as 1,800 feet above the present levels of the streams along the Salmon River above Challis.

Younger deposits

Most of the younger glacial deposits are confined to the lower parts of Atlanta basin and were left by a valley glacier which followed the course of the Middle Fork of the Boise River from the higher Sawtooth Range on the east. The glacier extended only to the lower end of Atlanta basin and on melting left successive terminal moraines across the basin floor. These deposits, which form low irregular hillocks and mounds stretching from one side of the basin to the other, are composed of unassorted gravel and boulders mostly of unweathered granitic rock.

Some of the boulders weigh many tons. The morainal loops stand out sharply be-
cause the unsorted and consequently poorly-drained material supports a heavy
stand of timber whereas the assorted, well-drained, water-worked deposits between
permit only the growth of grass and sagebrush (pls. 1 and 2).

On the south side of the river other deposits flank the basin at levels con-
siderably above the basin floor. On the lower slope of Atlanta Hill these form a
series of more or less parallel ridges at different levels for several hundred feet
above the town. The form and arrangement of these linear ridges suggest lateral
moraines produced at the margin of the glacier while the ice in the basin stood at
successively lower levels.

Recent alluvium

Most of the streams which cross the basin to the river have buried the moraine
but the amount of such alluvium is comparatively small and the covering rather thin.
The river is entrenched in the moraine, but has no flood plain except for a narrow
strip near the upper end of the basin.

The striking U-shape and broad valley floor of Montezuma Gulch may be the re-
sult of a thick accumulation of sediments, part of which may have been deposited
by ice, but most of which may have been deposited as glacial outwash from the high-
er slopes on the east. Part also is snowslide debris. The deposits in the gulch
are coarse, not well sorted, and the boulders are sub-angular to angular. Much of
the material forms fans at the mouths of the larger and steeper tributary valleys.
The flanking eastern slope is well marked by the scars of recent slides and snow-
slides have added considerable material, especially along the upper part of the
gulch.

Structure

Foreword

The Atlanta district appears to lie along a zone of marked structural weakness
in which the Idaho batholith has been so thoroughly and repeatedly shattered by
crustal movement that blocks of unfractured granitic rock more than a foot square
are difficult to find. The zone of weakness was initiated during the later stages
of consolidation of the batholith itself. Deep-seated shearing opened up fractures
in the upper part of the consolidated mass and permitted the upward movement of
aplitic and pegmatitic magmas and fluids from greater depths. This early fracture
system is preserved in the dike pattern of the aplites and pegmatites, and has had
much to do with the alignment of the structural elements of subsequent crustal
failures.

Some time after the emplacement of the aplites and pegmatites the district
was again subjected to shearing stresses of regional extent and the rocks related
to the Idaho batholith profoundly fissured and shattered, with the zones of especi-
ally intense brecciation utilized by mineralizing fluids emanating from magmatic
sources at great depths. These shear and fracture zones in the main conformed in
their trend to that of the fractures which guided the earlier aplite and pegmatite
dikes. The complexities of this shearing are preserved in part in the lode pattern
and in part in the pattern of the Miocene dikes, although the Miocene magmas were
apparently injected some time after the lodes had been formed and into a zone of
weakness along that which guided the mineralizing fluids. The dike belt itself
seems to have been guided by a local zone of weakness, produced at the same time
as that which provided access for the mineralizing solutions, but the dikes them-
selves appear to occupy new sets of fractures and fissures probably resulting from
collapse of the rocks over a deeper magma mass below.
The last major epoch of crustal unrest has been reflected in faulting and uplift. However, the earlier zones of weakness have been ignored and the faults pass transversely across the older structural lines, although as in previous disturbances the older fractures have been reopened to greater or lesser extent.

The structural features of the district are, therefore, reflected in dike and lode patterns, in faults, and in extensive and intricate joints. Atlanta Hill marks the site of a conspicuous zone of weakness in which fractures are exceptionally concentrated; the dike belt on the north side of the river marks another.

Relations of aplites and pegmatites

The high concentration of aplite and pegmatite dikes in the district has been mentioned as one of the striking features of its geology and is at the same time one of the most conspicuous elements of its structure. These are concentrated in a broad zone which stretches in a northeasterly direction beyond the immediate limits of the district. Most of the dikes strike either northeast or west-northwest in the same directions as the most conspicuous joints in the granitic rock. Some of them may occupy reopened joint planes, but those of largest size and particularly those which strike in the northeast quadrant appear to have been guided by planes of shearing, in part at least independent of any earlier jointing.

Those in the northwest quadrant have strikes ranging from N. 80° W. to N. 85° W., the average being about N. 75° W. Those in the northeast have strikes ranging from N. 40° E. to N. 70° E. The dip in either set is to the north at angles of from 60° to 85°. Dikes of northeast trend appear to be somewhat more numerous than those in the northwest quadrant, and may be somewhat larger. In many places the pegmatites lie in and along the aplites.

Dikes in another set of fractures are fairly conspicuous in the older quartz diorite and granodiorite along the Boise River below the district. These are nearly flat-lying dikes of pegmatite which cut across the steeper ones of northeast or northwest trend. Although they may be related to marginal thrusts produced by the upward and lateral shove of the main batholithic mass against its earlier consolidated shell, they appear to have rather diverse trends, but their relations could not be wholly determined.

The pattern of the aplite and pegmatite dikes is such as to suggest that the controlling fractures have in large part been produced by deep-seated shearing acting mainly in a northeasterly direction. The shearing probably reopened joint planes, particularly those of west-northwest trend, and produced additional fractures pointing in the northeast quadrant. It is interesting to note that the pegmatite and aplite patterns are practically identical and that the pegmatite has in part been superposed on the aplite. This relation suggests that the stresses active during the later stages of consolidation of the batholith were recurrent and acted over a considerable period of time.

Lode pattern

The lode pattern seems to reveal the most important structural event in the history of the district, and is evidence of an epoch of complicated shearing and fissuring, exceptionally intensified on and in the vicinity of Atlanta Hill. In a general way, the lode pattern accords with that of the aplites and pegmatites, but the deformation was much more severe and much less widely distributed, the structural failure being dominated by a major zone of shearing augmented by a host of subordinate laterals which join or approach the main zone at oblique angles (fig. 2).
The structural pattern is best explained by reference to the lode pattern shown in Figure 2. The main zone of shearing is occupied by the famous Atlanta lode and the related but subordinate oblique zones of fractures contain the lateral lodes on either side. The strike of the main lode of the main zone of shearing varies from N. 50° E. to N. 75° E. and the strike laterals, from N. 60° W. to N. 80° W. these closely follow the directions of the splites and pegmatites. Their dip is likewise variable, the main shear zone dipping steeply southeast for half its course and steeply northwest for the remainder, the laterals dipping mostly steeply northeast to vertical. The major shear zone, which is 40 to 120 feet wide, has been traced by its lode filling for a distance of nearly 2 miles across Atlanta Hill and a faulted segment in Flint Gulch for at least another half a mile. The laterals are from a few inches to 10 feet wide; in places as much as 40 feet. In part, the laterals fall into two groups, those which actually join the Atlanta lode and those which approach but do not actually reach it. The first group usually do not persist far from the lode, but have the relations of ordinary gash fractures which decrease in size away from the lode and practically disappear within a hundred feet. These do not include two large split segments of the lode which branch outward in the general manner of the gash laterals and which are nearly as large as the main lode itself. The laterals which approach the lode are the most extensive and many have been traced for at least a mile.

The shear and fracture zones are composed of a multitude of fractures, the more prominent of those in the main shear zone trending in the general direction of the zone itself, those of lesser prominence at angles oblique thereto and conforming with the west-northwest set. In some parts of the shear zone the rock has been so thoroughly brecciated that the fracture pattern cannot be wholly interpreted, although the dominance of the strike set, and to lesser extent that of the oblique set, may still be revealed. It is not unusual for the strike fractures (locally fissures) to end by changing their strike to conform with the west-northwest set and then disappear on nearing the margin of the shear zone. The fracturing is usually not uniform throughout, but is more intense along one or both walls of the shear zone. The fracturing extends beyond the lode itself, and more or less widely separated fractures are observed several hundreds of feet from the borders of the main zone of shearing. Some of the lateral fracture zones possess many of the features of the main shear zone—prominent fractures parallel to the strike of the lode bordered by zones of extensively broken rock in which the fractures appear to be without arrangement. The picture of the fracturing in them is not nearly so well shown as that of the main shear zone, probably because the lateral fracture zones have not been so adequately exposed in mine workings. Shearing has probably played an important role in their origin. The gash laterals appear more as fissures formed by having their walls pulled apart. They are larger and far more numerous near the upper part of the lode and become smaller and much less numerous and conspicuous with depth.

Along the middle of the Atlanta lode the granitic rock has been broken by nearly horizontal faults that are older than the shearing. Some of these dip gently in one direction and nearby in the opposite, although they strike either about N. 50° E., or N. 80° W. They have displacements of but a few inches and they have been offset by the fractures in the main shear zone. They, as well as the shear zone fractures, commonly contain veins of ore. The presence and relations of these nearly horizontal slips suggest that the country rock was affected by powerful compressive stresses before they were sheared along nearly vertical fracture planes.

Other fractures have been added to the shear and fracture zones as a result of later deformation. These have merely served to further complicate a structural pattern that was exceedingly complex at the beginning.
Most of the movement along the main Atlanta lode has been horizontal. Slickensides and grooves in the fractured ore and rock show that the northwest side of the shear zone has moved to the northeast with respect to the southeast side. This movement is in accord with the fracture and lode pattern itself, for the relations of the gash laterals are further evidence of horizontal movement in the same directions as that indicated by the grooves and slickensides. The whole lode pattern may be explained by the action of horizontal-shearing stresses acting in a northeast-southwest couple across the region. The main shear zone, marked by the Atlanta lode, represents the shearing parallel to the direction of application of the regional stresses, the oblique laterals, and the fracture zones result from the elongation of the rock mass incidental to but related to the shearing (Fig. 2).

The structural and textural relations of the ore show that the shearing extended over a considerable period of time and was more or less recurrent, for mineralization was repeatedly interrupted by structural adjustments, and movement continued after, as well as before, mineralization. The absence of dependable markers in the granitic country rock forbids measurement of displacements along the shear and various fracture zones.

Although the lode pattern is not unlike that of the aplite and pegmatite, the characteristics of the mineralization indicate that the shearing associated with the lode formation was much more severe and related to a considerably younger crustal disturbance of major magnitude. As the mineralization is believed to be pre-Miocene and is post-Cretaceous (younger than the Idaho batholith), the stresses responsible for the local deformation must probably be related to the Laramide disturbance of late Cretaceous and early Tertiary time. The shear and fracture zones are the product of the differential transmission of that stress through the massive rock of the batholith against the weak trough of sediments on the east side which were undergoing deformation by folding and faulting.

Miocene dike zone

The Miocene dike zone also affords interesting structural relations which probably have an important bearing on the local as well as on regional geologic problems. This dike zone is about 3 miles wide and is known to be not less than 10 miles long, perhaps several times that, but the significant feature is that its N. 55° to 60° E. trend about accords with that of the Atlanta lode. Most of the dikes strike about N. 70° E., a few N. 60° E., and some N. 40° E., or oblique to the direction of the belt as a whole. As the dike zone was not studied in detail, dikes of other trend may be present among those with a west-northwest strike might well be expected. All dikes examined are vertical or dip steeply to the north-northwest. The trend of the dike zone, as well as the pattern of the dikes, is practically identical with that of the Quartsburg-Grimes "porphyry belt" in Boise Basin.  

Because there is little resemblance between the dike pattern and those of the aplites, pegmatites, and the lodes, although all these zones show northeast trend, the dikes must have been guided by fractures produced by a type of stress entirely different from that which created the earlier fracture zones. Their controlling fractures might well be explained by collapse of a broad dome produced by intrusion of magma in the manner which Ross postulates for a related dike zone in the Cassia quadrangle.  

There, intrusion of Miocene pink granite has apparently arrested Tertiary volcanic strata into a broad dome, elongated northeast, and a collapse of the dome has produced longitudinal and transverse faults along which granophyre and other related magmas were injected into the openings caused by the faulting.

The relations at Atlanta suggest that the Miocene magma has taken advantage of an earlier zone of weakness, similar to the one occupied by the lodes, and that the granophyres were guided by openings produced by collapse of the rock mass above the underlying magma reservoir. By this process the dike zone would be controlled by the earlier zone of structural weakness, but the dike pattern would be the consequence of another set of forces.

Faulting

The lodes and dikes are all evidences of faulting inasmuch as the lodes have occupied shear and fracture zones produced by movements of rock masses. The granophyre dikes occupy faults and many of the aplite and pegmatite occupy fractures produced by shearing. These features need no further discussion, but something may be said concerning faults which have not been marked by lodes and dikes. Many of these were apparently produced at the same time as those which have guided mineralizing fluids and magmas - whereas others have been produced subsequently. The latter are perhaps the most interesting, for they are the most clearly defined and appear to possess greater magnitude.

Faults that may be correlated with those of the lode and dike zones are fairly widespread, but of no great size, whereas the younger faults are fewer and less widely distributed. The older faults have trends corresponding to those of the lodes and dikes; the younger are for the most part clearly independent. In places, the west-northwest set of splites have been displaced by slips which strike N. 50° to 60° E., probably by the shearing which preceded the mineralization for these slips commonly show horizontal striations. The Atlanta lode and some of those of west-northwest trend are also displaced along minor slips which strike about N. 40° E., and N. 80° E., or nearly parallel to the nearby Miocene dikes, a relation which suggests that the slips are the product of the Miocene disturbance.

The later major faulting has been wholly independent of the earlier systems of faulting, and can not be ascribed to a recurrence of the older stress conditions. The largest of these younger faults is designated the Montezuma fault, because of its influence on the alignment of Montezuma Gulch. Others of lesser magnitude, formed at the same time, are not named.

Montezuma fault

The Montezuma fault is known for nearly a mile, and not only controls the position of Montezuma Gulch and the deep saddle at its head and those across several ridges beyond, but is largely responsible for the abrupt scarp-like slope which separates the Sawtooth Range from the lower ridges on the west (pl. 1). The fault may be traced by the alignment of valleys, saddles, and faceted spurs for a distance of not less than 16 miles, the limits visible from Atlanta. Its general strike is about N. 30° W., and it dips steeply southwest.Measured from the two levels of ridge tops, its vertical displacement is as much as 2,000 feet, but the horizontal displacement is even greater. It cuts across the Atlanta lode in the bottom of Montezuma Gulch (fig. 2), and as the northeast segment appears in Flint Gulch the displacement is approximately 4,000 feet to the southeast. The fault also displaces the dike zone north of Atlanta in a similar way and has produced a marked offset in the river valley as well.

As erosion has not yet obliterated its reflection in the topography, the faulting has been recent. The faulting, however, antedates the latest glaciation as the moraine and outwash continue across the fault without interruption. The faulting is probably no older than late Tertiary and much of the movement may be early
Pleistocene. It may be pointed out that the Montezuma fault resembles that which bounds the northwest rim of Boise Basin, 45 miles west, in having a greater horizontal displacement than vertical.

Other faults

Other faults similar to the Montezuma also cut the Atlanta and lateral lodes, but their displacement ranges from a few inches to a few feet, rarely as much as 50 to 100 feet. One has been exposed on the No. 6 level on the Atlanta lode between the 1850 and 1960 crosscuts. Its strike is N. 30° W., but its dip is 85° E., and displacement about 20 feet horizontally in a direction opposite to that of the Montezuma. Another lies near the far end of the No. 6 level. Its displacement has been 50 feet or more, but in the same direction as that on the Montezuma fault. These two appear to be the most notable of the minor faults, although there are many others of northwesterly trend along which the displacement ranges from a few inches to a few feet.

Fracturing

Reference has already been made to the abundance of fractures in the country rock and their exceptional concentration on Atlanta Hill and along the Boise River to the north. These fractures have so intricately shattered the rock that they seem without order or reason, yet they are merely the product of the several periods of crustal disturbances already discussed and their pattern is but the composite of those formed during each disturbance. The fractures date from the closing stages of consolidation of the Idaho batholith to those produced incidental to the late block-faulting, and are, therefore, the result of not less than four epochs of disturbance. The earliest are the joints produced during the consolidation and cooling of the batholithic mass and those resulting from the action of shearing stresses during the latest stages of consolidation. These have had a marked influence on the distribution of subsequent fractures and were themselves repeatedly reopened during younger periods of diastrophism. Some of the fractures have polished and grooved surfaces, and displace others. Some are persistent for long distances and are members of zones of shearing; others are short and discontinuous. Some have plane surfaces; others curved. Some fractures have been pulled apart; others show evidence of shearing action. Their trends conform mainly with those of the splites and pegmatites, the lodes, the granophyre dikes, and the comparatively recent faults. The fractures are naturally most abundant in the granitic rock of the batholith and least in the granophyre dikes. Although they have to some extent been broken by fractures produced by reopening of the earlier trend lines, the granophyre dikes have escaped the earlier deformations.

Fractures in the batholithic rock

The most prominent of the fractures in the batholithic rock fall into five main sets. In one of these the fractures trend N. 50° W. to N. 85° W., in another N. 10° W. to N. 30° W., in a third N. 50° E. to N. 60° E., in the fourth N. 25° E. to N. 40° E., and the last, less widely distributed than the others, about N. 70° E. to N. 85° E. Most of the fractures in each of the sets have steep dips, mainly north. The most conspicuous fractures and those most widely distributed strike west-northwest and N. 50° E. to N. 60° E. in the direction of the splites, pegmatites, and lodes. These might be regarded as the master sets as they even assert some influence on the topography and control the patterns of some of the minor gulches and ridges. Each of the five sets, however, dominates the structure locally.

On Atlanta Hill, the west-northwest set (N. 50° W. to N. 85° W.) is everywhere conspicuous, but the northeast set (N. 50° E., to N. 60° E.) is particularly accentuated.
uated near and along the shear zone which includes the Atlanta lode and becomes a part of a more or less well-defined zone of sheathing. The dip of the northwest set is 35° to 65° N.E. and of the northeast set 55° N.W. to vertical, at least near the eastern end of the Atlanta lode. The set with the north-northwesterly strike (N. 10° W. to N. 30° W.) is also fairly prominent in places along the Atlanta lode.

The fractures of this set dip 25° N.E. to 65° S.W. and cut the lode. There are also numerous other fractures, some of them fairly prominent, which trend N. 30° E. to N. 40° E. (dips 86° to 80° N.W.), and a few which strike N. 70° E. (vertical dip).

The fractures are as abundant along the lode zone below Atlanta as on Atlanta Hill and have similar strikes and dips. Those trending from N. 55° W. to N. 80° W. are generally very prominent as well as persistent, and may have smooth, regular, as well as uneven, surfaces. In places, the fractures may be considered poorly-defined sheeted zones. The dip of the fractures range from 65° N.E. to 80° S.W.

The fractures of N. 60° E. to N. 65° E. trend are numerous and rather closely spaced. They generally persist for many feet and have smooth, polished surfaces. Their dip is from 80° N.W. to vertical. Those of N. 40° E. to N. 45° E., and from N. 70° E. to N. 85° E., strike are, however, exceptionally numerous in places, and closely spaced as to form sheeted zones. Some fractures are non-persistent whereas others may be traced for long distances. Their dips are steeply northwest at angles from 50° to 60°, mostly between 80° and 90°. Many fractures in the northeast quadrantal curve on the strike. The N. 20° W. set is also present. These fractures dip either to the southwest or northeast, and most of them are slicken-sided and show horizontal striations and grooves. These cut all other fractures and are the youngest in the district, probably produced at the same time as the fairly recent faults of similar trend.

Fractures in the Miocene dikes

The fractures in the Miocene dikes are more widely spaced than those in the granitic rock of the batholith, but nevertheless are fairly abundant. They trend in the same general directions as those in the batholithic rock, but the northeast set is most prominent and most continuous. Those of west-northwest trend (N. 60° W. to N. 70° W.) are fairly prominent, in part have uneven surfaces, in part smooth and regular, and persist for considerable distances. They dip mainly 55° to 86° S.W. Those which strike N. 50° E. to N. 60° E. are generally less persistent, and are bounded by smooth surfaces, commonly somewhat curved. These dip 76° to 86° N.W., less commonly steeply southwest. The most prominent fractures are those which strike N. 70° E. to N. 80° E., and dip 70° to 80° N.W., more or less parallel to the borders of the dikes. These have smooth surfaces, may curve and continue on in the direction of the N. 50° to 60° E. set. The N. 30° to 35° W. set is also conspicuous in places. The dip of the fractures is mostly northeast or southwest at angles greater than 50°. The fractures are smooth and cut across those of west-northwest and northeast trends. There are only a few fractures which do not conform to any of the above sets.

ORE DEPOSITS

HISTORY AND PRODUCTION

The Atlanta district has had a colorful history which began with the discovery of its rich silver ores in 1864 by placer miners, who had traced the gold in the gravels of Quartz Creek to its source in the Atlanta lode. The extraordinary richness of its ores soon became widely known and within a comparatively short time most, if not all, of the lodes in the district had been located. The remoteness and inaccessibility of the district, however, did much to hinder its development and to prevent it from becoming as famed as the other mining districts in southwestern Idaho discovered at about the same time. Although other mines were active
at the same time, the Buffalo mine, which marked the site of the original discovery and its adjoining neighbor, the Monarch, both on the Atlanta lode, were first in development and production. Other mines which may be mentioned were the Pettit (subsequently the Bagdad-Chase and Boise-Rochester), also on the Atlanta lode, and the Last Chance, Minerwa, Tacoma, Jesse Ponton, Washington, and Leonora (Big Lode).

