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THE QUARTZ MONZONITE BATHOLITHIC INTRUSION OF TWIN LAKES AND CLEAR CREEK DISTRICTS, LAKE AND CHAFFEE COUNTIES, COLORADO

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ILLUSTRATIONS.

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Introduction

In 1924 R. D. Crawford[2] described the batholith of monzonitic rocks in central Colorado and suggested that it probably furnished the ultimate source of the metals in many of the mining camps found around its borders. Such camps include Leadville, Aspen, Alma, Montezuma, Redcliff and Monarch. Since that time, nothing has been discovered which does not tend to confirm this idea so that now it seems to be accepted by geologists familiar with this region.

The following notes with respect to this monzonite batholith have been collected during extensive field excursions and examination of prospects during the last four years, principally in the Twin Lakes and Clear Creek districts. They are fragmental in character and are presented in hopes that they may be of some help toward further study of this batholith and the ores found in connection with it.

Description and Age of Rock.

The normal rock is of a uniform light bluish-gray color. It consists essentially of quartz, orthoclase, and plagioclase. Hexagonal-shaped crystals of biotite are almost always present in small amounts, accasionally representing as much as 10 per cent of the rock. In places common green hornblende is present in amount equal to the biotite; in other places it is very scarce or altogether wanting. Quartz seems always to be present in amounts usually of about 20 per cent, but the quantity varies greatly according to locality, sometimes constituting nearly half of the rock. It has a tendency to occur as characteristic, somewhat rounded grains. The plagioclase usually slightly exceeds the orthoclase and is near andesine in composition. The orthoclase has a tendency to form large individual crystals, so that often the rock has a porphyritic texture. These phenochrysts have been found as large as seven[2a] inches in maximum dimension and often enclose poikilitically subhedrons

[2]Crawford, R. D., A contribution to the igneous geology of central Colorado: Am. Jour. of Science, vol. 7, pp. 365-388, 1924.

[2a]J. T. Stark and F. F. Barnes, this volume and number, say nine inches. C. W. H

of andesine. The accessory minerals are titanite, apatite and magnetite. Zircon and allanite are also found occasionally.

Crawford gives the following criteria for the recognition of this monzonite: the absence of metamorphism, the hexagonal-shaped biotite crystals, the presence of titanite as an accessory mineral, the striated feldspars, the subhedrons of plagioclase poikilitically enclosed by orthoclase, and the absence of microcline, which is a common constituent of the pre-Cambrian granites with which the monzonite might be confused. To this list may be added the tendencies of the quartz grains to be round and the large euhedral crystals of orthoclase which occur in many varieties of the rock.

Relationships.

Muilenburg[3] has brought together analyses of several varieties of Tertiary igneous rocks from Monarch, Breckenridge, Leadville, Elk Mountains, Tarryall, and Ten Mile districts, and has shown convincingly that they all belong to one petrographic province; from this it is thought that the whole area embraced by these districts is underlain by the monzonite batholith. The relative ages of the various acid porphyries is often indeterminable or confused. In the Leadville district the so-called White porphyry is the older and the Gray porphyry is later, but both are premineral and were intruded before the reverse faulting and folding, which also preceded mineralization. In the Twin Lakes and Clear Creek districts (near the town of Granite, on the Arkansas River) several varieties of porphyry are found in the form of dikes. Some of these cannot be definitely correlated on appearance alone with the described varieties in the districts which have been studied. One of the most common varieties, however, much resembles the Leadville White porphyry in appearance and manner of "block" weathering. This rock is found cutting the pre-Cambrian rocks of the district as well as the main quartz monzonite batholith. Its age in reference to miner-

[3]Muilenburg, Garrett A., Geology of Tarryall district, Colo.: Colorado Geol. Survey Bull. 31, 1925.

alization has been particularly confusing because in places the mineral veins cut through the porphyry and in others apparently the porphyry cuts the veins. Either two ages of mineralization or two ages of porphyry are indicated and field observations do very little towards solving the problem. However, Behre[4] discovered the presence of dikes of rhyolite porphyry that are later than the White porphyry and much resembling it on Ball Mountain in the Leadville district. This later porphyry filled small faults which clearly offset older sheets of its predecessor. This suggests the probability that the dikes of porphyry which cut the main quartz monzonite batholith in the Clear Creek-Twin Lakes districts may be of later age than the rock generally referred to as White porphyry in pertinent literature.

