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UNITED STATES GEOLOGICAL SURVEY

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THE COPPER DEPOSITS OF THE ENCAMPMENT DISTRICT WYOMING

BY

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PART II. ECONOMIC GEOLOGY.

FERRIS-HAGGARTY MINE.

Location and development.—The Ferris-Haggarty property is located about 2 miles west of Bridger Peak, on the east side of Haggarty Creek. It was formerly known as the Rudefeha, a name which has since been given to the post-office located at the mine.

The surface outcrop of this important ore deposit was a small exposure of gossan surrounded by the loose surface wash which covers the general slope of the hillside in the vicinity. This gossan, which is composed of spongy iron oxide mixed with quartz, was penetrated to a depth of 35 feet with little or no evidence of the presence of copper, but at this depth sulphide ores, occurring in kernels and bunches within

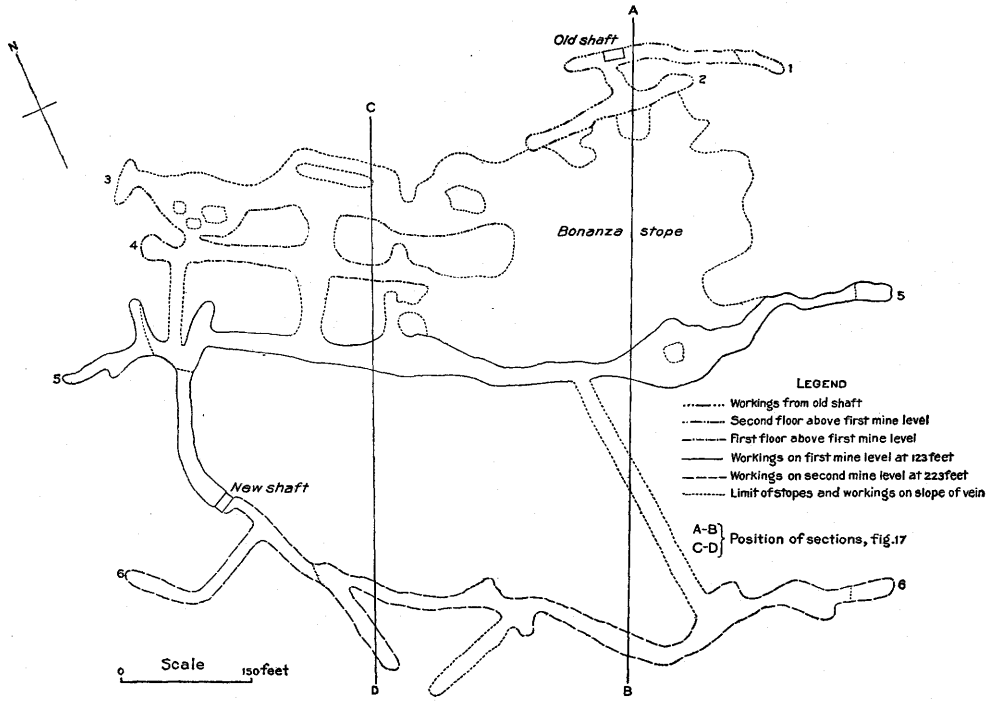

FIG. 13.—Ferris-Haggarty mine; plan of mine workings. Successive floors and levels are numbered to correspond with fig. 14.

the spongy iron oxide of the gossan, were encountered. The inclined shaft was continued to a depth of nearly 80 feet, and the ore was opened up both to the east and west in drifts at two levels (figs. 13, 14). A new shaft was then sunk at a point down the slope of the hillside, about 240 feet distant from the discovery. More than 30 feet of loose surface débris was penetrated before striking bed rock. The ore body was encountered at about 165 feet, and the shaft was continued to a total depth of 248 feet. At 123 feet a crosscut toward the north penetrated the hanging wall of the ore at a distance of 60 feet, and 100 feet lower the foot wall was reached

by a crosscut to the south, within a distance of about 40 feet. From these levels the ore body was developed by raises and intermediate floors in the vein, and in addition a large amount of high-grade ore was stoped out, especially in the eastern part of the mine. The horizontal length of the ore body varies from 250 to 300 feet.