During the early days, the ore from the upper workings of the Buffalo and Monarch mines was so rich that it was profitable to sort the high-grade and send it by pack-train to Rocky Bar and by bull-team to Kelton, Utah, the nearest railroad 230 miles away, for shipment to smelters and refineries in New Jersey and Omaha. Much of the ore netted between $700 and $800 in gold and silver per ton; one shipment of 40-1/2 tons yielded over $160,000. Because shipping costs were prohibitive on the lower-grade ore, stamp mills were soon erected, and ore ranging from $100 to $300 per ton was treated locally. Recovery, however, was rarely more than 50 to 60 per cent of the gold and silver, and when the tenor of the ore decreased to less than $30 a ton the mines could not be operated successfully.

At first, ore was treated in arrastres, but in 1866 the Monarch installed a mill on the Boise River. By 1869, however, the richest ore had been mined from the shallow workings. Because of the failure of its mill to affect satisfactory recovery from the lower-grade ore, the Monarch suspended operation and the district was inactive for several years thereafter.

Mining was revived in the middle seventies after lessees operating the Monarch mine 1874 had opened new bonanza deposits at greater depth. The ore was shipped to Kelton. Because the lessees had found the mine so profitable, the owners refused to renew the lease when it expired in 1878 and resumed operations themselves. The Buffalo had also resumed shipments to Omaha, but in the late seventies the grade of ore had so declined that shipping costs were prohibitive and a 10-stamp mill was erected. By this time the extraordinary richness of its ore had won worldwide recognition for the district. This cycle of mining activity continued into the eighties and was shared by the Last Chance, Big Lode, Tacoma, and several other properties. By the middle eighties, the richest of the ore had been mined from all known bodies and development at the Buffalo and Monarch had extended to the present deepest levels. Mining activity ceased in the middle eighties, for in every case the ore proved too refractory for current milling practice and the low recovery prohibited profitable mining on what today would be considered rich ore. Slowly the population dwindled and Atlanta became a ghost town.

Although some work was carried on between 1896 and 1899 by the Idaho Gold Mines on the Atlanta lode southwest of the Buffalo mine, mining was quiet for the next 15 years. The main revival did not begin until several years later when a number of the properties were reopened and the district entered its third major boom. The Monarch was reopened in 1902, completely rehabilitated by 1906, and had its new amalgamation, concentration, and cyanidation plant in operation from 1908 to 1910. In 1906, the Pettit was taken over by the Bagdad-Chase, and its newly equipped amalgamation and cyanidation mill was in full operation by 1908, and until early 1910 was one of the largest producers in the district. The Tacoma was also active between 1906 and 1909, but the mine to attract most attention was the Minerwa, which from 1909 to late 1911 led the district in the amount of bullion produced. In 1910 and 1911, the boom ended because of milling difficulties and the failure to make satisfactory recovery from the lower-grade ore then remaining, as roasting and cyanidation of the concentrates proved too costly.

Again mining was quiet until 1914. It was revived in 1915 when the Boise-Rochester, which had taken over the Bagdad-Chase, started deeper development and discovered two new ore bodies near the northeast end of the Atlanta lode. The mine
was active for the next two years and considerable ore produced from the more east-
ernly of the two bodies. In 1917, the Boise-Rochester was purchased by the St.
Joseph Lead Company, but the mine was allowed to remain idle until 1929 when an
option was taken on the Monarch mine and a minor amount of development was started
but suspended in 1930.

Work was resumed by the St. Joseph Lead Company in August, 1931. That date
marked the beginning of the greatest period of mining activity since the district
was discovered in the early sixties and extensively worked during the decade be-
ginning about 1875. The ghost town of Atlanta became a boom camp. A modern amal-
gamation-flotation concentrator was installed and in operation by February 1, 1932,
and the mine and mill were worked at capacity for the next four years. The milling
difficulties which had beset the early-day operations were corrected by flotation
and the recovery increased to about 90 per cent of the value of the ore. The dis-
trict became the leading gold producer in the state.

Deep development proved disappointing, however, and by the close of 1933 all
known ore bodies on the Boise-Rochester ground had been opened for stoping. A
royalty lease was then acquired on the adjoining Monarch. Underground development
was pushed and by the end of 1935 and early 1936 had been extended along the
Atlanta lode for more than 5,000 feet, undercutting all the known ore shoots along
the lode. All ore that could be profitably mined was stopped, old mill tailings
tested, and the Monarch dump milled. This development showed that commercial min-
eralization was confined to shallow shoots from 400 to 800 feet below the surface.
Operations were suspended early in 1936, mine and mill equipment dismantled and
later removed, and the mine sold. Lessees operating on a small scale continued
work on the Monarch after the middle of the year and a 50-ton, amalgamation-
flotation plant was installed at the old Monarch mill on the Boise River. Ore from
underground and from the old dumps was fed to the mill during 1937 and 1938. Some
work was also continued by lessees on the Boise-Rochester property. As a result of
underground disclosures made by lessees, the Boise-Rochester was reopened in 1938
by the Talcote Mines, Incorporated, which had purchased the property from the St.
Joseph Lead Company. The mill was reinstalled and ore treated. The Atlanta dis-
trict appeared to be on the threshold of another boom.

The records of production are very incomplete and imperfectly known. The
total production for the district probably exceeds $6,000,000, most of it divided
between the middle seventies and early eighties, and the recent period of activity.
The production from 1932 to 1938, inclusive, was approximately $2,000,000. Further
details on production are assembled and discussed in the treatment of the individ-
ual mines.

GENERAL CHARACTER

The deposits of the district are valued for their precious metals alone and
contain no other metals in amounts worthy of recovery. Much of the ore mined in
the early days was high-grade. The rich seams and stringers were confined to the
upper parts of the deposits which were characterized by an abundance of silver
minerals with some gold, although in later years the gold content increased. Most
of the gangue is quartz and the gold and other minerals form only a very small part
of each deposit. The kind, relations, and distribution of the minerals are typical
of epithermal precious metal deposits.
MINERALOGY

Foreword

The deposits consist largely of fine-grained quartz, part of which contains widespread and relatively abundant finely-crystalline arsenopyrite and lesser pyrite. The valuable minerals, gold and an assemblage of complex silver sulphosalts accompanied by minor amounts of pyrite and negligible amounts of lead, zinc, and copper sulphides, are associated with comb and drusy quartz. Deposition of the minerals was repeatedly interrupted and the deposits have been built up by successive deposition in breccias; first, breccias of country rock and thereafter breccias of the earlier minerals. Two generations of fine-grained quartz, the second accompanied by arsenopyrite, preceded the introduction and deposition of the comb and drusy quartz and associated ore minerals. A minor amount of quartz and calcite was deposited later. Although minor assemblages of silver minerals of supergene origin have added somewhat to the value of the surface ores, the shallow bonanzas appear to have been largely the product of hypogene enrichment.

The minerals are listed for convenient reference as ore minerals and gangue minerals, each subdivided according to metals and origin.

Ore minerals

Gold:
Hypogene: Gold (native) - - - - - - - - - - - - - - - Au

Silver:
Hypogene: Andorite (τ) - - - - - - - - - - - - - - - - AgS₂,2PbS,3Sb₂S₅
Margarite - - - - - - - - - - - - - - - - - - Ag₂S,3Sb₂S₅
Owyheeite - - - - - - - - - - - - - - - - - - 8PbS,2AgS,6Sb₂S₅
Polybasite - - - - - - - - - - - - - - - - - - 8Ag₂S,6Sb₂S₅
Promethite - - - - - - - - - - - - - - - - - - 3Ag₂S,3As₂S₅
Pyrrhotite - - - - - - - - - - - - - - - - - - 3Ag₂S,5Sb₂S₅
Stephanite - - - - - - - - - - - - - - - - - - 5Ag₂S,3Sb₂S₅
Xanthococite - - - - - - - - - - - - - - - - - - 3Ag₂S,5As₂S₅

Supergene: Argentite - - - - - - - - - - - - - - - Ag₂S
Cerargyrite (horn silver) - - - - - - - - - - - - AgCl
Silver (native) - - - - - - - - - - - - - - - - - - Ag
Stromeyerite (τ) - - - - - - - - - - - - - - - - - - (Cu,Ag)₂S

Copper:
Hypogene: Chalcocypirite - - - - - - - - - - - - - Cu₇FeS₄
Enargite - - - - - - - - - - - - - - - - - - Cu₇S₄Cu₄As₃S₈
Tetrahedrite - - - - - - - - - - - - - - - - - - 5Cu₂S₂(Fe₃,Fe₂,2n)S₂2Sb₂S₅

Supergene: Azurite - - - - - - - - - - - - - - - - - - CuCO₃·Cu(OH)₂
Linarite - - - - - - - - - - - - - - - - - - (Fe,2Cu)CO₃·(Fe₂,Cu)(OH)₂

Lead:
Hypogene: Galena - - - - - - - - - - - - - - - PbS
Supergene:Anglesite - - - - - - - - - - - - - - - PbSO₄

Zinc:
Hypogene: Sphalerite - - - - - - - - - - - - - - - ZnS

Molybdenum:
Hypogene: Molybdnite - - - - - - - - - - - - - - - MoS₂
Iron:
Hypogene: Arsenopyrite, FeAsS
Pyrite: FeS
Supergene: Goethite, Fe₂O₃·H₂O
Schorlomite, Fe₈O₉·2H₂O

Gangue minerals

Oxides:
Hypogene: Quartz, SiO₂
Carbonates:
Hypogene: Calcite, CaCO₃
Silicates:
Hypogene: Sericite, H₆K₆Al₃(Si₄O₁₂)
Sulphates:
Hypogene (?): Gypsum, CaSO₄·2H₂O

Ore minerals

Gold (Native): Although exceeded in weight by silver, native gold is by far the most valuable ore mineral in the deposits. In some of the rich bonanzas mined in the early days the ratio of silver to gold, by weight, was as much as 200 to 1. The amount of gold appeared to increase materially in the silver-rich bonanzas. It was more widely distributed than the silver, both laterally and vertically, and its ratio to silver increased downward and laterally from the bonanza zones. With depth the gold content declines less abruptly than the silver. Although most bonanzas were characterized by an abundance of silver minerals, a few contained a preponderance of gold.

Much of the gold forms microscopic grains. Nuggets were rarely seen in lodes, but coarse grains in placer gravels imply that considerable coarse gold was present in upper parts now eroded. Even in the richest ore the gold is generally not visible to the unaided eye. Although admixed with other minerals, the gold is not combined with other elements, but is free. As much as 60 per cent of it is recovered by simple amalgamation, the precise amount depending on the fineness of grinding needed to free the metal from associated minerals.

Some of the gold is free in the quartz, either as veinlets in fractures or as grains on and between quartz crystals in druses. Probably the larger part of the gold is intimately associated with various sulphides (pl. 3 and 4). Although some has been precipitated on surfaces, much of the gold appears to have been deposited by replacing the other metallic minerals. Even though the various metallic minerals have apparently differed considerably in their capacity to deposit gold—either by replacement or by simple precipitation—chalcopyrite seems to excel but pyrite is almost as effective. This replacement of chalcopyrite by gold has been observed in all polished surfaces of ore that contain gold, chalcopyrite, and other metallic minerals. Grains of gold were also found associated with pyrite, arsenopyrite, sphalerite, tetrahedrite, enargite, galeite, pyrargyrite, mimetite, polybasite, and other silver sulphosalts—for the most part replacing them, but among the gold shows the greatest preference for the pyrite. Inasmuch as the arsenopyrite is the most abundant and most widely distributed of the sulphides, it has probably caused the deposition of more gold than any other mineral. This fact should not lead to the conclusion that the arsenopyrite and gold are
A. Photomicrograph of polished surface of ore, showing gold grain (Au) in third-stage comb quartz (dark gray), and an admixture of galena (g) and pyrargyrite (p) filling between quartz crystals. x 115.

B. Gold (Au) replacing chalcopyrite (c), both filling between third-stage quartz crystals (black). x 115.

C. Gold (Au) replacing third-stage pyrite (py). Galena grain (g) also present. x 115.

D. Gold (Au) in contact with pyrite crystal (py), and replacing light gray chalcopyrite (c) and darker gray tetrahedrite (T). x 115.
A. Photomicrograph of polished surface of ore showing gold (Au) replacing chalcopyrite (c) and tetrahedrite (t). x 115.

B. Gold grain (Au) associated with pyrrargyrite (p) and tetrahedrite (t). Tetrahedrite and pyrrargyrite contain some elliptical grains of galena (g). x 115.

C. Expanding bomb structure resulting from the replacement of pyrite (mineral with high relief) by tetrahedrite (t). Tetrahedrite is in turn replaced by chalcopyrite (c). x 115.

D. Intimate relations of tetrahedrite and enargite (etched mineral of darker color, showing peculiar line pattern). x 115.
contemporaneous. On the contrary, the gold was deposited during a younger cycle of mineralization and was the last mineral deposited during that cycle.

Silver minerals

Hypogene

Most of the bonanzas contained abundant hypogene silver minerals. Even though bonanzas of silver ore were found in the Minerva and Tacoma veins, they were not widely distributed but were confined to the mid-part of the Atlanta lode and its nearby laterals. The zone of most intense silver mineralization centered in and about the Monarch and Buffalo ground and was less intense outward, so that the two most easterly ore bodies on the Atlanta lode apparently contained no recognizable silver minerals. The hypogene silver mineralization was even less persistent in depth and the bonanza ore was confined within 200 feet of the present surface although minor veins and streaks containing silver minerals commonly continued to lower levels but with greatly decreased volume and value.

The most abundant of the hypogene silver minerals were stephanite, pyrargyrite, polybasite, and miargyrite, but these were accompanied by a number of others which were present in variable amounts.

Andorite (1). This complex sulphantimonide of lead and silver (Ag₃S₂PbS₃Sb₂S₅) was tentatively identified as minute grains associated with galena, tetrahedrite, and polybasite in a single polished surface of ore. Most of the grains were lath-shaped, apparently prismatic, and occurred within the galena. The grains and laths had a greyish color, distinct light to dark grey polarization colors, and were negative to all etch reagents, except aqua regia. The grains were too minute to permit microchemical tests for lead, silver, antimony, and sulphur, but in view of its determined properties, including its hardness, the mineral is probably andorite. The mineral is probably a very rare constituent of the ore.

Miargyrite. The miargyrite (Ag₃S₂Sb₂S₅) appears to be one of the most widely distributed of the complex silver minerals found in the ore and fully as abundant as either pyrargyrite or polybasite in the specimens from the Atlanta lode. It is also as abundant as pyrargyrite and proustite in ore collected at the Tacoma. Mention of it has been made in earlier reports, probably because it had not been recognized. It may have been one of the most abundant minerals in the early-day bonanzas.

The miargyrite is more or less intimately associated with pyrargyrite, in parts of the pyrargyrite, in part as independent grains and crystals. Some of it was observed as small black crystals on the surface of quartz crystals in druses; elsewhere in formed irregular grains filling the spaces between quartz crystals. Where it is in contact with the pyrargyrite, the relations suggest that it has been added to the borders of the pyrargyrite or has penetrated and replaced it.

Owyheeite. Owyheeite, another sulphantimonide of lead and silver (8PbS·2Ag₃S·5Sb₂S₅), was identified in the polished surfaces of two silver-rich ore specimens as remnant grains partly replaced by pyrargyrite. This comparatively rare mineral is a very minor constituent of the ore and can be recognized only in polished surfaces.

Polybasite. This silver-rich sulphantimonide (8Ag₃S₂Sb₂S₅) was recognized in a number of specimens of the rich silver ore from the Atlanta lode and from one of its offshoots. It occurs both as grains associated with other silver minerals and as small crystals coating drusy quartz. The crystals are in the form of flattened
six-sided, tabular prisms with beveled edges and show triangular striations on the basal faces. Some crystals are isolated, others form aggregates which commonly show twinning. The crystals are iron-black; the streak also is black, but the thin splinters and flat crystals show reddish internal reflection. In polished surfaces, the polybasite is characterized by its pronounced greenish-yellow, blue, and violet polarization colors and it reacts to mercuric chloride and potassium cyanide etch tests. Unlike ordinary polybasite, this is quickly stained iridescent with nitric acid. Its relations to the other silver minerals are not clearly determined, but it appears to be one of the youngest of the silver sulphosalts. Polybasite is reported to have occurred widely, but was a minor constituent of the rich bonanza ores mined in the early days.

Proustite: The light red ruby silver, proustite (Ag₂S₄As₂S₈), appears to be rather widely distributed through the district and was identified in ore from the Atlanta lode as well as from the Tahona. Both proustite and pyrrargyrite occur in the same specimen of ore, apparently in isolated grains. Such grains are vermilion to aurora-red in color and yield a similarly colored streak. In some of the ore from the Atlanta lode it occurs as perfectly formed crystals on slickensided surfaces. These crystals are small, acute rhombohedrons, capped by obtuse rhombohedrons and basal pinacoids. The crystals are vermilion by transmitted light. In polished surfaces, the grains have such strong reddish internal reflection that their color is completely masked. Although proustite appears to be a conspicuous ingredient in the richer ore, it is not nearly as abundant as the dark red ruby silver, pyrrargyrite.

Pyrrargyrite: Pyrrargyrite (Ag₂S₄Sb₂S₈) is considered to be one of the most abundant minerals in the rich ores of the Atlanta lode. Although some of it occur as distinct crystals, more of it commonly forms granular masses, either alone or mixed with stephanite, polybasite, margvrite, galena, and tetrahedrite (pl. 4, b) or disseminated as minute grains or larger bunches and stringers in granular quartz. In places, it is so abundant that it gives the quartz a dark color. Some of the reports have described streaks of it near the walls of narrow quartz veins, the centers of which were brecciated and impregnated with stephanite and other silver minerals. In some specimens, crystals are set on those of quartz; elsewhere, grains are bounded by the faces of quartz crystals. In part of the polished surfaces, the pyrrargyrite is accompanied by gold, the grains of which project into the pyrrargyrite (pl. 4, b).

Stephanite: Stephanite (Ag₂S₄Sb₂S₈), or brittle silver, is reported to have been the most abundant ore mineral in the bonanzas, but only a minor amount was found in the ore collected by the writer. Most of it formed imperfectly crystalline and columnar black masses associated with less pyrrargyrite in comb quartz; some of it occurred as a filling along the centers of narrow veins bounded by lenses of pyrrargyrite and as grains with pyrrargyrite in coarse granular galena. Where studied by the writer, the stephanite occurred in quartz druses associated with scant chalcopyrite and pyrrargyrite as imperfect crystals too brittle and fragile to be preserved in polished surfaces. The mineral has an iron-black color and streak, and is very easily crushed.

Xanthocoenite: In several specimens crystals of the orange ruby silver, xanthocoenite (Ag₂S₄As₂S₈), were recognized associated with proustite crystals on slickensided surfaces of the ore. Although it has the same chemical composition as proustite, it may be readily distinguished from the latter by its orange-yellow color. It is apparently a minor constituent of the ore.

The supergene silver minerals are confined to the upper parts of the ore bodies, but apparently they added little to the richness of the early-day bonanzas, for Clayton points out that stephanite and ruby silver were far more abundant in the rich ore near the surface than argentite and native silver. Nevertheless, the supergene minerals caused some enrichment and they may be found in minor amounts in places as much as 200 feet below the surface.

Argentite: A little argentite (Ag₂S) was observed in ore which showed some evidence of supergene enrichment, but did not appear in any that was entirely hypogene. It was usually associated with more or less native silver either in fractures in the ore or as scattered grains in polished surfaces showing selective replacement of galena, tetrahedrite, and pyrrargyrite. Clayton reports that argentite occurred in some of the rich ores of the Atlanta lode in the form of mossy grains, subordinate, however, to the stephanite and pyrrargyrite.

Cerargyrite: Some horn silver (AgCl) is reported to have been present in the surface ore at the Monarch and other mines in the Atlanta district, but was not an important ore mineral. Some thin films and crusts of cerargyrite were found by the writer on several pieces of ore collected at the outcrop of the Atlanta lode above the Monarch and Pettit ore bodies.

Silver (native): Native silver was the most abundant of the supergene silver minerals and was found to depths of 200 feet or more below the present surface, mostly in the lower part of the zone affected by oxidation and supergene enrichment. In some places, it occurred as flat scales in fractures in the slightly altered primary ore, or as small wires in drusy clefts on and between the quartz crystals. Many excellent specimens of the wire silver were found in such clefts above the 200 level of the Monarch mine in the Pettit ore body during 1935. Native silver was also observed as microscopic grains in polished surfaces of the partly oxidized ore replacing galena and argentite, and, less commonly, tetrahedrite and pyrrargyrite.

Stromeyerite: Stromeyerite (Cu₄Ag₆S₈) has been reported by Shannon in some of the richest ore from the Atlanta lode as disseminated blue-tarnishing grains associated with mossy black argentite, in ore composed mostly of large masses of granular pyrrargyrite and stephanite. Its association with argentite suggests a supergene origin.

Copper minerals

Hypogene

Chalcopyrite: Chalcopyrite (CuFeS₂), another minor constituent of the ore, is confined to the richer ore shoots as microscopic grains associated with tetrahedrite and the complex silver sulphosalts. It is less commonly found as small grains, granules, and crystals in the quartz combs and crusts on and between the quartz crystals, usually with minor amounts of other sulphides of the same epoch. Some of the more coarsely crystalline chalcopyrite forms poorly-defined sphenoids, in part modified by other forms, resting on the faces of quartz crystals, but most of it occurs as irregular grains and granular masses completely filling the spaces between the quartz crystals.

The chalcopyrite is of special interest because it appears to be uniformly highly auriferous and more or less intimately associated with grains of native gold (pl. 3,b and 4, pl. 4,a). Of all the polished surfaces of ore studied, that showing chalcopyrite always contained the largest amount of gold, most of which replaced the chalcopyrite and, only to minor extent, the other minerals present. The

2/Ibid., p. 471
gold-chalcopyrite association suggests that the chalcopyrite has had a stronger attraction and has exerted a more powerful precipitating action on the gold than has any other mineral. Although where present it may have been of great importance unfortunately, the chalcopyrite is one of the least abundant minerals; therefore, it has little influence in controlling the general distribution of the gold through the deposits.