Crawford[5] described a diorite in the Tomichi district which was clearly earlier than the main monzonite magma, but probably closely related to it. A similar diorite is found in the Twin Lakes district[6] and probably bears the same relation, though little confirmatory evidence was found there. In fact, two different diorites are found in the southeastern part of the district; both of these Howell suggests may be related to the diorites of the Elk Mountains, which in turn are believed to be relatives of the quartz monzonite of the main batholith. The writer, however, regards Howell's "quartz hornblende diorite" as more probably of pre-Cambrian age,—an impression borne out not only by its altered appearance, but also by its lithologic and micropetrographic resemblance to the typical pre-Cambrian granite of the region. Its field relations are poorly shown by outcrops, but Howell found it cutting pre-Cambrian "Mt. Champion quartz monzonite," which means merely that it is later than that formation. Diorites belonging to the pre-

[4]Behre, C. H., Jr., Revision of structure and stratigraphy in Mosquito Range and Leadville district, Colo.: Colorado Scientific Soc., Proc., vol. 12, p. 42, 1929.

[5]Crawford, R. D., Geology and ore deposits of the Monarch and Tomichi districts, Colorado: Colorado Geol. Survey Bull. 4, p. 130, 1913.

[6]Howell, J. V., Twin Lakes district of Colorado: Colorado Geol. Survey Bull. 17, pp. 33, 51-53, 1918.

Cambrian complex are known in other parts of Colorado, and indeed a rock of very similar microscopic appearance and apparently definitely a part of this formation occurs in the lower valley of Clear Creek. Dr. G. M. Schwartz[7] studied thin sections from my specimens of this quartz hornblende diorite and as a result of this study is inclined to subscribe to the same interpretation. In any case, the other diorite, which consists largely of feldspars with a small amount of hornblende and biotite, would be closely related to the Tertiary quartz monzonite.

The finding of older diorite bodies of comparatively small extent in the region of this quartz monzonite batholith is in accordance with the generally suggested theory that the normal batholith is basic at the start and gradually becomes more acid by the sinking of the heavier ferromagnesian minerals. It should be recalled, however, that there has been some opposition to the general acceptance of this idea.

There also appears to be a granite phase of this batholith. The main mass of the rock near Montezuma is apparently granitic in type. Near Winfield in the Clear Creek area rather large dikes of fine-grained granitic rock cut the main batholith. Dr. Schwartz studied thin sections of specimens of these dikes and classified the rock as quartz monzonite, evidently the same as the wall rock, but finer grained.[8] The principal minerals are orthoclase, oligoclase, quartz and biotite, with magnetite and apatite as accessories. I studied the rock in powdered form microscopically and think the orthoclase exceeds the oligoclase sufficiently to suggest a granite; further, as the dikes cut the normal rock, this facies is evidently later. Farther up the south fork of Clear Creek is what appears to be a typical granite which may be related to these dikes. Its relations have not been studied, but it resembles the monzonite more closely than it resembles the pre-Cambrian granite.

[7]University of Minnesota. Oral communication.

[8]Oral communication.

Based on the correlation of the various outcrops of this rock on petrographic grounds, Crawford gives the age of this batholith as probably Tertiary. T. S. Lovering,[9] on the strength of his recent work in the Front Range, places it more definitely as earlier than late Eocene. In the area I covered, no evidence of its age was discovered excepting that on top of the pass between Tin Cup and Pitkin it is seen cutting and altering Garfield sediments of Upper Carboniferous age.

The following notes, however, may be of interest in determining the relative age of the quartz monzonite batholith and the lavas which overlie part of the area in the Twin Lakes and Clear Creek districts. At the Detroit mine near the foot of McNasser Gulch a vein was found cutting the pre-Cambrian rocks: this vein is truncated cleanly by a flow of Grizzly Peaks rhyolite, so is evidently older. In this area, the contact between the pre-Cambrian complex and the rhyolite flow is nearly flat, but where well exposed in an adit driven in part along the strike of the vein is seen to be very irregular. The vein is oxidized for perhaps sixty-five feet below the rhyolite capping and consists largely of quartz and limonite containing free gold—often high grade—in an extremely spotty distribution. Below the oxidized zone the vein is pyrite and much more uniform but low in grade. Oxidation is generally absent in this heavily glaciated area, but here the covering of rhyolite protected the part of the vein, oxidized before the flow occurred, from later erosion.