It is reported that the ore has been proved to continue downward some 50 feet or more to the level of the new adit which was opened in the spring of 1903. It is by means of this adit that the known reserves and the future possible discoveries of

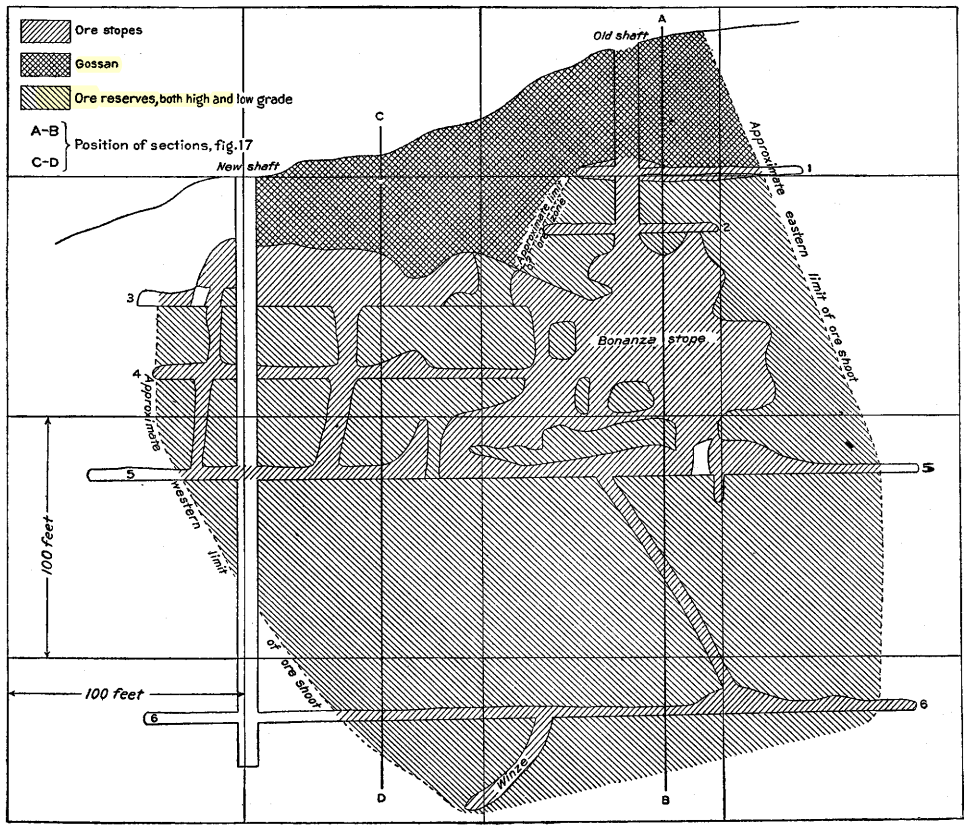

FIG. 14.—Ferris-Haggarty mine; projection of workings on vertical plane parallel to strike of ore body.

ore are to be taken out. At its mouth the ore may be conveniently loaded into the buckets of the aerial tramway which connects the mine with the concentrator and smelting plant at Encampment.

Because of the high cost of transportation, only high-grade mineral has been hitherto mined, excepting where the removal of low-grade material was necessitated in winning the shipping ore. Being developed in this way, practically no dead work had been done at the time this examination was made, and the workings were almost entirely confined to the vein.

Country rock.—The country rock at the Ferris-Haggarty mine is mainly quartzite and schist, belonging to the pre-Cambrian quartzite and slate formation. Intrusive gabbros, known in the district as diorites, occur near by, but are not encountered near the ore body.