The relations of chalcopyrite to other minerals do not seem to be as significant as in the case of the gold. It is commonly associated with pyrite and tetrahedrite (pl. 3,d and 4, a,c), penetrating and replacing them, and it appears to be younger than either. The pyrite forms residual islands in the chalcopyrite. The chalcopyrite generally forms veins and irregularly replaces the tetrahedrite, in some places as if by lobes. Where the chalcopyrite increases in abundance, the tetrahedrite forms "island-like" inclusions. Sphalerite usually forms grains with little evidence of replacement.

Enargite: Enargite (Cu₃S₄Cu₂As₂S₇) is also very sparse in the ore, but only in association with tetrahedrite (Cu₃S₄Cu₂(Fe₃Zn)₂S₅Sb₂S₆). It can be distinguished from the more common tetrahedrite by its pronounced polarization colors in polished ore surfaces and by its particular etch reactions (pl.4,d). In some of the ore it appears to be fully as abundant as the associated tetrahedrite. Its intimate association with the tetrahedrite suggests that the two are about contemporary, but the microscopic relations indicate that the enargite may have followed the tetrahedrite and may have penetrated and partly replaced the tetrahedrite (pl.4).

Tetrahedrite: Tetrahedrite (gray copper) was observed as thin veins accompanied by more or less pyrite, chalcopyrite, enargite, and pyrrylgenite, but it is usually only visible in polished surfaces where it forms minute grains and small granules associated with galena, pyrrylgenite, polybasite and other related silver minerals. Because it is present everywhere in the hypogene silver assemblages, mostly intimately associated with galena (pl.4,b), miargyrite, pyrrylgenite, and polybasite, it appears to be as widely distributed as the silver sulphosalts. Its relation to the galena is of interest. This mineral mostly forms elliptical blebs, and in places shows a poorly-defined graphic pattern. The tetrahedrite in turn forms rounded remnant grains or islands in the pyrrylgenite and miargyrite, and is in places replaced by native gold and supergene native silver.

Tests on some of the massive tetrahedrite show that it is the antimonial, and not the arsenical, variety, tennantite. It seems that the arsenic, instead of combining with the copper to give tennantite, or entering into the antimonial tetrahedrite, combined with the copper and sulphur in such a way as to produce enargite.

Supergene

Azurite: Small amounts of azurite, the basic copper carbonate (CuCO₃Cu(OH)₂), were observed in some of the oxidized and partly oxidized ores at the Monarch and other mines. This mineral forms small bluish stains and patches on quartz near partly altered sulphide grains, and is a product derived mainly from the oxidation of the tetrahedrite.

Limonite: Films and thin crusts of minute deep blue crystals of limonite with anglesite (PbCO₃PbSO₄) are described by Shannon 2 in a specimen from the Atlanta lode, lining cracks in coarse-grained argentiferous galena. It probably occurs sporadically in the oxidized and partly oxidized zones of some of the ore bodies.

Lead minerals

Galena: Highly argentiferous galena (PbS) has been reported by Shannon 2 as a common constituent of the rich-silver ores, but its presence has not been emphasized by others. In the present study it was found mostly as microscopic grains

1/ Shannon, R.W., op. cit., p. 459
2/ Ibid., p. 36.
associated with tetrahedrite and the complex silver sulphosalts (pl. 4,b). Since it is rarely observed, except in polished surfaces as a very minor ingredient of the silver-rich ore, it appears to be only as widespread as the silver mineralization.

Although of no economic value in these deposits, it is of mineralogic interest, particularly because of its relations to other minerals. It commonly forms in scattered, more or less elliptical, bodies in tetrahedrite (pl. 4,b) into which it has extended finger-like veinlets, in part replacing the tetrahedrite in such a way as to form poorly-defined graphic intergrowths. In places, it is itself penetrated in the same way by miargyrite with perfect micrographic relationships. It also occurs as residual rounded grains in pyrargyrite and polybasite and in similar form in the supergene argentite although the grains tend to be somewhat more irregular. The galena has served as one of the precipitants of gold and some grains were found which had been penetrated and partly replaced by the gold. The galena was unquestionably deposited during the same cycle of metallization as the gold and silver sulphosalts and, like them, tends to form between the crystals in the combs and druses of quartz.

Supergene

Anglesite: Anglesite (PbSO₄) has been reported by Shannon 1/ in the form of minute white crystals in little cavities in galena in the rich silver ore. As anglesite is the first mineral to which galena alters on oxidation, minor amounts of this mineral are to be expected in any of the oxidized or partly oxidized ore containing galena. Since the amount of galena in the ore is comparatively insignificant, the anglesite is probably even less so, and would be confined wholly to the oxidized parts of the ore bodies.

Zinc

Hypogene

Sphalerite: Sphalerite (ZnS) is another mineral which is scattered through some of the ore in grains so small as to be rarely visible to the unaided eye. In a few specimens it was observed as small pale brownish granules in open textured quartz combs and druses, but generally its grains are intimately associated with those of tetrahedrite, galena, pyrargyrite, polybasite, and other minerals, and it can be distinguished only in polished surfaces. Some of its grains contain gold, but the sphalerite has apparently been less effective than most other sulphides in causing gold deposition.

Molybdenum

Hypogene

Molybdenite: Molybdenite (MoS₂) was observed as thin veinlets in fractures in chloritized and somewhat potassic chloritized quartz monzonite on the dump at the West Tuhoma and along parts of the Atlanta lode. Apparently it is not associated with any of the quartzose ore, but is always alongside it in fractures in the somewhat altered granitic rock. Its relations to the fracture zones and to the quartzose ore suggest that it is not related to the period of gold and silver deposition, but to an earlier, probably entirely separate, period of mineralization. The mineral is notably conspicuous along parts of the Atlanta lode, but is not sufficiently abundant to constitute ore.

Iron minerals

Hyogene

Arsenopyrite: Arsenopyrite (FeAsS) is by far the most abundant metallic mineral in the district and is more or less uniformly distributed through all deposits regardless of the commercial value of the ore. The crystals, however, are so minute that they can rarely be seen without the aid of a microscope or strong lens (pl. 5). The mineral is generally recognized by the grayish color it imparts to the quartz. If such grayish quartz is given a sharp blow, the garlic odor of arsenic is at once apparent. The arsenopyrite occurs in very finely crystalline quartz, in places nearly cryptocrystalline, or chaledonic (pl. 5), rather than the coarse comb and druzy quartz with which the ore minerals are associated. Fragments of this fine-grained, grayish quartz are commonly cemented by the comb and druzy variety. It is clear that the arsenopyrite and its associated quartz belong to an earlier stage of mineral deposition.

There has been some misconception of the age relations of the gold and arsenopyrite because it was believed that the two minerals were about contemporaneous, for much of the arsenopyrite has been auriferous and mined as ore. The present study reveals that the gold and arsenopyrite belong to two entirely separate stages of deposition, but that the arsenopyrite has been a very effective precipitant of the gold in those parts of the deposits where the younger gold-bearing solutions were permitted to circulate.

Pyrite: Although deposited in variable but small amounts during each of several stages of mineral deposition, pyrite (FeS₂) is a minor constituent of the ore and wall rock. Most of it is exceedingly inconspicuous, partly because so little is present and partly because the crystals are so small, from microscopic size to those about one-eighth of an inch across. Most of the crystals are simple or striated cubes, those with striations showing pyritohedral combinations. Few are pyritohedrals alone. The pyrite is most abundant in the altered wall rock, but that pyrite is not auriferous. Some minute grains are associated with the arsenopyrite, and in other places crystals accompany a still younger generation of quartz it also appears as coarser grains and crystals in the comb and druzy quartz, in part alone and in part intimately associated with the tetrahedrite, chalcopyrite, galena, and various silver sulphosalts (pl. 3 and 4). The pyrite in the druzy and comb quartz is highly auriferous and next to chalcopyrite has been the most effective precipitant of gold.

Supergene

Limonite: The term "limonite", as here used, includes all the amorphous hydrated iron oxides, which chemically are said to consist of Fe₂O₃·H₂O (goethite) with differing amounts of adsorbed or capillary water. Limonite is not abundant in the oxidized parts of the deposits. Much of it is earthy and yellowish brown or reddish stains and patches of thin crusts on or near the exposed croppings.

Siderite: The iron arsenate, siderite (FeAsO₄·2H₂O), is the most conspicuous mineral in and near the outcrop where it forms greenish stains and thin crusts on the oxidized and partly oxidized ore. It has been derived from the oxidation of the arsenopyrite.

Footnotes:
A. Photomicrograph of thin section of ore showing finely crystalline second-stage quartz containing intimately associated black, minute arsenopyrite crystals, brecciated and the fractures filled with coarser crystals of clear, third-stage comb quartz with which the gold and other ore minerals are commonly associated. Uncrossed nicols. x 12.

B. Same as A, but with nicols crossed. x 12.

C. Early, moderately coarse-grained, first-stage quartz, shattered and invaded by minute quartz and arsenopyrite crystals (black) belonging to the second-stage of deposition. Plane polarized light, nicols uncrossed. x 12.

D. Same as C, but nicols crossed. x 12.
Gangue minerals

Quartz: Quartz (SiO$_2$) is the most abundant mineral of all deposits, comprising fully 95 per cent or more of the filling. Its abundance is largely the result of successive deposition in breccias; first, in breccias of granitic rock and thereafter in breccias of granitic rock and pre-existing quartz. The quartz also shows considerable variation in grain size and other characters. That deposited during earlier stages is exceedingly fine-grained and commonly contains phantom inclusions of the altered country rock. Apparently it was capable of replacing the country rock to a high degree, a property not shared to such an extent by that deposited during later stages, which was coarser-grained.

The earliest quartz is a white, massive variety, here and there accompanied by a very little pyrite. It is fine-to-medium-grained, depending largely upon the size of the body (pl. 5,a,d), its grain size suggesting fairly rapid cooling of the solution. It has permeated widely through the earlier brecciated country rock, and in turn has been repeatedly brecciated and in many places almost entirely replaced by younger generations.

The second quartz is in part even more finely crystalline than the first and is distinguished from it by its moderately gray to dark gray color, which is due to the finely crystalline arsenopyrite and pyrite in it. This grayish quartz has permeated and replaced both the earlier white quartz (pl. 5) and the refractioned granitic rock and contains them in innumerable phantom-like inclusions. It is even more widely distributed than the earlier quartz, and in most places is more abundant. The fineness of grain and the small size of its contained arsenopyrite and pyrite crystals probably reflect rapid crystallization induced by quick chilling of the mineral-bearing fluids. It is the most conspicuous quartz of the deposit and the one most easily recognized.

Quartz introduced after the fracturing of that containing the arsenopyrite is much coarser-grained (pl. 5,a,b) and possessed replacing power only locally and to minor degree. Some of it is coarsely granular, but most of it is in coarse combs and druses, where the individual crystals are generally less than one-fourth of an inch long. It is the quartz with which the gold and other sulphides are associated. Most of the ore minerals occur on and between the quartz crystals, which are white to colorless, and commonly glassy in appearance. Crystal faces are common and have not been destroyed or modified by the associated sulphides deposited in the openings between adjacent crystals. The total volume of this quartz apparently was less than that of earlier generations, since for the most part it only partly fills the fractures in the brecciated earlier fillings, leaving open cleats lined with crystals commonly coated by ore minerals. In those places where it occurs in greater volume and in more massive form it is white, medium and finely coarse-grained and appears to have permeated through the earlier fillings, retaining remnants of them as phantom-like inclusions. Apparently this quartz was deposited more slowly than that belonging to earlier stages as though the mineralizing solutions had not been as quickly chilled.

Some quartz crystals larger than those of the ore mineral stage have been observed in calcite seams and veinlets filling rather widely spaced fractures in the ore, cutting the earlier comb quartz as well as the older fine-grained variety. This quartz is present in very small amounts and is not found in all calcite seams.

Carbonates

Calcite: Calcite (CaCO$_3$) is a minor gangue mineral and is generally found in and near the commercial ore sheets as fillings in rather widely spaced fractures.
in the ore or as crusts on some of the third-stage drusy quartz. Its color ranges from white to buff, to faintly greenish and pinkish. This transition takes place within a single specimen, usually from white or pale green in the center outward to buff. The composition of the calcite is variable, in part ferriferous and in part manganiferous. However, it contains neither iron nor manganese in sufficient quantity to affect its optical properties so that the index of the slow ray on cleavage plates of all the calcite, regardless of color, is 1.66. Some of the calcite forms granular masses, some in flat, obtuse rhombohedrons; a part of it is lamellar. Nowhere has the calcite been found to contain gold. The lamellar calcite is not associated with the other, but may occur in fractures of younger age.

Siliicates

Sericite: Sericite, secondary white mica, (-\(\text{H}_{2}\text{O}\))\(\text{KAl}_3(\text{SiO}_4)_2\)) - is an alteration-mineral which was formed by the reaction of the mineralizing solutions prior to replacement of the granitic rock by quartz. Considerable of it is present in the ore mined, particularly in the gouge matrix of the crushed ore and in gouge seams produced by post-mineral faulting. The sericitized rock is dull in appearance and the feldspars are no longer vitreous but more or less earthy and chalky-white. The biotite in the rock is bleached and altered to grains of sericite somewhat larger than those found in the feldspar.

Sulphates

Gypsum: Crystals of gypsum (\(\text{CaSO}_4\cdot2\text{H}_2\text{O}\)), pseudomorphous after lamellar calcite, have been found in specimens of ore collected on some of the mine dumps, particularly at the portal of the No. 2 level of the Boise-Rochester mine. The substitution of carbonate by sulphate has usually not been complete so that calcite centers are invariably retained in the gypsum crystals. The relations suggest that the calcite was attacked by solutions containing sulphuric acid and partly replaced by gypsum. The sulphuric acid may possibly have formed from the oxidation of the sulphides and the gypsum may, therefore, be supergene, but the question of origin is not settled, for the sulphuric acid could have been contributed from magmatic sources. The gypsum, as well as the lamellar calcite, may have been a subsequent introduction into the Atlanta lode and related to a younger Miocene period of mineralization.

PARAGENESIS

General Features

As already indicated, the mineral deposits have not been the product of continuous deposition. The ore shows striking evidence of repeated brecciation during the general period of mineralization and the deposits are largely the product of successive deposition in breccias. Although in a geologic sense the whole period of ore formation was brief, each successive brecciation and deposition appears to accord with marked structural adjustments followed by new epochs or pulsations of mineralization. The mineralizing fluids were reintroduced at least four times after as many structural movements had thoroughly shattered and reopened the closed channels. The minerals were, therefore, deposited in four successive stages. The ore itself can be best described as a succession of superposed breccias, composed of fragmental inclusions of earlier fillings in younger fillings, much of the earlier fillings appearing as phantom inclusions through the built-up deposit.

The groups of minerals deposited after each reopening are given below for reference. These lists give the minerals in the general order of deposition, insofar as that order could be established, and the abundant minerals of each successive stage are underscored.
Hypogene mineral sequence

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<th>Stage 1</th>
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<th>Stage 4</th>
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<td>Gold (native)</td>
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To the above might be added two other stages of deposition, one earlier and one later than those tabulated. Each is believed to have a different origin and to be in no way genetically related to the main period of mineralization. The first would include the deposition of molybdenite in fractures in the shattered granitic rock, probably during the closing stages of consolidation of the Idaho batholith, the second the deposition of lamellar calcite and gypsum in fractures in the lode filling at a much later date, probably the Miocene. The deposits would, therefore, be in part a composite of three separate, unrelated periods of mineralization of which only the second has been of major magnitude and importance.

In order to make the general features of the paragenesis complete, the supergene sequence should also be considered. Mineral succession in the supergene ores, which were produced from the hypogene minerals through processes of oxidation, solution, and redeposition, is not clearly defined. It is sufficient to state that the scorodite, limonite, native silver, argentite, stromeyerite (?), linarite, anglesite, azurite, and cerargyrite are the products of supergene alteration and enrichment of the hypogene ores.

Hypogene mineralization

Stage 1: The first surge of mineralizing fluids into the zones of brecciated granitic rock introduced an abundance of quartz and very small amounts of pyrite. These fluids had great penetrating power and were capable of replacing the country rock to a marked degree and in consequence soaked through wide zones of the shattered country rock. In places, the replacement destroyed most of the evidence of the original granitic rock and the resulting quartz is massive. However, in most places the replacement was only partly complete and the quartz is filled with phantom-like inclusions of the altered quartz monzonite. This quartz is fine-grained as though the mineralizing fluids had been quickly chilled by rapid loss of heat in the wide zones of shattered rock. The mineralizing fluids did not, however, penetrate all parts of the breccia zones to the same extent so that quartz is only abundant in places; in other places, much of the quartz has been obscured through successive invasions of younger quartz. The associated pyrite is not uniformly distributed, but appears here and there in very scant amounts, apparently controlled by minute fractures in the quartz and by replacement of the quartz. Some of it may have extended out into the altered country rock.
Stage 2: The second wave of mineralizing fluids entered a zone of early quartz and country rock as extensively brecciated as the zone which permitted access of the earliest solutions. These fluids also possessed great penetrating power and were capable of wide-spread replacement. The fluids spread even more widely than the first, penetrated the early quartz breccia and extended outward into the fractured country rock along its. In this stage the fluids deposited finely crystalline quartz, small amounts of finely crystalline pyrite, and moderate amounts of minute crystals of arsenopyrite (pls. 5, a, and d). The quartz was deposited first and deposition continued during and after the sulphides had been precipitated. In places, the quartz and its contained sulphides have merely cemented the fragments of early quartz and altered country rock. In other places, they also appear as massive seams and veins. This quartz also has been found as elliptical and moderately angular shells around fragments of the early quartz and country rock. It stands out sharply because of its grayish color produced by the presence of finely crystalline arsenopyrite. In other places, it has penetrated into and partly replaced the early quartz and brecciated rock, and may appear to be filled with phantom inclusions of both. The intensity of this stage of mineralization varies from place to place, but its effects are more widespread than that of any other pulsation of the mineralizing fluids.

Stage 3: When the mineralizing solutions surged forward for a third time they encountered a zone of porosity as permeable as any that had preceded. Structural movements had shattered the entire zone, producing innumerable breccia fragments and open fractures. However, the fluids had less penetrating power, or less volume, than the earlier ones and were apparently not as quickly chilled, possibly because their temperatures were lower at the start. In most places the quartz of this stage, which is more coarsely crystalline, was deposited as a cementing material in the breccia (pl. 5, a, b) as coatings of crystals on the breccia fragments, and as open textured combs and druses in the fractures. Vugs and clefts lined with short quartz crystals are rather abundantly distributed through all the deposits because of the abundance of openings and the lack of sufficient quartz to fill them. In some places, however, the mineralizing fluids did penetrate the fragments, and they were more or less completely replaced by a white, massive, medium-to-coarse grained quartz. In such places, the deposits are more or less mottled and the quartz filled with numerous phantom inclusions of the earlier fillings with most of the mOTTing produced by the retic second-stage grayish quartz and its unreplaceable arsenopyrite and pyrite.

Most of the ore minerals associated with this stage of mineralization were deposited later than the quartz in the openings left between the quartz crystals in open-textured combs and druses (pls. 3, a, and 4, b). These minerals were deposited on the quartz without replacing it. Where the space was adequate, the ore minerals tended to develop crystal forms; where the filling was complete, the ore formed massive layers or irregular grains and granules between the quartz crystals.

Although in places there was probably considerable overlapping, the ore minerals were deposited in a more or less well-defined sequence. The succession was recorded in crustification, the deposition of the younger mineral on the older, and in replacement. The succession started with the deposition of pyrite, which alone shows perfect crystals. It appears, however, to be especially susceptible to replacement and the surfaces of contact with other sulphides are consistently irregular (pl. 5, c, d); where it is replaced by tetrahedrite (pl. 4, d), the exploded bomb structure is shown. Sphalerite, such as there is of it, replaces the pyrite in part, but it has not been susceptible to replacement itself, and most of it is included as grains in the younger minerals. In some places, its grains have been slightly fractured and the fractures filled with other minerals, particularly tetrahedrite. The tetrahedrite appears to be third in the sequence because veins of it cut the sphalerite. It is, in turn, irregularly penetrated and replaced by most
of the other ore minerals and held in them as rounded and irregular inclusions, es-
pecially by the ruby silver and miargyrite. It appears to be somewhat older than
the enargite for the latter occurs in it in the form of irregular veinlets which
suggest replacement (pl. 4,d). Both tetrahedrite and enargite preceded chalcopy-
rite for both are replaced by the chalcopyrite and are included as "islands". In
some of the ore, the tetrahedrite has been rather extensively replaced and only
that preserved as veinlets in the sphalerite has escaped. The chalcopyrite and
galena are closely associated, but the galena is apparently slightly younger and
engulfs minor inclusions of the chalcopyrite. As stated earlier, the galena pene-
trates and replaces the tetrahedrite in such a way as to show poorly-defined,
pseudo-eutectic intergrowths.

The minerals so far enumerated are of little economic importance because such
small quantities are present in the ore. The minerals of special economic interest
were deposited after these, but their sequence is far less certain, particularly be-
cause some are not in contact with other ore minerals but rest directly on the
quartz and possess crystal outline.