From evidence here and in central Colorado generally, the mineralization probably came later than the consolidation of the quartz monzonite magma and was associated with it. After the ore deposition, sufficient time for erosion and oxidation to the extent noted above must have elapsed before the deposit was covered by the lavas. The rhyolite itself contains considerable pyrite which is unaltered, and

[9]Oral communication.

hence it seems improbable that much oxidation took place after the vein was buried by the lava flow. Nothing definite is known concerning the age of the rhyolite, but it may probably be correlated with some one of the periods of vulcanism in the San Juan district, hence, of late Tertiary age. Other instances of similar conditions have been noted in both the Twin Lakes and Clear Creek districts.

In direct contradiction to the above evidence is the appearance of the various rocks in Clear Creek valley near Winfield. Here the valley sides are steep and outcrops very prominent, largely as cliffs. The section consists of quartz monzonite, pre-Cambrian granite and schist overlain by Red Mountain rhyolite. Looking at the cliffs from a distance, the formations above the quartz monzonite are iron stained and have the appearance of having been saturated by mineralizing emanations from the lower magma, which appears comparatively fresh. Both the pre-Cambrian and the overlying lava seem to have been mineralized about equally and the whole appearance suggests that the lava was earlier than the consolidation of the mineralizing magma. This impression seems confirmed by the distribution of molybdenite, a prominent mineral of this mineralization. It is found in veins in the quartz monzonite, and both in veins and disseminated mineralization in the pre-Cambrian formation; it is also disseminated through the rhyolite in places.

There seems little doubt that the overlying rhyolite belongs to the Red Mountain formation of Howell in the Twin Lakes district. It lies on top of the Grizzly Peaks rhyolite and so is younger, and both rhyolites from field evidence seem younger than the vein at the Detroit mine, which is thought to have derived its mineral from the quartz monzonite magma.

Spurr[10] visited the Mount Champion district near the head of Half Moon Creek in 1914 and concluded that the mineralization was of pre-Cambrian age—a fact not borne

[10]Spurr, Josiah Edward, The Ore Magmas: p. 193, 1923.

out by the type of its mineralization, the presence of manganosiderite, and the lack of deformation of ore bodies. If the mineralization at the Detroit mine can be considered pre-Cambrian also, all discrepancies disappear, but I feel very doubtful on this point. More field observations are necessary to clear up this problem.

Distribution.

The accompanying map (Fig. 1) gives a general picture for the area of the known outcrops of the quartz monzonite and the related diorite bodies. The source used in compiling the map is largely U. S. Government and Colorado state publications. The area shown as Tertiary diorite on the State geological map has been copied on this map. In the summer of 1929, Dr. G. M. Schwartz collected specimens of the granodiorite of Mt. Sopris and Mt. Snowmass and correlated it with the Mt. Princeton quartz monzonite on petrographic grounds.[11] The area in the Clear Creek valley and at the head of Taylor Park is the only part that represents my work.

I have examined morainal material from all the valleys on the east side of the Sawatch Range from Pine Creek north to Tennessee Pass and also from the valleys of Mitchell Creek and Homestake Creek to the north of Tennessee Pass and have found Tertiary monzonite float only in the detritus from Clear Creek and Twin Lakes Creek. It seems probable that no outcrops of monzonite, at least of any considerable size, will be found in these other drainage areas.

The outcrop in Clear Creek valley, as well as that at the head of Taylor Park, will be described in a little more detail. There is a fault of considerable throw crossing Clear Creek valley in a direction a little east of north, near Rockdale, an old abandoned mining camp about eight miles above the Arkansas River. This fault has been traced to the north up the small valley of Sheep Creek over the divide into the Twin Lakes side. To the south it passes up the valley of Clohesy's Creek, gradually climbing the mountain on

[11]Oral communication.