The ore occurs at and follows a definite horizon situated between 200 and 250 feet below the top of the quartzite-slate formation, the upper limit of which is marked by the appearance of heavy beds of conglomerate. A section of the bedded rocks as they are exposed upon the ridge which forms a spur from the Continental

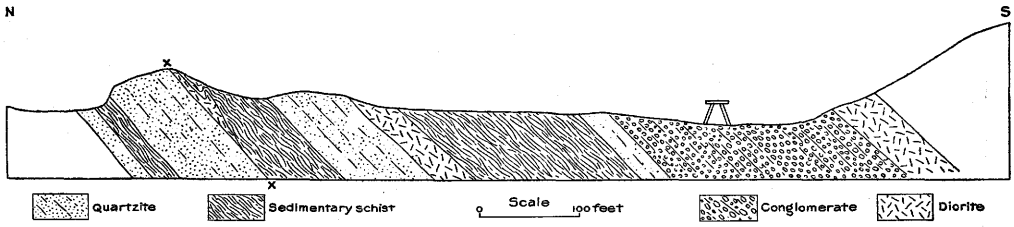

FIG. 15.—Section of bedded formations on ridge about one-half mile east of Ferris-Haggarty mine. The so-called "contact" horizon is marked by crosses. It is not mineralized at this place. Compare fig. 16.

Divide about one-half mile east of the mine, near the point where the tramway crosses, is given in fig. 15. This illustrates the alternation of varying strata below the ore horizon, while a complementary section (fig. 16), observed upon the ridge on the opposite side of Haggarty Gulch, gives the similar features of the strata which lie stratigraphically lower. Both sections show the intercalation of igneous rock and disclose the general attitude of the beds, which strike nearly east and west, dipping to the south at angles varying from 35° to 50°. In the mine work-

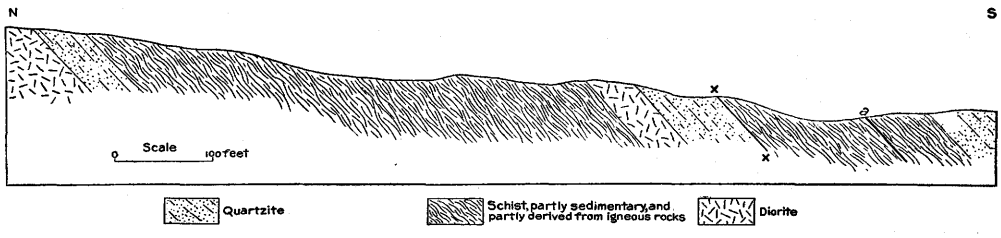

FIG. 16.—Section of bedded formations and intrusive rocks about one-half mile west of Ferris-Haggarty mine. The so-called "contact" horizon is marked by crosses. At *a* there is evidence of a considerable fault parallel with the bedding of the rocks.

ings the strata are observed to have a corresponding structure, though there are local minor variations, both in strike and dip, which bear an important relation to the ore deposit.

Jointing of country rock.—Throughout the mine the quartzite is broken by different sets of fractures, but these are rarely, if ever, represented by breaks in the hanging-wall schist, for in it adjustments and accommodations to movement caused bending of the strata and crumpling of its separate folia, while the brittle quartzite was fractured and brecciated. The most prominent fractures observed in the rocks

of the vicinity run in a direction nearly north and south—that is, nearly normal to the course of the vein—and, while nearly vertical, usually have a slight inclination to the east or west.

In the massive sandstone corresponding to the ore horizon, where it outcrops upon the crest of the ridge to the east of the mine, there are many small veins of quartz having a width of several inches near the contact of the quartzite and schist, but gradually becoming thinner toward the north, and finally disappearing at a distance of 30 feet or so. Other rocks, such as the intrusive diorite, likewise contain similar veinlets of quartz, showing the general occurrence of these fractures. They may be observed in exposures upon the west side of Haggarty Gulch opposite the mine, and in this vicinity there is also some evidence in the relations of outcrops of the rocks that important faults break the continuity of the strata along north and south fractures, and cause offsets of the beds toward the south as they are followed from east to west.

In the mine, fractures of the north-south system are to be observed at several places, though they are not uniformly developed throughout the workings. Locally they are rather closely spaced, as observed in the quartzite of the foot wall, and where this is the case, the schist which lies over the vein is often bent outward toward the south, and in the hollow thus formed the ore body is thicker than usual and the ore ordinarily of higher value. It seems that by bending in this way the more pliable schist has been able to take up or accommodate itself to movement which caused fracture in the brittle quartzite. The occurrence of fractures striking nearly parallel with the bedding of the quartzite and dipping in a contrary direction was noted at several points (figs. 24, 25), but there is less opportunity in this mine than in the Doane to observe the characteristics of the joint systems, since so great a share of the workings have been in the ore. Undoubtedly several sets of fractures have acted together to cause the brecciation of the brittle quartzite beneath the pliable schist, and in all probability there has been an important amount of crushing caused by movement along this horizon, in addition to adjustments along the different joints.