Chalcopyrite and andorite (§) seem to be the oldest of the silver minerals, both
having been somewhat replaced by pyrargyrite. Although each now appears only as
inclusions in the pyrargyrite, they may have replaced galena since they contain
lead. In some places, however, the pyrargyrite extends into and replaces the
galena without any evidence of an intermediate lead-silver-bearing mineral. Miarg-
gyrite is intimately associated with the pyrargyrite, but may be slightly younger
inasmuch as the grains usually adjoin or envelop those of the pyrargyrite. In
some places, the miargyrite extends into and replaces the galena in such a manner
as to form a typical "graphic" intergrowth. Inasmuch as it has been found as a
filling of veinlets bordered by walls of pyrargyrite, the stephanite is probably
somewhat younger than the pyrargyrite and miargyrite. It and the polybasite may be
closely contemporaneous, but precise relations between them could not be obtained.
Both proustite and xanthocnite appear to be younger than any of the other silver
sulphides, being found as small crystals on slip surfaces which pass through the
other silver-bearing minerals. Because it has been precipitated by all other met-
allie minerals, mostly by replacing them, gold has been the last mineral deposited
(pls. 3 and 4). The only minerals not found in contact with it were the proustite
and xanthocnite. Like so many of the silver sulphides, the gold also occurs as
independent grains on and between the quartz crystals (pl. 3,a).

Stage 4: The final pulsation of mineralization was preceded by structural
movement and brecciation much less intense and much less widespread than any which
had preceded earlier stages of deposition. Most of the reopening was localized in
the zones which had been most extensively brecciated and reopened during earlier
stages, and, therefore, in the zones containing the commercial third-stage ore.
The mineralizing fluids, however, introduced only small amounts of quartz and cal-
cite which were deposited in rather widely spaced fractures and other openings, in
places in the vugs unfilled by minerals of the previous stage. Although the de-
posits have been more or less severely shattered since the carbonate was deposited,
no other ore-bearing fluids were introduced, except very locally and perhaps at a
much later time when exceedingly minor amounts of lamellar, calcite, and gypsum
were deposited.

Supergene mineralization

The supergene mineralization has involved the oxidation and generally the
solution and redistribution of the metals of the hypogene ore into other minerals,
and has in part led to an enrichment of the original ore. The processes of super-
gene mineralization seem much more complex than those of the hypogene mineraliza-
tion, for the minerals can not be considered collectively, but only as separate in-
dividuals.
Oxidation of the arsenopyrite has given rise to conspicuous greenish stains and crusts of scorodite on and just below the surface cropings. Its oxidation permitted both the iron and arsenic to go into solution, but these quickly combined into an insoluble iron arsenate. The oxidation of the arsenopyrite as well as the pyrite gave rise to the formation of yellowish to reddish stains and crusts of limonitic iron oxides. Oxidation of the galena has produced minor amounts of the lead sulphate, anglesite. In places, linarite and azurite have resulted from the alteration of the copper-bearing minerals, the linarite from the combination of lead and copper sulphates, the azurite from the oxidation of the tetrahedrite.

The alteration of the silver minerals is of greater local interest. As these minerals were exposed to the attack of surface waters, they too were taken into solution and carried to somewhat lower levels by the ground-water and the mineral ingredients either dispersed or reprecipitated in other combinations, generally replacing the primary minerals. Some silver was precipitated as the insoluble chloride, cerargyrite, in the upper parts of the deposits. The silver, which was carried to greater depth, came in contact with the primary metallic minerals and was reprecipitated largely by selective replacement as argentite, and the argentite in turn by native silver, even though both were also deposited as such in fractures and cleats in the ore. The antimony and arsenic freed by the oxidation of the primary silver minerals were dispersed in the general underground circulation and removed from the deposits. Through these processes of oxidation, solution, and removal of the soluble materials, the gold was freed from its intimately admixed sulphides and made available for simple recovery by amalgamation.

CLASSIFICATION

These deposits have most of the characters of the precious-metal epithermal type, that is, of deposits formed near the surface by ascending thermal waters in genetic connection with igneous rocks. Among these affiliating characters may be mentioned the abundance of complex silver sulphosalts, particularly in the form of bonazas; the apparent shallow range of commercial deposition; the presence of very small amounts of various kinds of base-metals, including pyrite; the extremely fine crystallization of much of the quartz as well as the sulphides, features associated with rapid chilling in near-surface rocks; the presence of abundant open cavities, drusy or comb deposition, and extensive brecciation, features again related to fracturing near the surface; the successive stages of mineralization; and the extensive silicification of the shattered country rock. All these, Lindgren lists as characteristic features of the epithermal.

The mineralization has been confined to extensive fracture and shear zones, and the ore has been largely deposited as a filling of breccias. The deposits are, therefore, composite - not simple - and most of them are to be classed as lodes, rarely as veins. They may be more concisely classed as epithermal, siliceous, gold-silver lodes.

DESCRIPTION OF THE DEPOSITS

Distribution

Most of these deposits are confined to the upper part of Atlanta Hill, but some occur on the lower slopes and some extend across Grouse Creek and the Yuba River. The district is dominated by the Atlanta lode which has contained the most productive mines, namely, the Boise Rochester (Pettit), Monarch, and Buffalo. This lode extends in a southwesterly direction from the upper part of Montezuma Gulch.


35.
across the top of Atlanta Hill and the head of Quartz Creek, and down the slope
toward the Yuba River, a distance of nearly 2 miles. The other lodes are aligned
obliquely on both sides of the Atlanta and are especially numerous along the middle
and upper part of Quartz Gulch and on the Grouse Creek slope directly to the south.
Most of the lodes are shown on the geologic map (Fig. 2), but several lie beyond
its limits near the mouth of Quartz Gulch and also across Grouse Creek and the Yuba
River.

The main Atlanta lode is clearly indicated on the surface by the prominent
outcrop and by fairly closely-spaced cuts where the overburden is sufficiently
depth to conceal it. The others are indicated by the alignment of cuts and dumps
on and along the outcrops, which otherwise are largely concealed by soil.

Although numerous lodes have been found in a comparatively small area, only
a few of them have contained ore in commercial amounts. The most important of
these on the south side of the Atlanta lode are the Minerva and Last Chance, and
on the north side the Leonora (Big Lode), Jessie Benton, Tahoma, and Washington.

Controlling geologic features

The distribution of the deposits has been controlled wholly by structural
features. Although the country rock is largely massive, porphyritic quartz mono-
nite which is cut by dikes and seams of aplite and pegmatite, none of these is
more favorable to the occurrence of ore than the other. The local control is the
complicated zones of fracturing and brecciation.

It is believed that the lode pattern (Fig. 2), which includes the main Atlantas
and its associated system of oblique laterals, has been produced by the action of
regional horizontal shearing stresses, the Atlanta lode reflecting the general
direction of the shearing and the oblique set (the fracture zones) which relieved
the tensile component of the regional stress. This particular zone of weakness,
shown by complicated shearing and fracturing, has localized the mineralization by
providing adequate channels for the movement of mineralizing fluids for the de-
position of ore.

Structural relations

Atlanta lode

The Atlanta lode has been traced for nearly 2 miles across Atlanta Hill in a
direction about N. 80° E. (Fig. 2). Neither the lode nor the shearing are known
to extend across the Yuba River and across Montezuma Gulch. However, a faulted
segment is believed to continue up Flint Gulch about 1,800 feet southeast of the
saddle at the head of Montezuma Gulch and the bold quartz cropings of the offset
has been traced northeast for more than half a mile. The strike of the lode varies
somewhat from N. 60° E. On the surface, the extreme northeast part dips steeply
southeast, but at shallow depth the dip reverses to steeply northwest and the
average dip of the northeast third of the lode is of 70° to 80° NW. The middle
part of the lode dips steeply southeast but the southwestern end dips steeply
northwest at depth.

This lode is by far the largest in the district and is remarkable for its
thickness, which ranges from 40 to 120 feet, 60 to 70 feet representing a fair
average. However, the thickness also varies with depth just as the strike did.
Unfortunately, only a relatively small part of the lode-filling is commercial ore.
Commonly, the shoots range from 5 to 6 feet thick; exceptionally, they attain 35
feet. They extend for distances of 250 to 600 feet on either strike or dip.
The general form of the lode is more or less tabular. Locally, it is joined by numerous gash laterals and it divides to form two major forks, the laterals which extend from the main lode, both N. 80° W. or S. 80° E., dip steeply northeast. They are usually less than 2 feet thick next to the main lode and not more than 3 to 6 inches thick, 50 to 100 feet away. Some of them have contained veins of very rich ore, particularly near the surface, but with depth they decrease in number and size, and disappear almost entirely in the lowest mining levels.

The branches of the Atlanta lode are very much larger. One extends from the Boise-Rochester ground across into the Monarch on the northeast half of the lode. The lode appears merely to widen where it branches, but the hanging wall branch gradually swings away from the main lode in a west-southwesterly direction, curving more and more to the west and within 500 feet it has become completely detached and in another 500 feet is separated from the main lode by 140 feet of unbroken rock and is striking west-northwest (N. 80° W.) at the same angle as the oblique laterals. Its thickness is about 40 feet at that point. The lode branches again near the southwest end of the lode nearly 4,000 feet from the first.

The shear zone, which contains the Atlanta lode, is complicated in detail and extends beyond the limits of the lode itself. The ore is confined to those parts of the shear zone where the country rock has been most intensely fractured, or brecciated. The shear zone is made up of a set of fractures having the same trend as the zone itself, but it also contains a fairly prominent set of west-northwest fractures. Not uncommonly a prominent northeast fracture or fissure, when traced to the southwest, curves to the west and merges with a west-northwest set, at the same time becoming much less conspicuous. The shear zone also contains subordinate nearly flat fractures and other fractures of diverse trend, some of which were produced later, and are, therefore, not an actual part of the original zone of shearing. Some of these that trend northwest offset the main fracture zone.

The distribution of the fractures and the slickensides on the ore show that the movement which accompanied the fracturing was largely horizontal with a small vertical (normal) component, the northwest side of the shear zone having moved northeast with respect to the southwest side. With depth the west-northwest fracture planes, as well as the gash fractures of the same trend on the wall rock, became less conspicuous and apparently decrease in number and size. Only the fractures parallel to the shearing seem to persist.

**Oblique laterals**

The lateral system of lodes approach the Atlanta at an acute angle; some of them actually join, others die out before reaching the main zone of shear (Fig. 2). None is known to cross the Atlanta and none has been offset by the movement along the Atlanta shear zone. These oblique laterals have the same general trend as the gash branches of the Atlanta lode, but they persist for much greater distances. In different parts of the district their strike ranges from N. 85° W. to N. 85° W. They also show variations in dip; most of them dip steeply northeast, a few dip southwest.

These lodes are not nearly as large nor as persistent as the Atlanta lode, even though some were traced as much as a mile. Many are only 2 feet wide and few exceed 10 feet, although one, the Tahome, is locally as much as 40 feet wide. Part of some laterals remote from the Atlanta are larger than those which are near.

Few of these laterals were accessible underground and nothing definite could be learned about their characteristics. In the abundance of fractures and the intensity of brecciation some resemble the Atlanta lode, but the fracture pattern could not be deciphered from the available exposures. The accessible parts of the
latterals had been so affected by post-mineral movement that earlier structures had been largely obliterated. The intensity of fracturing may, however, decrease with depth. Here has been true of the minor gash veins near the Atlanta lode and this appears to be true in the case of the last Chance lode in which the volume of ore, as well as the fracturing, showed marked decline on lower levels. In most places the latterals have been subjected to as much post-ore movement as the Atlanta lode itself.

Ore shoots

General features

Although the mineralization is nearly as widespread as the shearing and fracturing, the shear and fracture zones are by no means uniformly or evenly mineralized, particularly with valuable ore minerals. Commercial ore is confined to more or less well-defined zones or shoots, apparently localized by structural conditions. The lodes contain numerous horns of altered or partly altered country rock, zones of more or less massive quartz containing immemorial angular inclusions and phantoms inclusions of silicified quartz monzonite, and also zones showing particularly intensive brecciation and fissuring, and containing veins of ore. Where the lode is as much as 40 to 80 feet wide, the mineable ore may be only 5 or 6 feet wide, and it usually lies along either the hanging wall or footwall, or both. Such shoots as are favorable to the occurrence of ore may be from 250 to 800 feet long. They are separated by areas of low-grade ore of equal size and may extend to depths of 300 to 800 feet. Those on the Atlanta lode are perhaps larger and more persistent than most of those on the oblique latters.

Atlanta lode

Distribution and size

The Atlanta lode has six main ore bodies, or ore shoots (fig. 3), named from northeast to southwest the Old Chunk, Central, Pettit, Monarch, Buffalo, and Idaho (Atlanta). These are spaced at irregular intervals over a distance of more than 5,000 feet along the lode and are separated by similar areas of “barren” lode material. These ore bodies range in stope length from about 250 feet to about 800 feet, and are distributed over a vertical range of about 1,000 feet. The individual shoots have a known pitch length of from 300 to 800 feet. All but one reach the present surface.

The size of these ore bodies is variable. The Old Chunk contained mineable ore for a distance of 620 feet along the lode and to a depth of 400 feet, most of the ore being confined to a segment 600 feet long by 300 feet deep. The thickness varied somewhat, but mostly ranged between 3 and 6 feet. The adjacent shoot, the Central, failed to reach the surface, but extended to a greater depth than any other, more than 100 feet below the next deepest. This ore body was 350 feet broad and had a pitch length of 570 feet. The thickness was from 3 to 5 feet, not differing much from that of the Old Chunk.

The largest shoot was the Pettit, about 300 feet southwest of the Central. It was productive over a maximum range of 800 feet both vertically and horizontally. A part of it was about 36 feet thick, but most of it was no more than 5 or 6 feet thick. The Pettit shoot, however, was not a single body, but a composite of three: one along the hanging wall of the lode, the largest along the footwall, and the third, a southeast oblique ore shoot, linking the hanging wall with the footwall. The ore body along the hanging wall actually lay along a major split in the lode and had ore for a distance of 400 feet over a vertical range of 600 feet. The shoot joined the footwall ore body at the top. Its average thickness was from 3 to 5 feet.
The oblique ore shoot connecting the hanging wall shoot with that on the footwall was stope d for a distance of 180 feet over a vertical range of 350 feet and for an average thickness of 3 feet. By far the largest shoot of the composite ore body was that along the footwall, in the main part of the lode, which was stope d 800 feet vertically over a maximum horizontal distance of 800 feet, its thickness ranging from 8 to 35 feet. The ore body as a whole was somewhat irregular and its upper half (footwall shoot) was twice as long as its lower half.

Although it was the most famous of the ore bodies, the Monarch is not the largest. It too, was more or less composite and contained ore shoots along both the hanging and foot walls. Most of these shoots were less than 6 feet thick and extended along the strike for 850 feet. The shoots decreased rapidly in length less than 200 feet below the surface. Some ore was mined to a depth of 600 feet, but the larger part was more than 300 feet above or half way to the surface. The next shot the Buffalo, although the smallest of all, was mined to about the same depth. Its overall length was only 250 feet, and its thickness was about the same as that of the Monarch ground. In general, the ore was more abundant and the body thicker along the hanging wall than along the footwall.

The sixth and most westerly shoot, about 1,600 feet southwest of the Buffalo, had an overall length of about 600 feet and contained commercial ore to a maximum depth of 400 feet. Its thickness was from 3 to 4 feet.

Many of the oblique veins contained seams of rich ore near and at their junction with the main lode. Although productive near the surface, these veins only persisted to shallow depths, and, except for an oblique vein being mined by the Taleche Mines, Inc., in 1938-39, in no case to the depth reached by the ore shoots along the main lode. On the other hand, the larger laterals have not been productive on or near the contact with the main zone, and have produced ore only on and near the surface; like the gash veins, they were impoverished at shallow depths.

Structural control

The distribution of the ore bodies appears to be rather closely associated with variations in the strike of the main lode. They are found in those parts of the lode where the strike diverges slightly eastward from the average trend of the lode (fig. 4). These zones of greater porosity have been produced by the movement of the walls along a curved shear zone.

As these zones with divergent strike were repeatedly reopened, each structural adjustment probably acted in the same direction as the earlier, and each was permitted to receive minerals during each pulsation of the mineralizing fluids. They were especially adapted to receive the third stage ore-bearing solutions, which apparently lacked the extensive penetrating power of the two preceding stages and was therefore destined to receive the commercial ore. Although the intervening zones were also broken during each structural movement and the earlier fillings more or less severely brecciated, the resulting pore space was apparently not so great as in the divergent zones and not as suitable for the deposition of the ore minerals. Such areas comprise the zones of "barren" or low-grade ore.

Although some ore bodies are notably thicker where the dip is steep than where it is flat, changes in the dip have played a minor role in the localization of the ore bodies. This increase in thickness is apparently a reflection of the small vertical component of the movement (fig. 5).

Distribution of the ore

Although much of the lode is a filling and replacement of breccias, first of country rock and later of country rock and the earlier fillings, the ore itself is
Figure 4 General plan of the workings along the Atlanta lode as revised and corrected to April 1935 indicating location of sections. A to K, shown in Figure 5.
confined to the zones of most extensive brecciation in those parts which were more or less continuously opened by the structural movements during the period of ore deposition, and in the same parts which later facilitated the introduction of calcite. The ore was deposited mainly as a filling in open spaces, either in fairly continuous strike fractures or in those of oblique trend. The sulphides were deposited between the crystals of the quartz combs and on the quartz dries. The gold itself was apparently capable of penetrating and being deposited in the adjoining fragments and masses of the earlier arsenopyrite-bearing quartz.

Much of the ore in the shoots has been in the form of overlapping lenses 4 to 12 feet wide, overlapping on both strike and dip, which trend and pitch slightly oblique to the strike and dip of the lode itself. The lenses were usually composed of a major layer of ore several inches to several feet thick, which lies parallel to the long dimensions of the body, but the shoots also contain minor veins and stringers. The layer of ore generally extended in a southwesterly direction, and near the end of the lens curved to the west-northwest and diminished in size. The ore then continues along an overlapping lens having the same characteristics as the preceding. Some of the layers of ore contained more or less well-defined streaks which were very rich and contained ore high in gold and silver. Ore lenses ended above and below by pinching.

The ore was by no means uniformly distributed through the ore shoots, but was most abundant and richest in the upper parts, largely in the form of streaks and bunches high in silver and gold. The range of commercial deposition was, however, comparatively shallow. A few hundred feet down the bonanzas were replaced by bodies of lower-grade ore containing few streaks of high-grade. The commercial limits of the deposit were reached within 400 to 800 feet. Silver was much more abundant in the upper parts of the lode than at depth and the content declined much more rapidly than that of gold. Silver did not have the horizontal distribution of the gold and its minerals were most abundant in the upper parts of the Monarch and Buffalo shoots and relatively absent in the Old Chunk and Central ore bodies.

Although the content of the metals was largely determined by the intensity of the third-stage metallization, the ore bodies generally do not contain much quartz of the first generation even though they do contain much larger amounts of the second-stage quartz and arsenopyrite. The ore minerals are mostly in breccias and fractures in the arsenopyrite-bearing quartz, and partly fill openings in the earlier quartz. The comb and drusey quartz is much less abundant between the ore bodies. However, in places, it has permeated the brecciated zone and almost closed the openings so as to leave no space for the deposition of the ore minerals. These more or less "barren" zones usually contain much more of the early massive quartz and as much of the arsenical-bearing quartz as in the ore shoots. These show the usual extensive brecciation and the phantom inclusion of older fillings and country rock in the younger, but show fewer open clefts and dries. The filling itself has not been as extensively broken by post-ore movements as that within the main ore bodies. The thin layer of gouge, which lies along the footwall of some of the ore bodies, is largely absent along the intervening "barren" zones.

Zoning

The good ore, although confined to comparatively shallow depths, shows some evidence of zoning, particularly in the distribution of the gold and silver. This zoning is revealed by the fact that the gold is distributed more widely and deeply than the silver. The silver is restricted to the upper parts of the ore bodies in and near the Buffalo and Monarch shoots, and is most abundant in the upper part of the Buffalo. For this reason, the district was better known in the early days for
the richness of the silver ores than for its gold ores. From the Buffalo as a center, the quantity of silver declined outward in both directions along the lode. Although it was still prominent in the Monarch and to some extent in nearby parts of the Pettit, it did not extend to the Central and Old Chunk ore shoots. Similarly, its quantity declined abruptly with depth and silver minerals were of little consequence more than 200 feet below the surface. Small amounts appeared here and there at greater depths. The range of the gold metallization appears to have been about twice that of silver, both vertically and horizontally.

Tenor of the ore

The tenor of the ore has varied greatly in the different ore shoots and in different parts of the same ore shoots, having been highest in the upper parts of each. Much of the ore mined prior to 1876 was rich enough to stand shipment by pack train and wagon to the railroad 250 miles away and by rail to smelters in Omaha and New Jersey. The value of many of these shipments averaged more than $700 a ton, some as much as $2,000 and small lots as much as $11,000. After the upper parts of the shoots had been robed of their bonanzas, ore assaying several hundred dollars to the ton was milled. When the heads declined to $30 a ton, mining operations were no longer profitable because only a part of the value could be recovered by amalgamation. Later improvements in milling methods permitted ore of somewhat lower-grade to be mined, but the tenor of the mined ore still remained notably high.

Between 1932 and 1935, inclusive, the St. Joseph Lead Company attempted to mine in such a way as to produce a mill feed averaging 0.5 ounce of gold per ton. In this they were not wholly successful, the limit actually ranging between 0.461 and 0.328 ounce of gold per ton and 1.734 and 1.036 ounce of silver. This was distributed as follows:

<table>
<thead>
<tr>
<th></th>
<th>1932</th>
<th>1933</th>
<th>1934</th>
<th>1935</th>
</tr>
</thead>
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<tr>
<td>Dry ore milled</td>
<td>61,208.6</td>
<td>69,066.8</td>
<td>66,996.0</td>
<td>57,576.0</td>
</tr>
<tr>
<td>Content</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Gold)</td>
<td>0.461 oz.</td>
<td>0.328 oz.</td>
<td>0.461 oz.</td>
<td>0.362 oz.</td>
</tr>
<tr>
<td>(Silver)</td>
<td>1.4866 oz.</td>
<td>1.734 oz.</td>
<td>1.194 oz.</td>
<td>1.036 oz.</td>
</tr>
</tbody>
</table>

Even under large scale operation, ore containing less than $6 to $9 a ton in gold and silver could not be profitably mined.