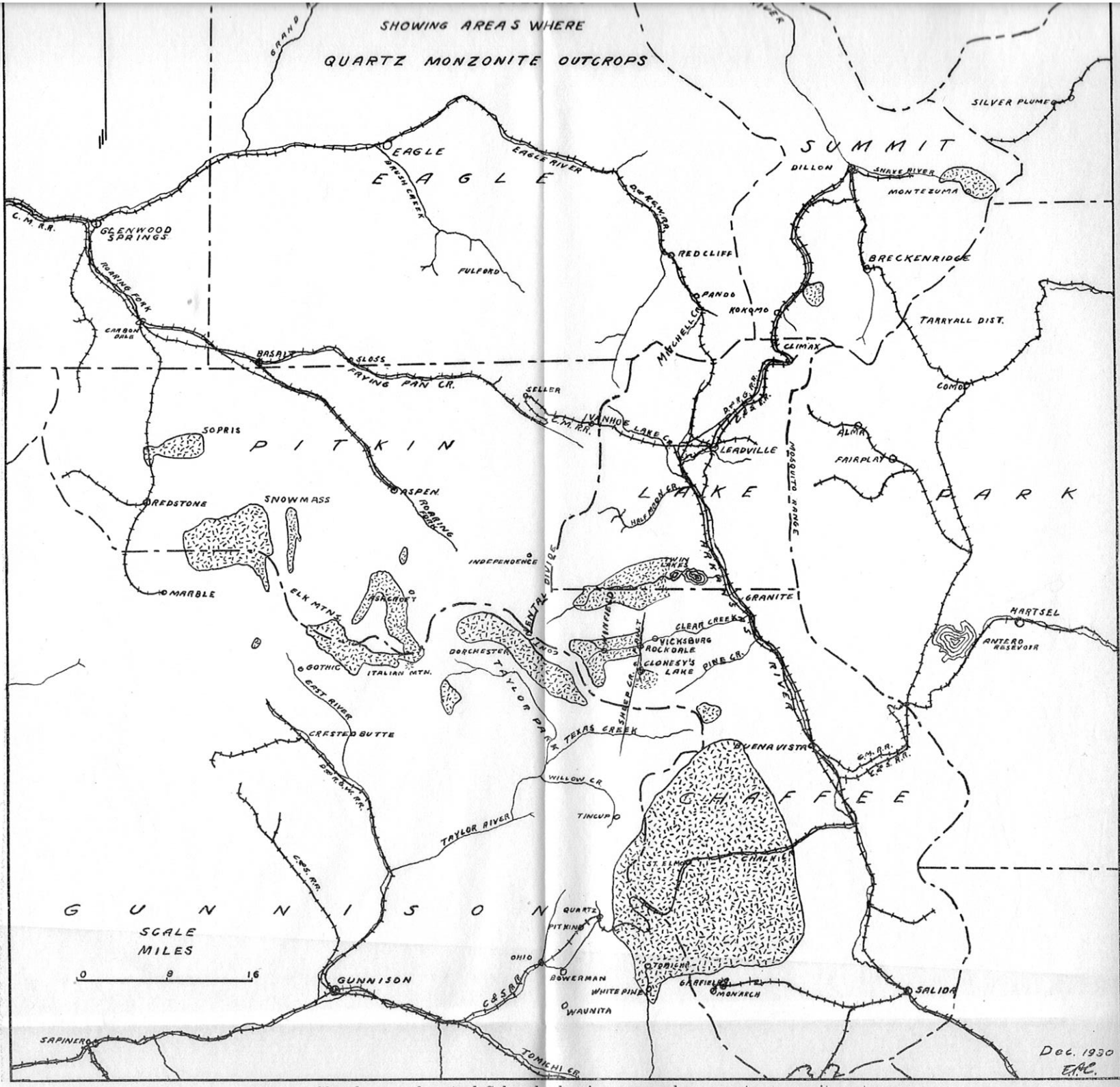

Fig. 1. Sketch map of central Colorado showing areas where quartz monzonite out crops.

the west side of this valley. An old prospector has told me it could be traced over the divide into the valley of Texas Creek and on south nearly to Tin Cup. As exposed in the canyon of Clohesy's Creek near its junction with Clear Creek, several planes of movement contain quartz and pyrite; so the fault is evidently pre-mineral. Slickensiding on the quartz indicates post mineral movement. The fault dips steeply to the west and as the west side is the upthrown side, it is a reverse fault at this place.