The ore.—The principal ore minerals which have been extracted from this mine are chalcocite and chalcopyrite, though bornite and covellite are occasionally found. Carbonate and oxide ores are present in small amounts only. The richest ore is found in the upper workings, where the proportion of chalcopyrite is less than on the lower levels. Much of the ore requires concentration, being mixed with the quartzite country rock, but no other gangue is present, and in the past all of the ore shipped has been practically free from foreign matter.

Occurrence of the ore.—The ore body in this mine follows a somewhat irregular zone of brecciation in the upper part of a definite stratum of quartzite, which,

in common with the beds associated with it, strikes nearly east and west and dips about 40° toward the south. Above this quartzite and sharply separated from it there is a bed of very fine-grained schist, which, though very much crumpled, contrasts with the quartzite below by reason of the practical absence of brecciation. This schist, which has a thickness estimated at about 50 feet, forms the hanging wall of the vein throughout the mine (figs. 15, 16, 17). There is no definite continuous foot wall, but the ore makes back into the quartzite in an extremely irregular manner, dependent either upon the completeness of brecciation or upon

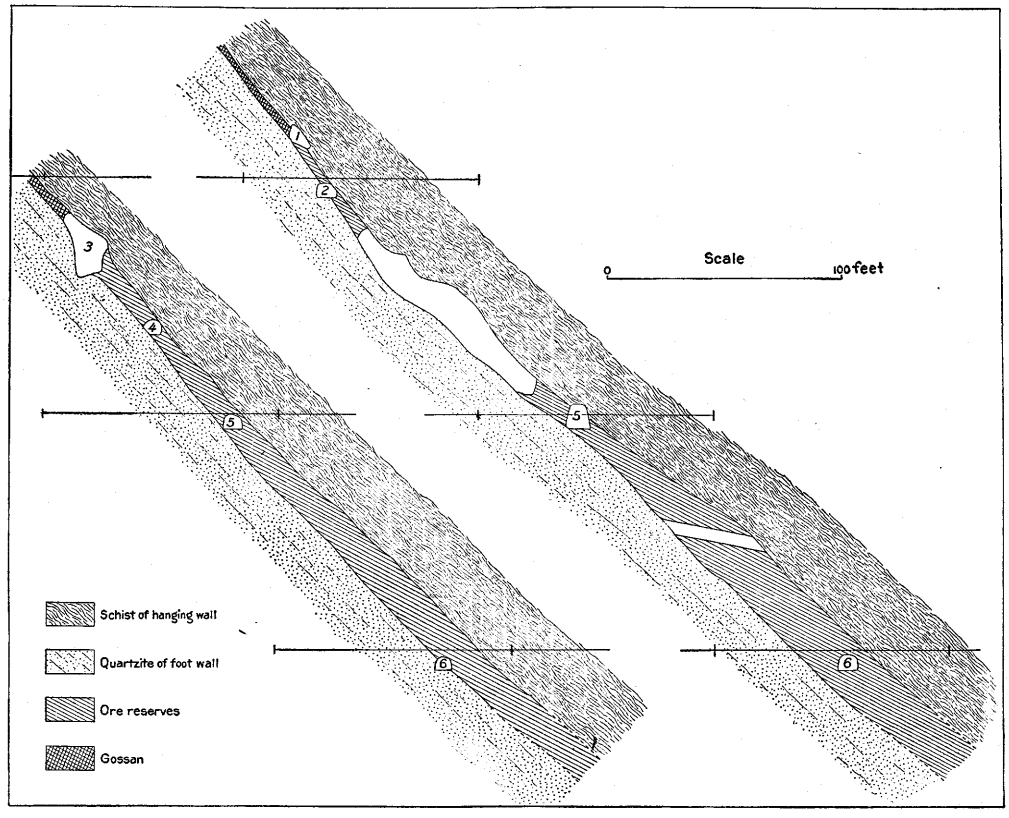

FIG. 17.—Ferris-Haggarty mine; transverse sections of the ore body along lines A B and C D in figs. 13 and 14.

the presence of cross fractures. The deposit has many of the characteristics of the Doane ore bodies, and is regarded as being of the same general type.