Oblique lateral veins

The distribution of the ore in the lateral lodes is similar to that in the Atlanta. The quantity and tenor of the ore is said to vary considerably in the different lodes, some of them containing ore of fairly low-grade, but of uniform distribution, others high-grade ore in smaller and less continuous bodies. As none of the ore shoots was accessible for study, nothing could be learned about the influence of structure on their distribution and little about the occurrence of the ore in them.

Not all the ore has the breccia-like appearance of that along the Atlanta lode. The ore from some of the laterals is composed of lightly fractured, grayish, second-stage quartz cut by rather sporadic veins of comb quartz. The productive veins however, show the extensive reopening and brocication of the main Atlanta lode, and contain an abundance of comb and druzy quartz cementing fragments of the earlier
quartz. In substance and structure much of it is indistinguishable from typical material of the Atlanta lode. Ore shoots probably coincide with the zones of most extensive brecciation and porosity, but the structural conditions responsible for these favorable zones cannot be stated. They may be related to variations in strike and dip of the fracture zones as along the main Atlanta lode. The upper parts of some of the bodies contained considerable silver ore, mostly of bonanza grade, but the silver minerals were confined to a shallow zone as in the main Atlanta.

Not enough is known of the distribution of the ore in the laterals to formulate any zonal scheme, although the laterals nearest to the Buffalo and Monarch contained silver sulphides as noted in the Tahoma some distance to the north.

Wall rock alteration

The country rock in and along the mineralized shear and fracture zones reveals marked changes in its appearance and composition, which is due to extensive alteration by the mineralizing fluids. As the lode is approached, the biotite in the granitic rock loses its distinctive blackish color and is replaced by greenish chlorite, but the rock shows no other evidence of change either in mineralogy or texture. However, in the inner part of the zone the chlorite shows evidence of bleaching and conversion to muscovite, and the feldspars become less translucent.

Inward from the feebly altered, chloritized zone the feldspars become white, then dull and chalky. The chlorite is destroyed and its place taken by colorless pseudomorphous grains of muscovite or sericite. Scattered small crystals of pyrit are found well within the zone. Although all minerals except the quartz and some of the minor accessories have been chemically modified, the texture of the granitic rock is preserved (pl. 6b). However, even the textural characteristics of the rock were modified and finally more or less completely obliterated (pl. 6c). The main change within this zone has been the formation of sericite. Detailed microscopic studies across the zone show that the chlorite was the first mineral to be altered to sericite, this change commencing well within the chloritic zone itself. The plagioclase was next to alter to sericite and during the early stages of its alteration showed patches of sericite irregularly distributed through the grains. As the intensity of alteration increased, the sericite grains enlarged into coarser aggregates and the original plagioclase could be recognized only from the shape of the coarse sericitic pseudomorphs. The muscovite and orthoclase were less readily altered and remained as clear grains even after the plagioclase had been rather extensively sericitized. As the intensity of alteration increased, the potash feldspars were also converted to sericite and like the plagioclase outlined as mere sericitic pseudomorphs, distinguished from the biotite by its finer grain. Only where the sericitization was especially intense does the quartz show any evidence of conversion to the finely crystalline mica. The pyrite was introduced after the rock had become more or less completely sericitized as the crystals replace the sericitized feldspars and biotite.

Although ghost-like shadows of the rock's original minerals and textures may be faintly preserved, in the intensely silicified zone the rock has largely lost its igneous character and greatly resembles the lode quartz (pl. 6d). Under this stage of intense alteration the sericite has been destroyed and its place taken by aggregates of finely-to-moderately-crystalline quartz. Near the outer margins of the zone, patches of the sericitized rock remain, but not even scattered grains of sericite are left well within it, and the silicified rock appears to gradually pass into the lode quartz (pl. 6d).

The wall rock studies indicate that large volumes of quartz were introduced into the country rock as the rock was penetrated by the ore-bearing fluids, and
A. Photomicrograph of thin section of the unaltered granitic country rock, the feldspars showing little or no evidence of attack by the mineralizing fluids. Crossed nicols. x 12.
B. Partly sericitized granitic wall rock, representing alteration of weak to moderate intensity, the polysynthetic twinning still faintly visible in the plagioclase grains. Quartz has not yet been attacked. Crossed nicols. x 12.
C. Intensely altered granitic wall rock, the original granitoid texture of the rock having been largely obliterated and the sericitized grains largely replaced by quartz. Crossed nicols. x 12.
D. Intensely altered granitic wall rock. Siliification has completely destroyed the original igneous texture and has removed all traces of the earlier sericitization. The rock is practically indistinguishable from the quartzose ore. Crossed nicols. x 12.
that moderate amounts of potash, iron, sulphur, and water were also added. These ingredients were apparently introduced in a regular order, which was determined by the temperatures of the solutions and, therefore, by the intensity of the alteration. As the fluids continued to permeate through the fracture zones, the rock was heated and the intensity of alteration increased. The zone of feeble alteration was crowded outward as the more moderate zone advanced upon it and the moderate zone was in turn encroached upon by the more intense. Chloritization was thus carried outward and gave way to sericitization, the sericitization in turn to silicification.

The wall-rock alteration is of further interest because widespread silicification is one of the characters commonly associated with epithermal mineralization.

Secondary enrichment

Supergene enrichment has been a factor in the formation of the richest ore, but apparently not the principal factor. It is reported that the surface zone yielded secondary ore of very high value, but even in the richest ore the stephanite and ruby silver were more abundant than the argentite and native silver. Supergene enrichment does not account for the occurrence of the rich silver-gold bonanzas.

The lower limit of enrichment is not clearly defined and probably depends more or less closely on the local topographic relief. Some rich pockets of native silver were found in the upper workings during recent mining activities, most of them within 200 feet of the surface, but one of this kind formed a very small part of the production. Rich silver-gold ore 180 feet below the top of the dump raise on Monarch ground showed no evidence of supergene enrichment. It appears that the bonanzas were largely the result of hypogene enrichment and the surficial ores would have been rich whether there had been supergene enrichment or not. As the bonanzas have been exhausted, the amount and distribution of supergene minerals can never be known. Decline in the grade of ore with depth appears to have been the result of relatively shallow hypogene mineralization, more or less typical of epithermal deposits.

GENESIS

The mineralogic, textural, and structural features of the deposits clearly indicate that the ore has been deposited by hydrothermal solutions derived ultimately from magmatic sources. Movement of the solutions was not a continuous process, but, as minerals were deposited, the channels would become plugged and deposition temporarily brought to an end until structural adjustments again reopened the channels and permitted the flow of solutions to resume. These pulsations of the mineralizing solutions were repeated four times corresponding to as many structural movements and openings of the shear and fracture zones. Since the mineral assemblage of each was more or less distinctive, each surge appears to have brought in solutions of somewhat different composition. The earlier pulsations deposited silica, the second carried considerable arsenopyrite, but the ore-bearing solutions were not introduced until after the fracture zones had been reopened for a third time. The ore was deposited in the zones most severely shattered and brecciated by the recurrent adjustments, particularly in the parts where openings were most abundant.

The arsenopyrite indicates that these fluids were probably comparatively hot as they started their upward journey. The fine crystallinity of much of the filling indicates that they were apparently rapidly chilled as they spread through the more numerous openings in the relatively cool rock nearer the surface and their load of minerals more or less abruptly deposited.
There are no data to fix precisely the time at which mineralization started, nor at which it came to an end, nor even to determine the precise geologic epoch at which it took place. The deposits are younger than the Idaho batholith. In view of the fact that they are contained in a deeply eroded part of the batholith and yet show evidence of having been formed at comparatively shallow depth, it does not appear likely that the mineralizing solutions were genetically related to that body. The mineralization must have taken place long after the Idaho batholith had consolidated, yet not as long after as the late Tertiary and early Quaternary block faulting nor apparently as recently as the Miocene igneous activity. The fact that a porphyry dike, presumably one of the Miocene granophyre series, is reported to cut the Tahoma lode suggests that the mineralization is older and not related to the Miocene metallization. This conclusion is further supported by the fact that the ore bodies are also cut by faults believed to be related to the Miocene disturbance, and again by the fact that the mineralization is different from that in deposits known to be genetically related to the Miocene dikes in Boise Basin. 2/ The mineralization presumably is related to igneous rocks, but such rocks, unless they be the diorite, syenite, and lamprophyre, have not been exposed by erosion.

The age of these seems to be indeterminate. As the Atlanta mineralization can not be satisfactorily related to either the mid-Tertiary or the late Jurassic or Cretaceous (Idaho batholith) periods of mineralization, it may be that the deposits are products of the early Tertiary metallization when mineralization was widespread throughout the Rocky Mountain region.

OUTLOOK

In general, bonanza ore deposits of the epithermal type are limited to shallow depths and those in the Atlanta district appear to be no exception. None of the commercial ore shoots has extended through a vertical range of more than 800 feet and all show a notable decline in the grade of the ore from the top to the bottom. Although the shearing and fracturing may continue to great depth, the ore has been deposited in the zone of abundant fractures and openings near the surface. There is no good geologic reason to believe that other ore shoots equally as rich may be expected at greater depth. Deeper mining would probably only confirm the evidence along the No. 9 level of the Atlanta lode that all ore shoots which extended as deeply as the No. 6 bottomed a short distance below it. To bear the added cost of mining, the grade of the deeper ore would necessarily have to be higher than that on the upper levels.

Mining operations by the St. Joseph Lead Company were suspended because the commercial ore, that is, ore carrying approximately 0.4 of an ounce of gold per ton, had been mined. Large amounts of lower-grade ore remain, but this was not able to pay for the cost of mining, even under the large scale operations of the St. Joseph Lead Company. Improvements in milling and mining methods can not affect materially the local costs of mining and milling. Because of the difficulty of maintaining development, mining costs are bound to increase. The metallurgical difficulties which beset the early-day operator are no longer an important factor. About 90 per cent of the gold and silver was saved by amalgamation and flotation during recent operations by the St. Joseph Lead Company. Because of the river road to Boise, transportation costs may be reduced to some extent, and, with lower labor costs, ore of somewhat lower grade than that mined by the St. Joseph Lead Company might be treated.

Some veins and pockets of high-grade have probably been overlooked on the upper levels and may be found and worked at a profit by lessees working on a small scale. However, such ore probably can not be produced in sufficient quantity to maintain even a mill of moderate size for any length of time. Although the low-grade ore remaining may arouse recurrent interest for many years to come, large-scale oper-


Mines and prospects

Boise-Rochester mine

History and development

The Boise-Rochester mine covers the northeast end of the Atlanta lode from the east crest of Atlanta Hill to the bottom of Montezuma Gulch, a distance of 2,700 feet (figs. 2 and 3). In the early days, this part of the lode was included in the Lombard, Stedman, and Old Chunk properties, which were later combined and known for many years as the General Pettit. Later the Pettit was purchased by the Bagdad Chase Gold Mining Company and the mine became known as the Bagdad Chase. When the property was acquired by the Boise-Rochester Mining Company, the mine became known as the Boise-Rochester. After the St. Joseph Lead Company obtained possession of the mine, there was some tendency to refer to it as the St. Joe, but in general the name, Boise-Rochester, has persisted.

Data on the early history and development of the mine are meager. It was worked about 1869 and considerable ore was mined in the seventies, all from an ore body (Pettit) near the west end of the property. This ore body was first opened through a 100-foot vertical shaft, later through a tunnel from the lower slope facing Montezuma Gulch. The tunnel was known as the No. 2 or General Pettit. From it a connection was made with the bottom of the shaft through a 300-foot vertical raise and four intermediate levels were driven. The mine was operated through this tunnel for a number of years, but details of its operation are lacking. The mine had its own mill, of 20 stamps near the bottom of the gulch, but mill recovery was apparently unsatisfactory and the mine finally suspended operations.

In 1906, the Pettit mine, which was then developed to a depth of 500 feet, was sold to the Bagdad Chase Gold Mining Company. This company repaired and in part re-equipped the Pettit mill, installed a power plant on the Boise River, and extended the development underground. By 1908, the mine and mill were in full operation, bullion was produced and concentrates roasted and then cyanided. The capacity of the mill was doubled by adding another battery of 20 stamps and by enlarging the cyanide plant to 150 tons. During 1909, about 80 per cent of the bullion was won by amalgamation, and the mine was one of the largest producers of bullion in the district. Although the mill continued to run on tailings for a longer time, the mine was closed in March, 1910, because of milling difficulties. The mine was idle for several years, but in 1914 the work was resumed by the Boise-Rochester Mining Company.

This new company carried the development to greater depth. The No. 6 tunnel, a crosscut, was driven and intersected the lode 2,200 feet northeast of the Pettit shaft and 430 feet below the No. 2 Pettit tunnel. A new ore body was discovered in 1915 at the point where the crosscut intersected the lode on the Old Chunk claim. As the drift was carried toward the Pettit, another ore body (Central) was found about midway. During 1915 and 1916, the company began to work the Old Chunk ore body by stopes from the No. 6 level, and during 1917 by stopes from the No. 5 (Siilson) tunnel driven about 100 feet above the No. 6. During 1915, the mill was in operation for about half the year, but recovery was not satisfactory and the next year a 100-ton flotation plant was added. The mill continued to run until September, 1917, when the ore in the Old Chunk shaft above the No. 6 had been practically exhausted. Then, the mine was optioned to the St. Joseph Lead Company. The St. Joseph Lead Company also acquired the Atlanta group (Idaho Gold Mines) on the opposite end of the Atlanta lode, controlling in all 10 patented and 19 unpatented
claims, three of which were held partly under lease and option. The company held the entire property in reserve and no work was done from 1917 until 1929.

In 1929, the St. Joseph Lead Company drove about 650 feet of tunnels and crosscuts and also acquired an option on the adjoining Monarch property. The development was continued into 1930, but mostly confined to advancing the drift on the No. 6 level to the Monarch shaft, 1,900 feet from the end line of the Boise-Rochester group. All work was temporarily suspended in July, 1930. In August, 1931, the company began to prepare the mine for extensive operation. The No. 6 and No. 9 tunnels were rehabilitated; the No. 9, a 1,900-foot crosscut, 280 feet vertically below the No. 6, was extended to a point beneath the Old Chuck ore shoot and a raise made to the No. 6. In the mean time, an amalgamation-flotation mill was erected across the gulch from the old Bagdad Chase, and was in operation February 1, 1932. From then on through 1935 the company was the largest producer of gold in Idaho.

During 1932, the No. 9 tunnel was extended westward along the lode to undercut the Central ore body, another raise was made on the Old Chuck ore shoot to a point 150 feet about the No. 9 and an intermediate level, the 750, driven east 280 feet. However, good ore was not revealed except in raises from 35 to 40 feet above the intermediate. The ore from the Old Chuck ore body was not removed until the following year. All ore mined in 1932 came from the Central ore body above the No. 6 level, and from the Hanging Wall shoot of the Pettit ore body between the No. 6 and 1,450 intermediate, 200 feet above the No. 6.

In 1933, the No. 9 was extended beneath the Pettit to the present face and a raise made to the 775 footwall drift. A raise was also driven from the No. 9 to the No. 6 on the Central ore body and the 700 intermediate carried northeastward for about 350 feet. The 750 east drift on the Old Chuck ore shoot was continued to the west for 150 feet and all ore mined between this level and the No. 6. What ore had not been mined above the No. 6 on the Central ore body in 1932 was removed in 1933 and in addition all ore was stope between the 700 intermediate and the No. 6, and some from about the No. 9. The Hanging Wall shoot was also mined between the 1,450 and the No. 2 Pettit, and some ore stope between the 775 footwall drift and the No. 6. Drifting along the Hanging Wall shoot on the No. 6 level had disclosed a body of ore extending southeast toward the footwall from the 1,450 crosscut. This ore shoot, the Southeast, was followed by drift to the footwall where another ore shoot was found. The 1,450 intermediate level was then driven above and stoping was carried on both above and below the No. 6 level on the Southeast shoot. Waste raises on the 1,450 intermediate then disclosed commercial ore on the Footwall ore shoot and during 1933 ore was stope from the Footwall shoot for the short distance above each of the No. 9, No. 6, and 1,450 levels, and some beneath the No. 2 Pettit. This ore shoot proved to be the largest and most productive in the mine. By the end of the year all development on the Boise-Rochester had been completed necessary to the removal of all known ore.

During 1934, the company acquired a lease on the Monarch. Practically all development was transferred to Monarch ground, advancing the No. 6 level to the Buffalo shaft and running raises and drifts on the Footwall ore shoot, which on the upper levels had in part crossed over into the adjoining property. The remainder of the ore between the No. 9 and the 700 intermediate on the Central ore body was mined. The ore which remained on the hanging wall and southeast ore shoots on the Pettit between the 775 footwall drift and the No. 6, and much of that on the Footwall shoot between the No. 6 and 1,450 intermediate and the 1,450 intermediate and the Pettit No. 2, was mined. The remainder was mined the next year, except for a small block below the No. 6 level, which was removed in 1935.
Beginning on September 19, 1935, a combined head of mine ore, largely from the Pettit ore body on the Monarch ground, and old milling tails were fed to the mill. At the close of the year, the Monarch dump was milled and early in 1936 operations brought to a close. During the latter part of 1935 and the early part of 1936, the No. 6 drift was driven 3,045 feet beyond the Monarch shaft to undercut and prospect the ore shoot on the company’s Atlanta claims on the southwest end of the lode. The mine and mill were then dismantled and much of the equipment trucked to Mountain Home during the early summer months. The property was sold later in the year.

After the mine had been sold, lessees started work on small rich gash stringers and exposed one oblique seam several hundred feet long. In 1938, the Talache Mines, Incorporated, took over active management, blocked out enough ore along the oblique vein to furnish feed to a mill for several months and then re-equipped the mill. Considerable new work was done underground.

The mine has been developed by 9 tunnels (fig. 3), but the only ones of importance are the No. 6 and No. 9, the former having been driven beneath or through all known ore shoots in the Atlanta lode (figs. 3 and 4). The No. 9 served as the main haulage level, all ore on or above the No. 6 being dumped into a raise and drawn out in the No. 9 tunnel, level with the top of the ore bin at the mill. Formerly the ore had been trammed from the portal of the Pettit No. 2 to the Pettit and Bagdad Chase mill across the gulch. All the mine workings, except some of those made in the early days, are shown in plan (fig. 4) and in longitudinal section (fig. 3). These also show some of the workings on the Monarch, Buffalo, and Atlanta claims. Because of the heaviness of the ground along the lode, the drifts and other openings could not be kept open for any length of time, and most of those of recent date were inaccessible by the summer of 1934. Because of this, all permanent levels and raises were driven in the hanging wall and all stopes were kept filled to the working face.

Production

The production from the Boise-Rochester mine is not precisely known, but probably exceeds $2,500,000. No figures are available on the production from the old Pettit mine, and that from the Bagdad Chase from 1908 to 1910, inclusive, is reported by Ballard to have been about $320,000. The early-day production from the Pettit may have been less than $100,000. The production from the Old Chunk ore body from 1916 to 1917, inclusive, was approximately $350,000. These figures, however, are little more than a third of the production from 1932 to 1935, inclusive, which is estimated at about $1,775,976, with that for 1932 at $364,091; for 1933, about $390,025; for 1934, $803,330; and for 1935, about $106,628. The figures for 1934 and 1935 do not include the production from the Pettit ore body on Monarch ground.

Geologic features

Although the Atlanta lode crosses the Boise-Rochester ground in a northeast–southwest strike, its trend is not uniformly the same but varies somewhat on either side of a general N. 50° E. line. Such variation in strike is significant for the main ore shoots lie along those parts of the lode that strike more easterly or westerly than the lode as a whole. The dip of the lode across the property is everywhere northwest at a relatively steep angle, mostly about 70° to 80° N.W., except in the upper part of the Old Chunk ore shoot where the dip is steeply southwesterly.

east (fig. 5, sections J and K).

For most of the explored length the lode appears to be from 40 to 60 feet wide, locally as much as 80 feet, but the entire shear zone is not uniformly mineralized and includes much fractured rock which contains little ore, or is but little altered. Both the shear zone and lode tend to pinch and swell along the strike and dip, and the intensity of the pre-and-post-mineral fracturing likewise varies from place to place, being most intense in and along the commercial ore zones. The numerous gash veins which lie adjacent to the lode, especially along the hanging wall, trend west or west-northwest. Although they may be as much as 2 feet thick where they join the main lode, they generally narrow to 4 inches or less within a hundred feet. Many are reported to be fairly large and conspicuous in the upper workings, but they are small and inconspicuous on the No. 6 and few may be recognized on the No. 9. At the 960 crosscut, the lode widens and splits, the footwall branch continuing on in the southwesterly direction, the hanging-wall branch gradually curving toward the west away from the footwall. This branch changes to an independent shear zone, which, on the Monarch ground, becomes a member of the west-northwest lode system. At the 1,450 crosscut, however, the hanging-wall shear zone is linked to the footwall by a prominent oblique south-eastward-trending fissure, developed as a gash fracture produced by differential movement between the two walls and having the relations of other gash fractures of west-northwest trend.

A lamprophyre dike lies in or near the shear zone, in places crossing the lode at an oblique angle in a general westerly direction and passing outward into the hanging wall. The dike has been considerably altered and fractured in and along the lode. Although intruded so closely after the mineralization as to have been affected by all post-ore structural adjustments, it is post-ore. In parts of the ore zone, the dike has been so extensively brecciated and so admixed with shattered ore fragments that it has been mistaken for a pre-ore intrusive. This dike or others similar to it were uncovered along many parts of the lode during mining operations.