East of this fault (for which I propose the name of "Sheep Creek"), the rocks in the Clear Creek valley all belong to the pre-Cambrian complex, with the exception of small outcrops of porphyry resembling the Lincoln porphyry which cut the pre-Cambrian rocks. To the west of the fault the quartz monzonite contact with the pre-Cambrian granite is about six hundred feet above the valley floor on the north side and somewhat higher on the south side of Clear Creek valley. Following up the north side of the valley for about six miles, the contact rises at nearly the same gradient as the stream, so that it remains at about the same height above the valley floor. Beyond this point the quartz monzonite has not been traced, but it probably passes under the crest of the Continental Divide and is part of the same body which is seen at the head of Taylor Park above Dorchester. On the south side of the valley the relations are similar except that along the south fork of Clear Creek the contact rises faster to the south than does the creek bottom, so that at a point about three miles above Winfield it is perhaps one thousand feet above the valley floor. It is here along the south fork that what is thought to be the granite facies of the rock was noticed; the intermediate dikes already mentioned are a little lower.

The mountains composed of the quartz monzonite show a tendency to have one of two shapes. Some suggest tetragonal pyramids; others are the ridge type ending in what appears from a close point of observation to be a trigonal pyramid of which the edge nearest the ridge rises at a slight

angle toward it. The lack of these shapes along the crest of the range suggests that the monzonite does not form the top of the divide, but I have not anywhere verified this by personal observation.

Around Clohesy's Lake is found an outcrop of the quartz monzonite which corresponds very closely to the typical variety of Princeton quartz monzonite described by Crawford.[12] It differs from the other facies found in the Clear Creek valley by being much more equigranular and having more dark minerals. Its relations to the fault and other rocks of the district have not been studied.

At the head of Taylor Park the quartz monzonite is first found on the north side of Texas Creek and continues north along the west side of the main Continental Divide to Dorchester and nearly to Italian Mountain. The rock has been found in several places in this area, but the boundaries have nowhere been traced so they must be considered indefinite.

Ores of the Early Mineralization.

The ores of the Clear Creek and Twin Lakes districts belong to what Emmons calls endobatholithic deposits[13] and occur mostly in vein form cutting the quartz monzonite and the pre-Cambrian granite. The filling is mostly quartz and the veins are often banded. Some of them are frozen to the walls, whereas others has distinct gouge seams along them. In the Clear Creek district the most valuable minerals found have been those containing silver. Zinc, lead, copper, bismuth and molybdenum minerals are also found in the district. The silver occurs in what is commonly called "sulphurets" (perhaps secondary sooty chalcocite), intimately associated with native bismuth and bismuthinite, and as minute inclusions, probably argentite, in galena. It may occur also in other mineral composition. Zinc occurs as marmatite with lesser amounts of the lighter-colored "resin

[12]Crawford, R. D., op. cit. pp. 78-79.

[13]Emmons, W. H., Metalliferous lode systems and igneous intrusives: Amer. Inst. Min. Metal. Engrs. Trans. Vol. LXXIV, pp. 29-70, 1926.
Presented before the Society.

jack." Often the high-grade silver ores contain very little zinc. Galena usually is small in amount, and normally occurs as distorted crystals. When etched with 1-1 HNO_3 it shows many small inclusions of a light mineral which is attacked by the acid to a lesser degree than the galena and is probably argentite. Qualitative tests show that the galena often contains a considerable percentage of bismuth and sometimes antimony. Copper occurs as chalcopyrite and in places as covellite, both of which apparently contain very little silver. Pyrite is found in all the veins, but occurs in relatively minor amounts and is apparently barren of precious metals.

Some of the bismuth minerals assay as much as a thousands ounces of silver to the ton whereas others are almost barren. Apparently there is no difference in the appearance of the two, but there seems to be a difference in the association. Both bismuthinite and metallic bismuth when closely associated with molybdenite contain almost no silver; when occurring by themselves in quartz, they usually are high in silver.