At the time the mine was visited the Ferris-Haggarty ore body had been followed from its outcrop to a depth of 266 feet below the surface, giving a known length on the dip of over 400 feet (figs. 14, 17). It is reported that the ore has been found to extend into the lower workings which have been opened from the new adit completed in the winter of 1902–3, so that the full depth to which the mineralization continues has not been ascertained as yet.

The upper limit of the ore where it passes into the gossan which forms the surface capping has been fully determined in the upper stopes and found to be rather irregular at a depth of from 35 to 60 feet (fig. 17). The drifts and stopes which have been opened at different levels show that the high-grade ore, at least, is rather sharply bounded. In the first mine level, at a depth of 125 feet, the horizontal length of the ore shoot is about 300 feet, while in the second level, 100 feet below, it is some 50 feet less (figs. 13, 14).

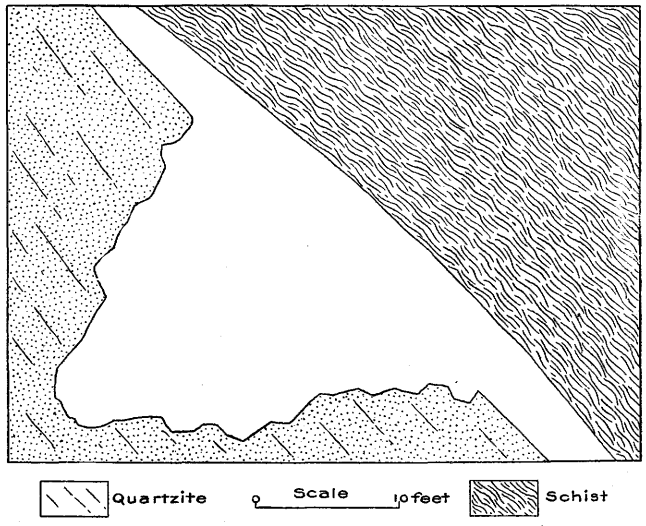

FIG 18.—Ferris-Haggarty mine; north-south sketch section through Bonanza stope at first mine level. Shows form of ore body and irregularity of foot wall. Compare fig. 19.

Along its strike the ore body seems to be limited by the disappearance of brecciation in the quartzite, but there is often low-grade ore beyond the present excavations, and few opportunities were afforded for conclusive observation

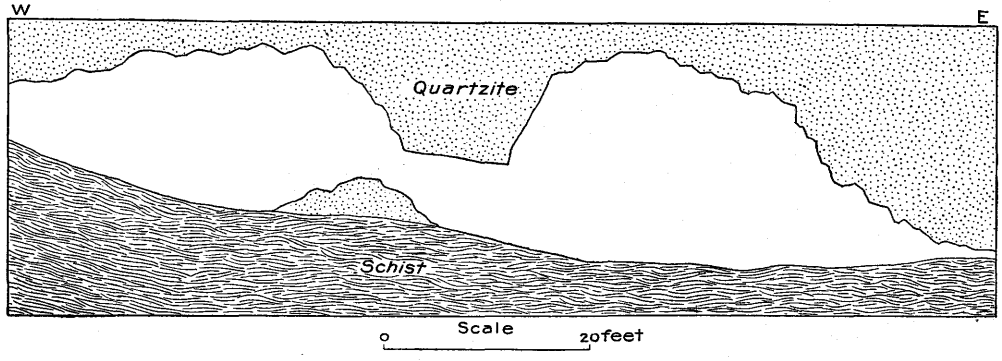

FIG. 19.—Ferris-Haggarty mine; sketch section through Bonanza stope parallel to strike and at right angles to dip of ore body. Compare figure 18.

upon this point. The thickness of the vein is extremely irregular, varying from a few inches near the ends up to 30 feet, or even more in some places (figs. 11, 18, 19).