Distribution of the ore

The lode is complex. The ore seems generally trend in the direction of the strongest and most persistent fractures, which are usually those parallel to the direction of the shear zone. Numerous seams also extend obliquely toward the hanging wall in the manner of gash veins, but they do not persist far and are not as large as those which parallel the shear zone. Most of those which lie parallel to the shear zone eventually curve toward the west and become oblique seams which soon pinch and become low-grade. The ore is continued along the lode in other overlapping seams similar to the first.

In some places, the more intense mineralization lies within the shear zone or lode; elsewhere it lies along one or both walls. The ore occurs in lenticular shoots, which are made up of some large as well as small lenses. In places, these lenses form bodies 4 to 12 feet wide, which tend to dip toward the walls of the lode, but they do not actually extend to the wall. The ore is in part distributed in the form of lenticular pockets in the more highly mineralized parts of the lode, usually along the wall. As there is no clear line of demarcation between ore and waste, the limits of all ore bodies must be determined by assay.

The stopes afford little information on the distribution and manner of occurrence of ore lenses. They merely indicate the zones wherein the lode material could be profitably mined. As pointed out elsewhere, the shoots persist from 300 to 600 feet on the strike, from 400 to 800 feet on the dip, and range from 4 to 8 feet in thickness, locally as much as 35 feet. All of the quartz is not ore, and
occasionally massive quartz extends for many feet beyond the limits of the shoots. The distribution of the ore shoots has been determined by zones of special porosity and permeability, which in turn have been dependent on variations in the strike of the zone of shearing itself, namely, along those parts of the lode where the strike is more easterly than for the lode as a whole. In those localities the horizontal shearing stresses, which have acted essentially parallel to the zone of shearing, have tended to move the walls apart, increasing the relative amount of pore space while decreasing the space available for ore in the parts between. Gash fractures or zones of gash fractures oblique to the zone of shearing have also favored ore deposition and commercial ore zones because of the increased amount of pore space available for ore. The Old Chunk, Central, Footwall, and perhaps the Hanging Wall, ore bodies are examples of ore shoots localized by changes in the direction of strike; the Southeast ore body by gash fractures of oblique trend.

Ore shoots

The Pettit is by far the largest of the three main ore shoots on the Boise-Rochester ground. The Old Chunk and Central ore shoots are simple, single ore bodies, but the Pettit is a composite of three separate ore bodies, the Hanging Wall, the Foot Wall, and the Southeast. The details concerning each of the ore bodies follow.

Old Chunk

The Old Chunk, the most easterly of the ore bodies along the Atlanta lode, was one of the larger (see page 38). Except where its extreme northeast corner is cut off, the ore body seems to be untouched by erosion. The longitudinal section (fig. 3) shows that much of the ore was less than 200 feet above the No. 6 level and that very little occurred below it. The ore body appears to be the most shallow of any along the Atlanta lode. Above the No. 6 level the ore body dipped southeast, but below it, steeply northeast (fig. 5, cross sections J and K).

It is probably coincidence that the bottom of the ore body should have ended at the No. 6 tunnel level. It was the showing along the No. 6 that largely prompted the St. Joseph Lead Company to acquire possession of the mine with the natural expectation that the ore would continue to a depth at least equal to that already mined. Deeper development along the No. 9 level proved fruitless and no commercial ore was revealed until raises had been carried 35 to 40 feet above the 750 intermediate level, or a distance little more than 100 feet below the No. 6 (fig. 3). Although it yielded about $360,000, the tonnage of ore mined above the No. 6 was not learned, but the total output below the No. 6 was only 3,641 tons.

The strike of the ore body is about W. 56° E., or slightly oblique to the general trend of the lode at either end (fig. 4). The ore body appears to be restricted to a zone of especially intense fracturing and lies within exceptionally heavy ground. None of the workings on it is now accessible, except some of the crosscuts on the No. 9 level. In these the granitic rock is considerably fractured, but not particularly altered.

The ore body was notably quartzose, but carried considerable arsenopyrite and perhaps minor amounts of other sulphides. It did not, however, contain silver-bearing minerals and the gold lay in the quartz or intimately associated with arsenopyrite. This ore body contained the only coarse grains of gold that were found in the mine.
The Central ore body is separated from the Old Chunk by about 600 feet of ground too low in precious metals for profitable extraction. However, some ore was mined from a stope about 100 feet long and 20 feet high on the No. 6 level about midway between the two shoots (fig. 3). This small ore body conformed with a minor variation on the strike of the major shear zone and its characters are much like those of the Old Chunk and Central.

The Central ore shoot is approximately bisected by the No. 6 level. Although it was necessary to raise as much as 40 feet above the No. 9 before the ore was compact and rich enough to be stope, it is the only ore body which extended to the No. 9 level. On the No. 9, the ore was in bunches and too widely disseminated to be commercial.

The ore body has a general trend of N. 65° to 70° E. and is, therefore, more oblique to the general direction of the lode than the Old Chunk (fig. 4). A cross section of the ore body (fig. 5, section I) shows minor variations in dip. The dimensions of the ore body are given on page 35 and the stopes are shown in Figure 3.

The ore mined contained somewhat less than 0.5 ounce of gold per ton and only small amounts of silver. The mineralisation was not much different from that of the Old Chunk, except that the gold was not as coarse, and there were few, if any, exceptionally rich pockets. The body produced 38,235 tons of ore.

Hanging Wall (Pettit)

The Hanging Wall ore body is separated from the Central by about 300 feet of practically barren, friable quartz, and occupies the hanging wall branch of the split Atlanta lode. It was the first of the ore shoots on the Pettit to be mined on the No. 6 level, largely because the prospecting had been directed along the hanging wall and because the larger body on the footwall was found later. The ore shoot has a general trend of about N. 70° E. (fig. 4), but as it approaches the property line the tenor of the ore decreases even though the shearing swings out at an increasingly larger angle. Its western border approximately coincides with the property line just beyond the 1,550 crosscut on the No. 6 level. Its eastern margin is near the 1,150 crosscut.

This body, like the Central, was longer than wide, but it did not extend to the No. 9 level. Its dip is less steep than that of the footwall body, and, at about the 250 level, the two joined and continued upward as a single ore shoot (fig. 5, section D-D', E-E', F-F', and H-H'). Its average stope length above the No. 6 level was 400 feet and its height to the No. 2 about 400 feet. Below the No. 6 level, a segment 150 feet long and about 100 feet high, and from 3 to 5 feet thick, just above the 775 intermediate was rich enough to be stope.

During 1932, the body produced 36,863 tons of ore between the No. 6 and the 1,450 intermediate and for a short distance above the intermediate. The dimensions of the block mined were 370 feet on the strike to an average height of 215 feet, the average thickness about 8 feet. In 1933, the stope was completed through to the No. 2 Pettit, 400 feet above the No. 6, the average stope length being 380 feet and its thickness from 4 to 5 feet. Another was opened on the 775 intermediate, 150 feet below the No. 6 level over a length of 150 feet and stopped upward 50 feet. The 1933 tonnage was not segregated from that from the Foot Wall body, but probably more than half of the 45,426 tons came from the hanging wall shoot. The remainder of the ore below the No. 6 was mined in 1934 over about the
same length as that of the year before and totaled 2,800 tons. The thickness of
the lower end of the body ranged from 2 to 4 feet.

The ore on the hanging wall was notably siliceous and contained insignificant
amounts of arsenopyrite, but considerable of the younger comb and drusy quartz.
Little or no silver was found on or below the No. 6 level and little above except,
perhaps, near the No. 2 Pettit. The ore was not as much broken nor the ground as
heavy as along some of the other ore shoots. The mineable ore forms a small pro-
portion of the total amount of quartz present along the hanging wall.

Southeast (Pettit)

The Southeast ore body, as pointed out on pages 38 and 39, occupies the
oblique fracture zone which links the hanging wall body with the footwall in the
vicinity of the 1,450 crosscut on the No. 6 level. This oblique fracture zone
extends 8° 70′ E. from the hanging wall and was disclosed in the 1,450 crosscut
and drifted on to the southeast to the footwall of the main shear zone. It con-
tained mineable ore only for the first 180 feet. It was later opened on the 1,450
intermediate level 180 feet above, but contained ore only between the No. 6 and
1,460 and between the 775 Intermediate and the No. 6 level, a vertical distance
of 350 feet (fig. 5, cross section G-G′). In the vicinity of the 1,450 level the
body pinched to a mere seam and was bounded by sharp walls. Although the body
was no more than 3 feet thick, it produced 4,200 tons of ore, most of which was
mined in 1933; the remainder in 1934.

The ore in the Southeast body differed from that in adjoining shoots by con-
taining abundant silver minerals in the form of high-grade seams, particularly
above the No. 6 level. It also contained a larger proportion of gold so that much
of the ore was combined with that from other bodies to increase the value of the
mill feed.

Foot Wall (Pettit)

The Foot Wall ore body, the largest on the Atlanta lode - not only in length
and depth but also in the quantity of ore - is about equally divided between the
Boise-Rochester and Monarch mines. The body, however, is nearly twice as deep
on the Boise-Rochester as it is on the Monarch. Its stope length is about 800
feet, half of which is on the Monarch; its maximum depth on the Boise-Rochester
is about 800 feet, in the Monarch about 450 feet. Altogether it has produced
about 144,000 tons of ore since early 1933, somewhat more than half of which came
from the Boise-Rochester. To this should be added an unknown but large tonnage
from the Pettit No. 2 level to the surface 400 feet above, an amount probably as
large as that mined from the section below the No. 2 Pettit. The lode above the
No. 2 Pettit level is reported to have been 30 to 50 feet wide and to have con-
tained zones of commercial ore 6 to 15 feet wide and as much as 400 feet long.

The 1,460 Southeast drift on the No. 6 level had reached the footwall of the
shear zone at a point where the ore was non-commercial and the presence of commer-
cial ore a few feet distant was unsuspected until the disclosures at the higher
level prompted drifting southwestward along the footwall on the No. 6 level. Dur-
ing 1933, the footwall ore body was opened over a length of 360 feet on the No. 6
level and the 1,460, and for 135 feet on the 775 Intermediate below the No. 6
level. A section 50 feet high and 360 feet long was also opened under the No. 2
Pettit level. Some ore was mined from six small stopes on the No. 9, but the
Foot Wall ore body proved to be largely non-commercial below the No. 6 level. The
ore body was 4 to 8 feet across at these places. Its production, combined with
that from the Hanging Wall and Southeast ore bodies, was 43,426 tons.

51.
Stoping continued in 1934 between the No. 6 and 1,460 intermediate levels, and above the 1,460, that above the No. 6, carried 70 feet above the 1935 stopes over a distance not quite as long as that below. This particular segment produced 9,187 tons of ore, the body ranging from 4 to 5 feet thick. At the same time, the production above the 1,460 intermediate was 38,315 tons over a length of 400 feet and a height of about 60 feet. The much larger quantity of ore in this segment was caused by the greatly increased thickness of the ore body, which locally ranged up to 35 feet thick (fig. 5, cross sections D-D', E-E', F-F', H-H'). Near the 1,460 level the ore body had divided into two parts with a small horse of country rock between, but these parts united above and the thickness of the body in part decreased to 5 or 6 feet, its normal thickness.

The 1935 work included a strip about 350 feet long and 60 to 70 feet high just below the 1,480 intermediate and a 200 by 20 to 40 feet strip midway between the 1,460 and the Pettit No. 2. The production was 10,986 tons.

During 1934, 1935, and early 1936, stoping was also carried on on the neighboring Monarch ground, adding more than 56,406 tons to the Pettit production and giving a total output for the entire Pettit ore shoot, including all three bodies, of 196,528 tons.

The general trend of the Foot wall ore body is about N. 60° E., its direction very slightly oblique to that of the zone of shearing as a whole (fig. 4). The footwall of the ore body was bounded by a prominent band of gouge which contained considerable pulverized ore. The ore body itself was more or less conspicuously shattered and broken throughout. The dip of the footwall body is steep and the thicker parts of the ore body accord with a local steepening and reversal of dip.

The ore on the footwall ore body was notably darker than that in the hanging wall and it contained much more arsenopyrite. Its tenor was also somewhat higher. Its values were mainly in gold, but there were appreciable amounts of silver, particularly on the higher levels, where bonanza streaks and pockets of ore rich in both silver minerals and gold were mined. Ruby silver was rarely observed in the ore in the No. 6 level nor was there any notable amount anywhere below the 1,460 intermediate. It was more abundant on the Monarch ground than on the Boise-Rochester and most abundant of all in the upper workings in the Monarch.

Character of the ore

The general character of the ore was discussed in the detailed description of each of the ore bodies. Much of the ore resembled a breccia, which was cemented by third-stage comb and drusy quartz, composed of fragments of the grayish, fine-grained, arsenopyrite, and contained second-stage quartz in which may be phantom inclusions of early white quartz and altered granitic rock. The early white quartz is prominent, particularly in the "barren" zones between the main ore shoots, but even in the "barren" zones it has been rather extensively brecciated and cemented by the grayish second-stage quartz and by lesser amounts of the third stage. The early quartz is much less conspicuous in the commercial ore zones, probably because it has been more extensively replaced by the second-stage quartz and the latter in turn more thoroughly penetrated by the third-stage comb and drusy quartz and the valuable ingredients it contains. Calcite, in part the brownish ferriferous variety, appears in widely scattered fractures through the ore shoots.

Tenor of the ore

Although, by careful selection, veins and pockets of ore extraordinarily rich
in gold and silver might be obtained from each of the ore bodies and from some of the barren zones, the assay results would be no fair measure of the tenor of the ore that must necessarily be mined for quantity production. The high-grade must be mixed with ore of lower grade and in order to raise the average value of the lower grade ore and perhaps make it commercial.

The St. Joseph Lead Company sought to maintain an average mill head of 0.5 ounce of gold per ton. During 1932, the assay value of the 51,642.7 tons of ore mined was 0.4614 oz. of gold and 1.4866 oz. of silver per ton. The stope ore was fairly regular in grade and its value somewhat higher than given above, but the ore was diluted and the value lowered by the addition of low-grade ore from development. During 1933, the assay value of the 59,352.4 tons of ore mined was 0.328 oz. of gold and 1.724 oz. of silver per ton. The lower value resulted from the addition of a larger proportion of low-grade ore from the deep development where the grade was not as high as above. In 1934, the gold in the stope ore was higher than in 1933, although the silver did not increase. The 68,484.6 tons of ore mined assayed 0.461 oz. of gold and 1.194 oz. of silver per ton. In 1935, both gold and silver values declined, due in part to a decrease in the richness of the ore and to the addition of marginal ore. The 57,637.1 tons of stoping ore, in large part from Monarch ground, had an assay value of 0.362 oz. of gold per ton and 1.038 oz. of silver.

The method of prospecting used by the St. Joseph Lead Company leaves little possibility that important bodies of ore of commercial tenor may have escaped discovery. As the stopes were advanced, waste had to be mined for back fill and this was done by carrying a cross-sectional cut about 5 feet wide across the width of the lode, the cuts staggered from foot to hanging wall at intervals of about 46 feet and carried upward with the stope as the ore was mined. By this means a complete vertical cross-sectional cut of the lode for its entire width was made, and any overlapping or unknown ore shoots which might have paralleled the ore were mined as they were discovered.

According to company figures, ore valued at less than $6 a ton in gold and silver could not be profitably mined. This may suggest that ore ranging from $5 to $6 per ton may remain in a fairly large quantity.

**Monarch mine**

**History and development**

The Monarch mine lies near the head of Quartz Gulch about 1-1/2 miles south of Atlanta at an elevation of about 6,800 feet on what has generally been considered the richest segment of the Atlanta Lode. It lies between the original discoverer, on the Buffalo claim and the Boise-Rochester, and covers about 1,400 feet of the lode (fig. 2).

The Monarch is the most noted of the mines in the Atlanta district and its history is closely interwoven with that of the district itself. Ore from the mine was treated in arrastras in 1885. A year later the mine was sold to the Monarch Gold and Silver Mining Company. A 2-mile ditch was laid to a mill site on the Boise River near the mouth of Quartz Creek. Considerable ore was mined, mostly from two levels, at shallow depth. The main, or Atkins, level was driven from a point a short distance west of the present Monarch shaft. An older adit had been driven a short distance above. The operations, however, did not prove wholly successful as the mill recovery was low. In 1869, operations were suspended. There was little activity for several years thereafter while the owners endeavored to dispose of the mine on the English market.
Work was resumed by lessees in 1874 and the mine was active for several years thereafter with considerable profit to those holding the lease. The Lantass tunnel was driven from some distance down Quarts Gulch and intersected the lode about 400 feet from the portal and 120 feet below the earlier workings. Two ore bodies were exposed on the Lantass level, and, as drifting continued along the lode, raises were made to the upper levels and the richest ore stopped out. The best of the ore was sorted, sacked, packed on mules to Rocky Bar and from there to Kelton, Utah, by wagon for shipment to eastern smelters. A mill was refitted, but the recovery was not satisfactory. The lease expired in 1876 and because the lessees had found the mine so profitable the owners refused to renew the lease and resumed operation themselves.

As most, if not all, the ore had apparently been mined above the Lantass level the owners were forced to sink a shaft, which by 1882 had reached a depth of 250 feet. During the next year, the shaft was sunk to 400 feet and three levels 100 feet apart were opened and connected by raises. A 20-stamp mill was also completed during the summer months. Within the next two years the shaft was sunk to a depth of 600 feet and another level run on the 500. Considerable ore was mined and milled, but the recovery was low. The grade of the ore became lower with depth so that mining became unprofitable and the company, the Atlanta Mining Company, suspended work.

The Monarch mine then remained idle until 1902 when work was resumed by the Atlanta Mines Company. In the meantime, the workings had become inaccessible and the old tunnels and drifts had to be reopened. A 1000-foot tunnel was driven to the Buffalo and Monarch, part of it for 200 feet alongside the footwall (North) ore body at about the No. 1 level. The No. 2 level was entirely reopened, the No. 3 for 900 feet, but the No. 3 and No. 4 remained untouched. Most of the reopening was completed by 1906. An aerial tram 1-3/4 miles long from the mine to the mill was completed at that time, together with a 150-ton amalgamation, concentration, and cyanidation plant at the site of the old mill on the Boise River. Electric power was installed at both the mill and mine from the company's plant on the river about 2 miles below Atlanta. Mill tests were not satisfactory and roasting of the concentrates was found necessary. The main production was yielded between May and the end of the year 1910. The bullion had a high percentage of silver. However, due to the added cost of roasting the concentrates and the poor recovery of gold from the lower-grade ores, the mine suspended operation at the close of the year and was practically idle throughout 1911. Although some of the old dumps were worked by the Atlanta Leasing Company from 1916 to 1917, it remained idle until 1930 when the St. Joseph Lead Company extended its No. 6 level to the Monarch shaft.

The St. Joseph Lead Company did not, however, exercise an option to buy the mine, but instead secured a 10 per cent royalty lease and in 1934 began extensive development on the Pettit ore shoot, which in the upper levels had crossed into the Monarch ground. The 1,460 intermediate and the 250 were extended westward from the Boise-Rochester and were joined by raises from the No. 6 level. Crosscuts had previously been driven from the No. 6 level every 100 feet to explore the lode between the Boise-Rochester ground and the Monarch shaft, and this practice was continued in 1934 in extending the No. 6 to the Buffalo shaft. The work carried over into early 1936. No good ore was opened in the Monarch shoot.

After the St. Joseph Lead Company suspended operations in 1936, the Atlanta Mines Company leased certain blocks of ground and work continued through the remainder of the year. Late in the year the company erected a 50-ton amalgamation-flotation concentrator at the old Monarch mill, but was unable to secure sufficient ore for continuous operation during the winter and the richest of the high-grade was hand-sorted and trucked to the railroad. Small amounts of ore were mined through 1937 and 1938, but much of the ore milled during that time came from old dumps.

54.
The plan of the workings on the Monarch ground is shown in Figure 4, and the longitudinal section in Figure 3. The mine appears to have been developed in an orderly way by the six levels from the shaft, including the Lantus as the No. 1 level, and by the Atkins and older shallow levels near the collar of the shaft. The No. 6 level of the St. Joseph Lead Company was driven at about the same level as the No. 4 on the Monarch shaft.

In addition to the Monarch mine, the Atlanta Mines Company also owns the Buffalo, Silver Tide, and Last Chance mines, each of which is treated separately here. The company controls six patented lode claims, five patented mill sites and three patented placer claims. The surface along the Atlanta lode as far as 300 feet east of the Monarch end line was rich enough to pay for placer working.

Production

The total production of the Monarch mine could not be assembled, but is known to exceed $2,000,000. According to company records, the ore mined between 1865 and 1874 was worth $200,000; that mined by lessees between 1874 and 1877, $525,000; between 1879 and 1882, $225,000; and between 1882 and 1886, $250,000. This gives a total of $1,200,000 for the early-day production to which must be added the production from 1906 to 1910, from 1915 to 1917, and from 1934 to 1936. The figures for the company's production during the 1906 to 1910 work were not learned, but probably did not exceed $100,000. Likewise, no figures were obtained in the amount of bullion produced from the dumps by the Atlanta Leasing Company from 1915 to 1917. However, most of the work was probably on the Buffalo dump and need not be counted. The value of the ore produced from the Pettit shoot on Monarch ground in 1934 was $249,623.40 and in 1935, $469,658.20, or a total of $719,281.60. To this should be added the value of some 20,000 tons of dump material, which yielded about 0.142 oz. of gold and 0.053 oz. of silver per ton during 1935, as well as a small amount of stope ore, and that mined after the work had been suspended by the St. Joseph Lead Company and had been continued by lessees. The total, including that produced during 1936, should exceed $2,000,000 by a small margin.

Geologic features

The Monarch mine covers the mid-part of the Atlanta lode and explores two main ore shoots, the principal one the Monarch, the other an extension of the Pettit. The two are separated by a very narrow zone of relatively barren ground. The second ore body was largely unknown until the work of the St. Joseph Lead Company showed that commercial ore extended from the Pettit across into Monarch ground. The Lantus tunnel had been driven northeastward in the wall of the lode to the property end line many years before and had prospected the ore body by crosscuts, but apparently the ore then was not sufficiently rich for early-day extraction and had been left unmined.