Molybdenite occurs in small amounts fairly widely scattered through the area. It is found in veins in the quartz monzonite and pre-Cambrian granite, sometimes associated with bismuth and copper minerals, but apparently never with sphalerite, galena, and ores high in silver; it may be found in the same vein with zinc and lead sulphides, but is always in a different part of the vein. It is also found along the contact of the quartz monzonite and the pre-Cambrian schists, with a considerable development of muscovite. In places it is thinly disseminated through the Red Mountain rhyolite. It appears to be always very closely associated with quartz, usually a sort of cherty variety.

Specularite occurs in the veins found in the pre-Cambrian granite, but is scarce or wanting in the quartz monzonite. In the Clear Creek district gold is relatively scarce, but it is always present in minor amounts, an ore running 100 ounces in silver perhaps containing 0.12 ounces in gold to the ton. In the Twin Lakes district the ore occurrence is

essentially similar to that in the Clear Creek district, but in the Twin Lakes district gold is the dominant mineral and is often found native, in small high grade pockets.

Ores of the Later Mineralization.

Along Clear Creek many veins of a later age are found cutting the quartz monzonite. The filling of these veins is largely a light-pink, manganese-bearing calcite containing no sulphides whatever. The intersection of these veins with those of the earlier age has been explored in a good many places, apparently in the hope of finding a concentration of ore there, but always with disappointing results.

Some veins are mentioned by Howell as occurring in the rhyolite flows of this district. These contain coarse galena in barite gangue and are very different from the veins found in the pre-Cambrian formation and in the quartz monzonite. I saw one such deposit which consisted of a spotty occurrence of galena and sphalerite in a gangue of calcite, barite, fluorite, and rhodochrosite. None of these veins have yielded ores of commercial value as far as is known, and I have no evidence which would show their relationship to other veins of the district or whether they would continue downward into the lower rocks.

Prior to 1880 many prospectors were in the Clear Creek and Twin Lakes valleys, and a very considerable amount of prospecting was going on. Following the discovery of the rich silver-lead ore at Aspen, however, most of the prospectors left for that camp and but little has been done in these districts since. Mineralization is widespread, but ore bodies of commercial grade are evidently of sporadic occurrence, though usually high grade. What is known of the history of the districts would indicate that the cost of finding these small ore bodies exceeds the profit to be derived from mining them when once found. The few efforts to prospect the country on any extensive scale, which have taken place in recent years, would certainly indicate this. It was thought that a careful study of the geology, especially of the relations of ore occurrence to structure and to alteration of the

country rock might materially lessen this cost of finding new ore bodies. How far it may be possible to go along these lines is of course problematical. The present study, incomplete as it is, has brought out the following facts which may be briefly summarized here in conclusion.

Conclusion

The favorable host rocks are the pre-Cambrian granite and gneisses and the quartz monzonite itself. The lavas, so far, have not been found to contain commercial ore bodies and the schists appear to be distinctly unfavorable. Most of the ore bodies have occurred in veins with a northeast trend and it appears that this system of fracturing was more or less open and available at the time of introduction of the mineralizing solutions. Enrichment of the veins along or in porphyry dikes apparently does not take place nor is there enrichment at the intersection of the mineral-bearing quartz veins with the barren calcite veins. Oxidation is scarce on account of the large amount of glacial scouring, but in places veins, oxidized before the eruption of the lavas, have been protected by the lavas from the direct action of the ice and such places, in my opinion, offer favorable chances for exploration.

The molybdenum mineralization appears quite extensive and to be disseminated through all the formations as well as occurring in veins in both the pre-Cambrian granite and quartz monzonite. The association of non-argentiferous bismuth minerals as well as small amounts of copper minerals with the molybdenite, and the association or argentiferous bismuth minerals with the galena and sphalerite appear to divide the mineralization into two definite classes.

The area in question is of great interest from a geological point of view because it offers an excellent opportunity to study the top of the quartz monzonite batholith and the mineralization connected with it over a considerable vertical range. From a commercial point of view, however, it appears to be not so interesting.