The structural features of the lode have been adequately discussed elsewhere. The general relations on the Monarch do not differ materially from those on other parts of the lode. The lode is from 40 to 100 feet wide and shows the usual complicated shearing prior to and during mineralization. It differs in the character of the mineralization by the relative abundance of silver minerals. In the northeast part of the mine the lode dips as steeply northwest as on the Boise-Rochester ground, but at some point between the Pettit and Monarch ore bodies the dip changes to steeply southeast, apparently without having had any material effect on the structure and size of the ore bodies. Both ore bodies show a control by variations in trend and in each case occur where the strike is about N. 70° E. The lode has numerous "branches" which diverge to the east and west. Some of these have been productive for short distances from the lode, some of them have high-grade seams as rich and as productive as those within the lode itself. One of these was being mined from the dump raise in 1936.
The footwall body has been offset about 10 feet, the hanging wall body about 20 feet, just east of the 2,050 crosscut on the No. 6 level. This fault is marked by 1 to 2 inches of gouge and it strikes about N. 30° W. and dips 35° N.E. The movement has carried the hanging wall side of the fault to the northwest with respect to the footwall. This fault is also present at the face of the 250 level, but its displacement was not learned.

A lamprophyre dike also lies along the Monarch ore body and extends across the No. 6 tunnel between the Monarch shaft and the dump raise. There the dike strikes N. 80° E.

Ore shoots

Monarch

The Monarch ore body, as pointed out on page 39, has a stope length of 850 feet and a maximum height of 550 feet. However, the most productive part extended only to a depth of 300 feet below the surface. Very little ore was mined below the No. 4 level and between the No. 1 and No. 2, and the amount between the No. 4 and No. 2 was not as large as that above the No. 1.

Although there were numerous veins and spurs of rich ore that penetrate the lode in various directions, in the upper part of the body the commercial ore was found mainly in two zones, one near the hanging wall, the other near the foot wall. The two ore zones ranged from one to six feet and more thick and the gash veins from mere veinlets to one or two feet thick. The two ore zones were connected by crosscuts and all the richest parts of the lode were stope out prior to the eighties. Bodies of low-grade were left as well as numerous small veins of rich ore. When the upper workings were reopened during the period of activity from 1902 to 1910, the new drift along the ore zone on the north side of the lode on the No. 1 level showed the ore to average 7-1/2 feet wide and to be worth about $7.25 a ton. On the No. 2 level, the ore body was reported to be from 10 to 30 feet wide, and in one of the crosscuts averaged $20.80 in gold and $1.40 in silver for the entire width of 30 feet. (Price based on 20c.67 gold.) Some rich zones one to five feet wide were exposed in several places at greater depth, but in the lowest level the ore appeared to be low-grade, although some rich veins were present.

The ore in the Monarch body was noted for the abundance of silver in the upper workings, particularly pyrargyrite, proustite, stephanite, and polybasite, as well as subordinate amounts of argentite and native silver. Although the value of gold was greater than that of silver, the silver minerals made up most of the bonanza veins. The amount of low-grade silver and other primary silver minerals declined greatly with increasing depth. Some small amounts persisted to the lowest level. The ratio of gold to silver thus became greater with depth.

Some of the earliest ore mined was exceptionally rich and netted as much as $800 a ton even after the costly haul to Kelton, Utah, and shipment to New Jersey and to Omaha smelters. As the grade of ore decreased with depth and shipping cost became prohibitive, the ore was milled.

The first ore treated is reported to have assayed from $25 to $100 per ton, but, because treatment by amalgamation was not successful, the average recovery was but $25 to $30 to the ton. When the value of the ore dropped below $20 per ton in the eighties, operations had to cease. When the mine was reopened in 1902, the mill heads averaged but $8 a ton in gold and silver, and apparently could not bear the cost of mining and treatment. The average value of the ore on the two lower levels, according to assay records, is close to $7.50 per ton in gold and
silver (price based on $20.67 gold). Only 53 tons of ore from this shoot were mined by the St. Joseph Lead Company, and this ore came 60 feet above the Lantos level at the east end of the ore shoot.

Pettit

The Pettit ore shoot was confined to the footwall of the lode and was commercial only above the 1,450 intermediate level, although in one place some ore did extend a short distance below it (fig. 3). The ore body on the hanging wall ended at about the property line. Although the hanging wall zone was exposed in each of the crosscuts from the 1,650 to the 1,950 on the No. 6 (St. Joe) level, and in crosscuts on some of the upper levels, ore in adequate quantity for mining was not found (fig. 4). The hanging wall zone continued to swing farther and farther from the footwall and where last exposed, between the 1,950 and 2,050 crosscuts on the No. 6 tunnel, it had a strike N. 80° W. At that point, as mentioned on page 37, the hanging wall shearing appeared separated from the shearing along the main lode and had become a lateral lode about 40 feet wide, containing considerable quartz on both the hanging and foot walls. Some work was done by lessees on the hanging wall body in the 1,650 crosscut in 1936, but the ore pinched a short distance above the level and the work was abandoned.

The footwall body on the Monarch ground extended about 400 feet from the Boise-Rochester end line and had an average height of 350 feet. Next to the property line the body was mined to a height of 500 feet above the 1,450 intermediate level, or within 50 feet of the surface. The thickness of the body ranged from 5 to 20 feet (fig. 5, cross section A-A', B-B', and C-C'). In 1934, it produced 18,669 tons of ore; in 1935, 46,832 tons. The amount of ore mined in 1936 was not learned, but was much less than that mined in 1934. The ore produced during 1934 and 1935 is reported to have yielded $718,927.60. It is of interest to note that the lode was barren on the 1,450 level for the first 120 feet west of the property line, although it was present 40 feet higher; beyond the barren zone the ore appeared along the drift for 220 feet. It extended only a short distance below the 1,450 over a distance of 150 feet.

After the St. Joseph Lead Company suspended operations, part of the ground on and above the 250 level was leased, but the results of this work are not known. Small veins of high-grade were reported to have been mined.

The ore on the Monarch part of the Pettit shoot contained somewhat more silver than on the Boise-Rochester, but otherwise there was little difference. Small scattered bonanza pockets and seams were found here and there, mostly above the 250 level.

Dump Raise ore body

The Dump Raise ore body was cut on the No. 6 level a short distance southwest of the Monarch shaft and again penetrated by the dump raise about 180 feet from the surface. The ore is confined to a lateral vein which strikes N. 85° W. and dips 80° SW. On the No. 6 level the vein contains as much as 14 inches of quartz, but apparently does not contain sufficient gold and silver to justify mining. Some distance up the dump raise, however, the vein contains considerable high-grade and during the latter part of 1936 was being mined under lease. The vein was 2 to 12 inches thick and contained streaks and crystals of ruby silver, polybasite, stephanite, gold, chalcopyrite, and other minerals. The sorted ore was rich enough to ship without milling. The vein appeared to be increasing in thickness toward the Atlanta lode and is, therefore, like other veins which extend obliquely into the hanging and foot walls of the main lode.
The Buffalo mine marks the site of the first discovery of the precious metals on the Atlanta lode, and is, therefore, the oldest mine in the district. It lies along the upper part of Quartz Gulch on the southwest side of the Monarch (fig. 2). The Buffalo claim is only 480 feet long and 100 feet wide, yet it contained one of the richest deposits of ore on the Atlanta lode. It won world-wide fame for the richness of its ores, particularly in the abundance of silver minerals, and did more perhaps to attract outside attention to the Atlanta district in the early days than any other mine.

Its early history has not been adequately recorded. Discovered in 1864, it is reported to have produced 6,406 ounces of silver the following year. The first work was a crosscut and level 230 feet long near the surface. Later an adit 425 feet long was driven which intersected the lode only 70 feet below the upper level. The extraordinarily rich ore was packed by mule to Kelton, Utah, 230 miles away, and shipped from there to Omaha for treatment. Later, when roads were built into the country, the ore was taken from Rocky Ear to Kelton by bull teams.

In 1875, the mine was acquired by the Buffalo and Idaho Gold and Silver Mining Company. Work began on the Buffalo shaft. By the end of 1877, it had been sunk to a depth of 200 feet below the adit level. For some time the company shipped the ore to Omaha, but as the deeper ore was not so abundant nor so rich as that in the upper workings, a 10-stamp mill was installed on the Boise River below the Monarch mill. It is reported that 151 tons shipped to Omaha netted bullion worth $114,654, whereas, in 1881, 1,701 tons of ore treated in the Buffalo mill yielded 102,376 ounces of bullion, containing $66,101.36 in gold and $113,468.30 in silver. The mine was active until the middle eighties, producing bullion and extending the development each year. By 1885, the mine had been developed by shaft to a depth of 600 feet and had 6 levels. The next year the shaft had reached a depth of 625 feet and later was sunk to 670 feet to the No. 7 level. Data on subsequent history are meager. Apparently the tenor and quantity of the ore decreased so markedly on the lower levels that mining became unprofitable and the mine was closed.

The Buffalo mine was later acquired by the Atlanta Mines Company. Like the Monarch, it remained idle from the late eighties until 1902 when work at rehabilitation was started on both properties. A 900-foot crosscut was driven to tap the Buffalo shaft on the third level and a drift continued to the Monarch. No other work was done on the Buffalo until 1915. Then the Buffalo dump, as well as several others, was treated by the Atlanta Leasing Company. In 1934 and 1935, the St. Joseph Lead Company drove its No. 6 tunnel to and beyond the Buffalo shaft and mined 256 tons of ore from a point a short distance to the west of the shaft. The levels on the Buffalo are from 200 to 500 feet long, spaced at intervals of about 100 feet (figs. 3 and 4). From them numerous crosscuts have been driven across the lode to expose all bodies of ore. The No. 6 level of the St. Joseph Lead Company crosses the claim just above the No. 4 level of the old Buffalo workings (fig. 3).

Production

The total production of the Buffalo mine is not accurately known, but it appears to have been not less than $1,200,000. The production prior to 1874 is given as about $200,000; that from 1874 to the middle eighties as $700,000 from the mill, and $120,000 from shipments to Omaha. To this should be added the value of the bullion produced from the dumps in 1915 to 1917 and the value of the ore mined by the St. Joseph Lead Company in 1934. The production above the 100-foot level of the mine is reported to have been about $1,000,000.
The Atlanta lode is from 40 to 60 feet wide where it crosses the Buffalo claim and dips steeply southeast. Its ore body appears to have been localized by a slight variation in the general trend of the lode. Its direction is about N. 60° E., slightly oblique to the trend of the lode as a whole. Although the ore body was one of the smallest on the Atlanta lode, its size was more than compensated for by the richness of its ores, especially on the upper 100 feet. The shoot has a maximum stope length of 250 feet and has been exposed to a depth of about 870 feet. Most of the rich ore was bottomed above the No. 3 level and that below was in small, more or less lenticular masses, which contained small amounts of high-grade ore.

The main ore body is reported to have lain along the hanging wall and to have averaged 2-1/2 feet thick. A smaller ore body occupied the footwall zone. In between these two bodies there were scattered seams and streaks, some of which were individually very rich and as much as 12 inches thick. The ore above the No. 1 level was mined for a length of 230 feet, on the No. 2 level for 260 feet. However, with increasing depth the length and richness of the ore zones decreased greatly and became scattered through increasingly greater amounts of low-grade.

Silver minerals were exceptionally abundant in the ore on the upper levels so that the silver comprised two-thirds of the gross value of the production. In 161 tons of ore shipped to the Omaha smelter, there were 16,871.58 ounces of silver to 88,30 ounces of gold, a ratio of nearly 200 to 1. Stephanite, pyrrargyrite, proustite, and probably polybasite were notably abundant, but there were only minor amounts of argentite and native silver. The amount of stephanite and ruby silver decreased greatly with depth, although minor amounts appeared in high-grade veins even in the lowest workings. With depth the ratio of gold to silver increased mainly because silver declined, not because gold increased. It is reported that the smaller veins, which carried more ruby silver and stephanite than the larger, were less reliable than the larger because the silver minerals were not as uniformly distributed as through the larger bodies.

It is difficult to estimate the tenor of the ore mined. Some of the bonanza pockets near the surface are reported to have contained ore assaying $6,000 to the ton. That treated in the mill assayed from $100 to $800 to the ton. Some of the shipments of the crude ore to the New Jersey and Omaha smelters yielded as much as $2,000 to the ton. When the grade of ore dropped below $20 to $25 to the ton, operations had to cease. Much of the low-grade is reported to have assayed between $4 and $20 per ton.

Idaho (Atlanta) Gold mine

History and development

The Idaho Gold mine is included in the strip of the Atlanta lode between the west end line of the Monarch group and the Yuba River. It lies just below the west crest of Atlanta Hill near the head of a prominent gulch, which leads to the river, a short distance below the mouth of Grouse Creek.

Although details of its early-day activities are very meager, the mine was known and worked in the early days. The earliest workings included cuts and shallow tunnels on the outcrop near and along the top of Atlanta Hill. There are other openings lower in the gulch and near the river. The largest operator was the Buffalo and Atlanta Company, which by 1880 had driven a 1400-foot crosscut from Grouse Creek to intersect the lode on the North Star ground, supposedly at a depth of about 1,000 feet below the deepest workings on the Buffalo and Monarch ground, but the workings were not carried southeastward along the lode. This long cross-
cut was known as the Yuba. Several years later, a 20-stamp mill was erected near its portal and considerable ore from the shallow workings in and near the outcrop of the lode was treated. Deep development was apparently discontinued in the early eighties and there is no record of further activity until about 1895 when the Idaho Gold Mines began extensive development of a rich ore shoot known in the upper part of the gulch. Four tunnels were driven in the ore and by 1899 all the ore had been stopped above the lowest tunnel, about 400 feet under the highest outcrop. Operations were then suspended. The mine appears to have been idle until 1909 when some of the tunnels were retimbered. No active mining was carried on until 1917. At that time, the property was acquired by the St. Joseph Lead Company. It was idle until late 1935 and early 1936 when the St. Joseph Lead Company extended its No. 6 level to undercut the old workings above in the hope of finding a continuation of the ore shoot. No good ore was found and the work was abandoned.

The position of the four tunnels and the No. 6 St. Joe West Drift is shown in the longitudinal section of the Atlanta lode (fig. 3), and the plan of the No. 6 in Figure 4. The first tunnel at the very head of the gulch passed through the ore shoot in a comparatively short distance. The second, known as the Carruthers, cuts the lode at a depth of about 200 feet beneath the No. 1, and the third, known as the Craig, 90 feet below the No. 2. The fourth, known as the Drawer, was driven about 120 feet below the No. 3. The No. 6 level of the St. Joseph Lead Company is about 187 feet below the No. 4. All known ore has been stopped above the No. 4, but there has been no stoping below it.

The mine is reported to have had a considerable production, but the amount was not learned. The work in the far west end of the No. 6 level produced 17 tons of ore in 1936.

Geologic features

Although the lode maintains its general southwest trend across the property, it has been offset in several places by faults of northwest trend and its course has been otherwise modified by minor variations in strike and dip. One of the faults was uncovered in the 600 West Drift. It displaced the lode to the northwest about 40 feet. The most marked variation in its trend is along the main ore shoot where, as along the ore shoots in other parts of the lode, the strike is more east-west than that for the lode as a whole. Near the surface the lode dips about 75° S.E., but on the 600 level it has changed to 85° N.W.

The lode appears to be as much as 70 feet wide on the surface and from 40 to 50 feet on the 600 level, nearly 600 feet below. It reaches its maximum width at the crest of the hill and diminishes somewhat southwestward, even though it is still 40 to 50 feet wide where intersected by the Yuba tunnel. The ore shoot in it is about 600 feet long and was commercial to a depth of about 400 feet below the highest point on the outcrop. The No. 4 level marks the bottom of the commercial ore. At that depth, the ore was low-grade and still lower in the St. Joe 600 West Drift, 187 feet below.

Quartz is very conspicuous on the outcrop and shows the common three stages of deposition, including large amounts of the comb and drusy variety. The ore in the upper workings is reported to have been high-grade, rich in silver, mostly in bonanza-like bunches. Although the shearing is still fairly prominent on the No. 6 level, the quartz is not so conspicuous nor the mineralization so intense. Assays on lode material beneath the old stopes at this depth generally contained less than 0.15 ounce of gold in samples taken across an advancing 5-foot face, much of it less than 0.10 ounce.
It is reported that as the No. 6 drift advanced southwestward from the Monarch shaft, the shearing and mineralization became less well defined and that ore of commercial grade was found nowhere west of the Buffalo ground. The mine map (Fig. 4) shows that much of the drift is in the lode and that crosscuts through the lode were made at 500-foot intervals. Cuts and shallow tunnels spaced at 100-foot intervals also explore the lode southwestward from the Buffalo shaft. Each has exposed considerable quartz, but apparently little or no ore of commercial grade.

**Hill and Davis**

The Hill and Davis claim, which crosses the west rim of Atlanta Hill and extends a short distance down the slope toward the Yuba River, is one of the oldest claims in the district. However, it is only 600 feet long and 100 feet wide. It adjoins the claims of the Idaho Gold Mines (Atlanta No. 1 and No. 2 claims of the St. Joseph Lead Company), and has been prospected by a number of shallow cuts and tunnels of which only the cuts are accessible. It has also been prospected as much as 600 feet below the outcrop by a crosscut from the No. 6 West Drift of the St. Joseph Lead Company (Fig. 4). This deep crosscut was driven during 1935 and early 1936, but the date at which the surface and near surface work was done could not be learned. Much of it was probably done during the very early days of the camp.

The claim appears to cover either a branch or spur of the Atlanta lode some 300 feet west of the point at which the lode appears to fork. The lode does not have the characteristics of the usual gash vein nor of the general west-northwest group. It is nearly as wide on the surface as the main Atlanta lode and strikes about N. 65° E., an angle only slightly greater than that of the main lode. Its dip is about 80° S.E. on the surface, but in the crosscut 600 feet below its direction is reversed to steeply northeast. Although the lode is apparently as much as 60 feet across on the surface, the zone of shearing itself, 600 feet below, is little more than half as broad.

Much quartz is exposed along the outcrop, in part stained by limonite, in part by greenish scorodite. The drusy third-stage quartz appears to be rather abundant and some of it at or near the surface is reported to be fairly rich in gold and silver. The quartz exposed on the crosscut 600 feet below, on the other hand, shows only sparse sulphides, mostly arsenopyrite and pyrite. The lode at depth is composed mostly of altered granitic rock apparently far too low in gold to be regarded as ore.

**Last Chance mine**

**History and development**

The Last Chance mine adjoins the Monarch on the south and is on a lateral which branches from the Atlanta lode about 130 feet southwest of the Monarch shaft. Its workings are mainly in and along the gulch above the Monarch.

Although this mine was discovered and worked in the early days, and was known as one of the richest in the district, details of its earlier history are lacking. In 1881, it was owned by the Atlanta Hill Gold Mining Company, and had been worked by a tunnel about 580 feet long to a depth of 150 feet and opened further by a shaft near the lower west end of the property to a depth of 340 feet. The company purchased a 10-stamp, steam mill at the mouth of Quartz Creek and operated it from 1882 to 1884. By the end of 1884, most of the ore above the main level had been mined and some work had been done on two levels from the shaft below the main adit. This mine was later acquired by the Atlanta Mines Company and a crosscut driven.
No data could be obtained on the amount of ore mined or the mill production. The mine is reported to have produced small lots of very rich ore.

Geologic features

The lode strikes about S. 85° E. and dips, as indicated by the spacing of the levels on the mine map, steeply south. Its junction with the Atlanta lode was exposed in the Lantos tunnel, but at that point it apparently contained little ore and the main mineralized section of the lode was some distance to the east-south-east. Although the lode is comparatively narrow, generally no more than 3 feet wide, scattered pockets of very rich ore were found, particularly in the upper workings. These have apparently been found over a length of 500 to 600 feet.

The ore was clearly of the bonanza type. Ore milled in the early days is reported to have yielded $100 per ton, half of which was in free gold, 20 to 30 per cent in sulphide concentrates, and the balance in silver. There were also some specimens which were exceedingly rich in crystallized gold. It is reported that a piece of quartz weighing 5 pounds yielded 15 ounces of gold worth $24 per ounce, and another 7-1/4 pound sample, 46 ounces of gold valued at $666. These rich pockets are reported to have been confined to the upper workings and to have become less abundant and smaller with depth. In the drift from the Monarch crosscut the lode apparently contained insufficient ore to justify further development.

A 2-inch streak of quartz exposed in this lowest level is reported to have had an assay value of $133 per ton, a 10-inch layer of quartz, $14.00, and a 36-inch layer on the south side of the 10-inch, $8.50.

Silver Tide

The Silver Tide vein is one of the laterals from the Atlanta lode. It was discovered and prospected in the early days, but little underground work has been done on it. It branches from the Atlanta lode about 400 feet northeast of the Monarch shaft and trends west across the Silver Tide claims which are owned by the Atlanta Mines Company.

The vein is comparatively narrow, except in the vicinity of the Atlanta where the combined cropping of both is about 130 feet across. Although rich streaks and pockets have been found, its ore is reported to be low-grade. This lode was not positively identified on the St. Joe No. 5 level, but, like so many of the oblique laterals, it has probably diminished in size and tenor with depth.

Minerva mine

Location

The Minerva mine explores one of the principal lodes belonging to the west-northwest system, and lies a short distance south of the Atlanta lode on the upper southern slope of Atlanta Hill (fig. 2). The mill is on Grouse Creek. Both the mine and the mill are reached by the Yuba River-Grouse Creek road which ends at the mill about 4 miles above the junction of the Yuba with the Middle Fork of the Boise. The portal of the lowest tunnel is about 1,350 feet above the mill at an altitude of 6,700 feet. The two were formerly connected by a 2,000-foot tram which has been destroyed by snow-slides. The property covers much of the steep

1/ Ballard, S. W., op. cit., p. 10.
The Minerva is one of the oldest mines in the district, but it apparently attracted little attention until the early part of the present century. The first mention of its development is contained in Mineral Resources of the United States for 1908. It is recorded there that the Minerva Mining Company operated a 10-stamp mill during the year on ore taken out in development, and that a tunnel about 800 feet long had cut the lode 200 feet below the old workings. These old workings comprise several hundred feet of shallow tunnels and drifts, completely inaccessible, and numerous outs which had been made many years before, probably prior to the eighties. Mining was resumed shortly before 1906 for the mill, as well as the tram connecting the portal of the lowest crosscut with the mill, were completed and put in operation that year. In 1906, 650 feet of new workings increased the total to 2,600 feet, including drifts, crosscuts, and raises, but milling operations were somewhat curtailed while a cyanide plant was being installed to treat the tailings from the stamp mill. Development continued in 1907, but the mill was run only part of the time. Large shipments of bullion were not made until the last three months of 1908. During 1909, the mine was one of the largest producers in the district, and in 1910 led the county in bullion output. At that time, the mill was increased to 20 stamps and maintained capacity production until October, 1911, when all the ore above the main level had been stoped. The mine then suspended operations and remained idle until 1919 when the lower adit was reopened and a 50-foot winze sunk on ore below the tunnel level. No other work was done and the mine has been idle since then.

All entries to underground workings were blocked in 1936, and the writer was unable to obtain first-hand information on development and subsurface geology. Ballard, who had access to mine maps in 1928, states that the main adit crosscut extends in a northerly direction for about 800 feet before it cuts the Minerva lode and that about 2,200 feet of drifts had been driven on the lode, mainly to the east of the adit. The lode apparently had been stoped for a distance of 500 feet each way from the crosscut to the next level 160 feet above. Stopes also extended above the intermediate level, but it could not be determined whether they reached the old workings above it. The map showed no connection between the lower workings and the shallow ones made at an earlier date. From the 160 intermediate level a short crosscut had been driven south from the Minerva to another lode. This lode had been cut in the main crosscut, but, so far as could be learned, stoping ore was found only above the 150-foot intermediate level. Any future development would have to be carried on entirely below the present workings.

The mine has had a considerable production, particularly from 1906 to 1912, but the writer was unable to obtain any statistics either on this fairly recent work or on that of the earlier days. The mine has been noted for its free-milling gold ores, particularly in the oxidized zone, and also for the richness of the ore. In 1906, the ore is reported to have assayed about one ounce of gold per ton, more than 60 per cent of which was saved by amalgamation.

Geologic features

The Minerva lode is one of four west-northwest lodes which cross the property and the only one extensively developed. A short distance to the south another, the Alaska, has been partly developed and explored. The others have been prospected by surface cuts and shallow tunnels. These lodes are parallel and may be traced by croppings and the alignment of cuts for distances of 2,000 to 4,000 feet. They approach the Atlanta lode at a fairly acute angle. The Minerva and Alaska appear

Ballard, S. M., op. cit., p. 38.
to strike the Atlanta lode about 1,500 feet northwest of the Minerva mine, in or near the workings of the Idaho Gold mine. These lodes are controlled by major fractures and are not the ordinary gash variety locally dependent on the shearing along the Atlanta lode. The known ore bodies in them lie some distance away from the Atlanta shear zone.

The Minerva appears to strike about N. 65° W. and to dip about 45° N.E. Its thickness ranges from 2 to 30 feet, the average about 8 or 10 feet. In two places, it is reported to have been displaced from 100 to 150 feet by faults of northeasterly trend. The lode is by no means uniformly mineralized, but the commercial ore is reported to have been confined to a shoot about 600 feet long and in places 4 to 5 sets wide. The lode matrix is extensively shattered and the ground is as heavy and difficult to maintain as that along the Atlanta lode, because of repeated adjustments along the fracture zone during and after mineralization.

The ore is very similar to that of the Atlanta lode. It shows as many periods of broculation and mineral deposition, but, in part, it may have greater porosity and contain more drusy quartz. That in the outcrop is stained by greenish scorodite and brownish limonite oxides, and in places is made up largely of the third-stage drusy quartz that encrusts extensively brocinated fragments of the earlier lode matrix. The primary ore is reported to contain pyrite and free gold as well as considerable ruby silver in ore or less well-defined, bonanza-like pockets. It is also reported that there are large bodies of fair uniform grade, much of which assayed about $14 to the ton in gold and silver. The gold was exceptionally free. As much as 60 per cent of the gold was recovered by amalgamation and 25 per cent on the tables in a concentrate worth from $100 to $200 per ton. The ore is reported to persist and to maintain a good grade to the bottom of the mine. 

Tahoma mine

Location and development

The Tahoma mine is in the lower part of Quartz Gulch, just within the map-area (fig. 2). There are workings on both sides of the creek, but the principal development and production has been on the slope on the west side. Although this mine is one of the oldest in the district, the data on its history and development are very incomplete. By 1881, it was one of the most extensively developed mines on Atlanta Hill and had been opened by four tunnels. It was then opened by the Tahoma Company, but in 1883 it passed under control of the Boston Company. This company erected a 20-stamp mill and continued to run the mine and mill the ores for a considerable period of time. Excessively heavy ground caused mining difficulties making operation intermittent so that the mine was idle during most of the late eighties and nineties. Some work was done in 1906 and 1907 by the Tahoma Mining and Milling Company, and their 10-stamp mill on the Boise River was in operation part of the time. At that time, the mine was reported to have had large reserves of ore, but operations were apparently suspended shortly thereafter. The mine was idle until 1933 when it was acquired by the Coronado Gold Mines, Inc. Two tunnels at creek level were either driven or rehabilitated, one on the west side of the creek beneath the old stopes, the other on the east side of the creek (fig. 6). The property was idle in 1936.

No data are available on the extent of the older workings. In 1881, the four tunnels were reported to total 1,150 feet and to have had additional drifts and crosscuts. All workings above the tunnel opened in 1933 on the west side of the creek are completely caved and, so far as known, there is but one short tunnel above

Ballard, S. M., op. cit., p. 35.
May, Frank: Oral communication.

64.
Figure 8. Geologic sketch map of the accessible underground workings at the Tahoma mine.

Workings not shown in normal relation.
the recently opened one on the east side. The lower tunnels on both sides of the
creek were accessible and were mapped (fig. 6). That on the west side has about
1,150 feet of crosscuts and drifts, several raises, and a winze; that on the east
side 865 feet of workings.

Production data are not available. Prior to 1883, ore from the Tahoma was
treated in the Buffalo mill. It is reported that, in 1861, 300 tons of ore yielded
$100 to $150 per ton. No mention is made of the production prior to or since
1861.

Geologic features

Several lodes extend across the property, but only the Tahoma has been extens-
ively developed. Another, on the Baltimore claim from 100 to 200 feet to the south,
has been exposed in several caved tunnels on the west side of the creek and by the
main tunnel on the east side. One or two others north of the Tahoma were prospect-
ed by outs and tunnels in the early days.

The lodes appear to be parallel and, therefore, should strike about N. 50° W.
and dip steeply northeast, in accordance with the general strike and dip of the
Tahoma. The strike and dip of the Tahoma are not uniform, however. Although its
average trend is about N. 50° W., it varies somewhat from place to place. Its dip
is difficult to determine, but on the lower tunnel on the west side of the creek is
approximately 80° N.E.

The Tahoma lode is one of the largest of the west-northwest set, and has been
prospected for a distance of not less than 4,000 feet. All that could be learned
of its magnitude in the upper workings was that it had an average thickness of 35
feet. In the lower workings, its thickness appears to range from 10 to 40 feet,
but the volume of quartz and sulphides in the lode may be somewhat less with depth.
Where the lode is shown, about 270 feet from the portal of the crosscut on the west
side of the creek, it is only about 10 feet across (fig. 6), but it widens toward
the northwest. The drift is in the footwall for the next 140 feet and the full
size of the lode can not be determined until the drift passes diagonally through
into the hanging wall (fig. 6). From this point, the drift is mostly in the hang-
ing wall, in places in the lode itself. The thickness is only partly revealed in
crosscuts. In some places, however, the fracture zone appears to be as much as 40
feet across and locally may be even more.

Near the face of the tunnel on the east side of the creek the lode is composed
of not less than 35 feet of massive quartz and has additional thin quartz seams in
the fractured rock along the hanging wall (fig. 6). The lode appears equally as
large on the surface, 200 feet or more directly above. Numerous outs and caved
tunnels farther to the southeast afford evidence of the great length of the lode,
give no clue to its size.

The Tahoma lode has been more severely disturbed by structural adjustments
than most others, both during and after ore deposition. Consequently, the ground
is exceptionally heavy. It is reported that upper tunnels and stopes could not be
readily kept open, but were rapidly filled with the crushed, more or less plastic,
loose matrix, much of which would flow in from above and from the sides. It may be
that this lode was affected much more by the mid-Tertiary faulting than the others.
Eldridge reports a dike of white, decomposed porphyry in the upper workings; 2

1/Suchard, H. C., Production of gold and silver in the United States: Report of
the Director of the Mint upon the Statistics of Production of the Precious Metals
in the United States, 1861, pp. 176; 1862.
2/Eldridge, G. H., A geologic reconnaissance across Idaho: U.S. Geol. Survey Eight-
to 50 feet thick, which cuts the lode at an acute angle, its strike being N. 26° W., its dip 45° S.W. to the vertical. On some of the levels, the lode is reported to have been offset by the dike, but a second fault, 50 or 60 feet beyond and approximately parallel to the dike, had again brought the lode into alignment. This dike was not observed in the recent lower workings, but there is ample evidence of post-mineral movement which might well be related to Miocene disturbance. The lode zone is tremendously shattered and in places contains an abundance of gouge, especially along the footwall. Lateral offsets may be hidden by the heavy lagging under the roof and along the sides of the tunnel.

In the upper workings, the ore is reported to have formed lenticular bodies 2 to 12 feet thick. In the lower tunnel, the lode appears to contain scattered bunches of quartz and quartz veins, as much as 4 feet wide in one place where the drift is in the lode itself. In other places, as shown in Figure 6, the bunches of quartz and quartz seams are smaller, generally less than 2 to 3 feet wide. The ore on this level appears to be sporadic and confined largely to small shoots and pockets. The large mass in and near the face of the east tunnel appears to be an exception, but whether or not it contains ore of commercial grade was not learned. This quartz has not been as greatly shattered by post-mineral movement as has that elsewhere along the lode, and it contains less sulphides.

The ore shows the usual three stages of quartz, and, locally, considerable fourth stage, somewhat ferriferous calcite. The second-stage quartz is the fine-grained variety, high in arsenopyrite. The third-stage is the comb and drusy variety. Some of that on the dump at the mouth of the lower tunnel west of the creek contains small amounts of manganosite and pyrrhotite. It is reported that ruby silver was abundant in the upper workings. Although some of the ore treated in the Buffalo mill yielded from $150 to $160 per ton in gold and silver, the average tenor is reported to have been $60 to $100 per ton.

The parallel lode on the Baltimore claim is apparently much smaller and less extensively mineralized. Small amounts of ore remain at the portals of the caved tunnels on the west side of the creek. The drift along the lode on the east side of the creek is so tightly timbered that nothing could be learned, except that the zone of crushed, gougy rock is broad, the ground heavy, and the lode there has little or no quartz.

Big Lode mine

The Big Lode mine is in Quartz Gulch about midway between the Tehama and the Monarch. Although it was known as the Leonora in the early days, in 1882 it was acquired by the Big Lode Mining Company. This company installed a 20-stamp mill and concentrator, but nothing could be learned of its further activities. No mention is made of the property in any published reports until 1905 when it was reported that the Washburn Milling Company operated a 20-stamp mill on ores from the Big Lode. Again there is no mention of the property until 1919 when the mine was reopened. Milling tests during the next year produced a little gold and silver bullion. Since then mining operations have been suspended and the mine has remained idle. No record could be found of mine production.

The main tunnel is near the creek and its portal leads directly to the mill. From the size of the dump, the underground workings must have been fairly extensive. A projection of the level on a claim map of the district shows the crosscut to extend in a west-southwesterly direction for about 600 feet to the main lode and then to curve and follow the lode some distance to the northwest. There are other old dumps on the slope above and several caved tunnels along and under the creek just above the mill.
The alignment of old cuts and dumps suggests that several lodes cross the property, but apparently only one, the Leonora, has been mined. It, as well as the others, appears to strike about N. 65° W., and to dip steeply northeast. Whether or not the northeast dip is maintained with depth could not be learned. The lodes possess considerable length; the Leonora alone has been traced for more than 1,000 feet. It is reported to have an average thickness of 15 feet, but, to judge from surface exposures, the others can be not more than 8 feet thick and most of them must be considerably less.

The mineralization resembles that in other lodes on Atlanta Hill. The ore exposed in the outcrops shows the three main varieties of quartz in breccias. Druse quartz is abundant in some places as are limonitic oxides and scorodite. Sulphides were sufficiently abundant at depth to be a serious obstacle in the recovery of silver and gold by stamp amalgamation. The ore first mined was reported to be rich, but at a depth of 60 feet the lode is reported to have increased in size. The gold and silver were thus more widely dispersed and the tenor of the ore correspondingly diminished. Early-day assays showed the ore to run about $15 a ton in silver and about $8 in gold.

**Jessie Benton mine**

The Jessie Benton mine is in Quartz Gulch some distance up the slope on the east side of the creek. The mine is one of the oldest in the district and has been worked intermittently from the time of its discovery until 1910, although never on a very large scale. The only evidence of its former activity is the presence of several large dumps at the portals of caved tunnels some distance above the creek. During the early days, its ore was apparently treated in the Buffalo and other mills. Later the mine must have installed its own mill for Mineral Resources of the United States for 1905 mentions that the mill had been closed pending the installation of additional machinery. The mine is reported to have produced about $80,000 in gold and silver bullion from the shallow surface workings. Ownership of the property is now vested in the Bixby group.

The Jessie Benton lode is one of the longest in the district and has been exposed on both sides of Quartz Gulch. It crosses the creek below the Big Lode and extends east-southeasterly up the slope to the top of Atlanta Hill and apparently passes over into Montezuma Gulch not far from the Atlanta lode. Mining, however, has been confined to the section between the creek and the top of the hill, especially to the part about half way up the slope. Several adjacent parallel lodes do not appear to be as long nor as well mineralized as the Jessie Benton. Although the lodes are continuous for considerable distances, they pinch and swell, and in part are barren. In places, the lodes are as much as 10 feet thick, in other places no more than a few inches.

The ore which remains on the dumps of the Jessie Benton contains considerable finely crystalline arsenopyrite and pyrite. The outcrops are partly stained by greenish scorodite and brownish limonitic oxides. Some of the ore mined in the early days was high-grade for 100 tons of ore treated by the Buffalo mill in 1883 was worth $123.53 per ton.

**Atlanta Gold Mines Corporation**

The property of the Atlanta Gold Mines Corporation lies in lower Quartz Gulch about half a mile above the town of Atlanta. It consists of 6 unpatented claims and covers three or four lodes, all of which were known and worked in the early day:

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2/ Idem, 1883, p. 447, 1884.

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67.
Figure 7. Geologic sketch map of the underground workings at the Paymaster.
These lodes are the Washington, Gold Nugget, and Wonder, but only the Gold Nugget was being developed in 1886; the others have apparently been idle for many years. The Washington had been opened by several tunnels driven at least several hundred feet in the lode, but the workings are now inaccessible. The workings on the Wonder are likewise caved, but are reported to have included a drift 168 feet long. The workings on each lode are on the east side of Quartz Creek, in part nearly at creek level. The present work on the Gold Nugget includes a tunnel 200 feet long and two short crosscuts besides a number of pits, some of which were made many years ago. The owners of the Washington operated a 20-stamp mill during the early eighties.

The production from these lodes is not known. Some ore is reported to have been shipped from the Wonder, and considerable ore was handled by the Washington mill. It is reported that in 1884 the total yield from the Washington was about 6,400 ounces.

The lodes belong to the west-northwest system, and are spaced about a few hundred feet apart, the Washington on the north and the Wonder on the south. The Washington is reported to be from 2 to 22 feet thick, but the richer ore was in a layer 12 to 18 inches wide which assayed about $40 in gold. The Wonder is probably the largest and most conspicuous of the three lodes and may be traced by the alignment of old cuts for more than 1,600 feet on the east side of the creek. It is also known to extend on the west side of the creek, but beneath considerable overburden. The lode is reported to be from 2 to 12 feet thick in the tunnel and it appears equally thick in cuts and tunnels higher up the slope. The ore is a breccia of the fine-grained, dark gray quartz containing arsenopyrite in a matrix of comb and drussy quartz. The ore in the cropping is partly oxidized.

The relations of the Gold Nugget vein are somewhat obscure. There appear to be two fracture zones, one of which strikes N. 50° W., and dips 50° N.E., the other of which strikes N. 70° W. and dips vertically. That with the more northerly strike is considered to be the Gold Nugget, the other a cross fracture. The width of the Gold Nugget fracture zone ranges up to 12 feet and contains bunches and lenses of ore, in places from 1 to 2 feet thick. The other zone is from 4 to 5 feet wide and contains scattered thin veins of quartz. Two tunnels driven to intersect the Gold Nugget were apparently on the cross lode. In the upper tunnel the lode is cut off by a fault which strikes N. 40° E. and dips vertically. The continuation of the lode beyond this fault has not been found.

Paymaster

The Paymaster claims lie along a tributary of Quartz Creek, less than half a mile west of the Monarch, on one of the lodes of the west-northwest system. Some work was done on the lode in the early days, but the most extensive development, principally a tunnel with about 200 feet of workings including a short crosscut and longer drift (fig. 7), was made in recent years. This tunnel is in the bottom of the gulch and a short distance below an old 50-foot adit and a series of five cuts which extend west-northwest up the slope to the top of the ridge. An old tunnel below and on the opposite side of the gulch is caved.

The lode strikes about N. 80° - 85° W. and dips vertically or steeply south. It was traced in a west-northwest direction to the crest of the ridge about 500 feet from the bottom of the gulch, and may join the lode on the other side of the next gulch. This probable extension of the lode crosses the Yube divide and indicates an overall length of not less than 2,500 feet, so that it is one of the

1/Burchard, H. C., op. cit., 1884, p. 259, 1885.
2/Idem, p. 259.
The zone of fractured granitic rock is as much as 15 feet wide on the surface and in places is largely quartz, much of it of the drusy variety.

In the 50-foot adit the lode structure appears to be fairly simple, but in the main lower tunnel the structural relations appear to have been complicated by much post-mineral movement, considerable of it along fracture zones which cross the lode (fig. 7). The ground is exceedingly heavy and the walls and roof concealed by heavy, closely spaced timbers and lagging. The zone of shearing appears to be considerably wider than that above and is not entirely exposed by the crosscuts and drifts. Some slips of northeast trend are conspicuous and have brought unaltered granitic rock against the altered and have displaced segments of the lode laterally to the northeast (fig. 7). The apparent size of the zone of shearing may be due in part to the post-mineral faulting.

Bunches and small discontinuous lenses of shattered quartz as much as 10 inches thick are scattered through parts of the crushed and altered rock. Seams of black gouge containing crushed ore are also conspicuous. In addition to the drusy quartz, the ore contains some of the older fine-grained quartz containing arsenopyrite.

Greenback prospect

The Greenback prospect is on the north side and somewhat below the Silver Tide of the Monarch group in the upper part of Quartz Gulch. In 1936, some work was under way on the lower of two short, closely-spaced tunnels. The upper, about 50 feet long, follows the lode just under the outcrop. The other, about 70 feet long, is no more than 40 or 50 feet lower and is in part beside the lode and in part around an old cave.

The fracture zone is as much as 16 feet across and has the usual strike and dip of the west-northwest fracture system. It may be traced in an east-southeast direction for nearly 2,000 feet by the alignment of old cuts and dumps to within a few hundred feet of the Atlanta lode.

The lode comprises thin veins and small bunches of quartz scattered irregularly through the fractured granitic rock. Most of the quartz is the dark gray and drusy varieties, partly iron-stained. It is reported that small pockets of rich ore have been mined along different parts of the lode.

Fall group

The Fall group lies along Plouse Creek about a mile above its junction with the Yuba River on the opposite side of the valley from the Minerva mine. Active development was in progress on this group during 1936, and small amounts of ore were treated locally in a 3-ton mill. This mill was operated intermittently on ore mined during development. Mining had begun early in 1936. The development consisted of about 146 feet of crosscuts and drifts in one tunnel. Two other tunnels had been started, but the work had scarcely extended beyond the portals.

The lode had not been exposed adequately to show its exact trend and size. The main zone of shearing appears to be as much as 25 feet wide and to be made up of fractures of west-northwest trend which are aligned in such a way as to produce a zone extending N. 60° E. and dipping about 60° S.E. Most of the individual fractures strike about N. 70° W. and contain narrow quartz veins, stringers, and nests. Some of the veins are as much as 8 inches thick, but they characteristically pinch and swell on both strike and dip. By sorting, these veins yield high-grade quartz which supplies the mill. Although the tunnel is only slightly below
first-stage, white quartz, which has, however, here and there been somewhat broc- 
ciated and in places cemented by small amounts of the second-stage quartz. In 
placers, this younger quartz is white, chalcedonic; in other places it is grayish, 
similar to that in the main part of the lode. Third-stage, drusy quartz was ob-
served only as float. Much of the lode material is hard and massive, but in some 
places it has been sheared by post-mineral movement and made fairly friable. For 
the most part, the outcrop is somewhat iron-stained, conspicuously so in places, 
but it was not found to contain scorodite.