Upon any level in the mine the intersection of a horizontal plane with the surface formed by the hanging wall is a curve concave toward the north. This is illustrated in fig. 20, in which the general shape of the vein upon the first

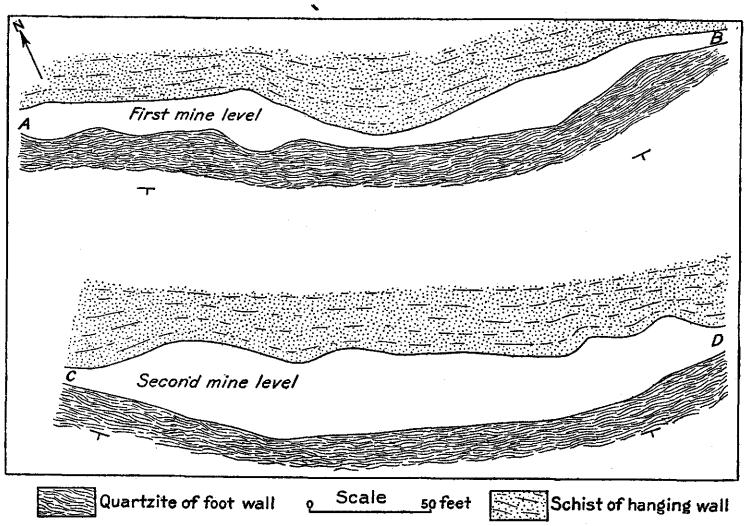

FIG. 20.—Ferris-Haggarty mine; plans of ore body on first and second mine levels. The general bowing toward the south is well shown. Compare levels 5 and 6 in figs. 13 and 14.

and second mine levels is given in horizontal plan, and in fig. 21, which is an idealized diagram showing in horizontal section the relation of the ore body to the country rock and to the north-south fractures.

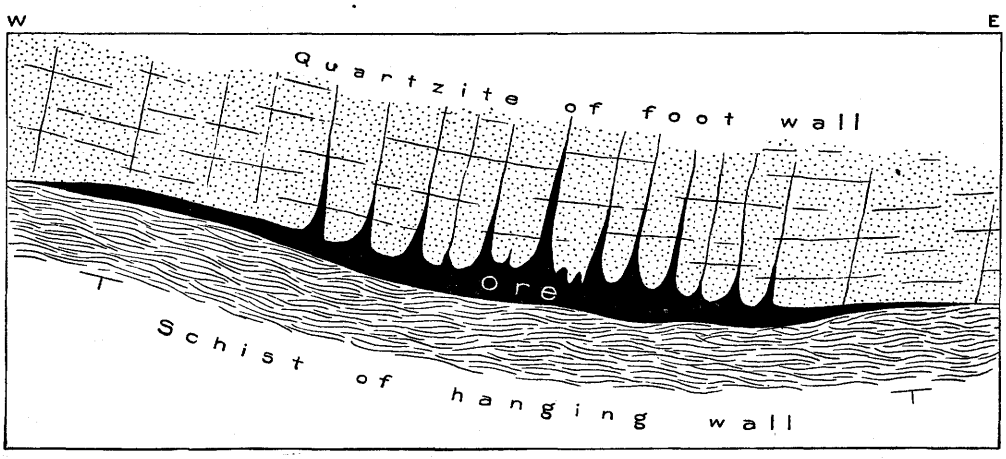

FIG. 21.—Ferris-Haggarty mine; idealized horizontal section of ore body, showing general convexity toward the south and the filling of north-south fractures.

Combined with the horizontal curving of the hanging-wall surface there is variation in dip, or irregular bending up and down from the plane of average inclination, so that the under surface of the schist overlying the ore is seen to be

a warped surface of very intricate contour. However, its irregularities are gentle rather than abrupt, and the fidelity with which the ore body follows the surface of division between the quartzite and the schist gives a sharply defined hanging wall, a feature which is illustrated in several of the accompanying diagrams.

The foot wall has none of the regularity of the hanging wall, where the ore makes in the country rock in various ways, doubtless dependent upon local differences in the development of the fractures and brecciation in the quartzite (figs. 23, 24, 25).

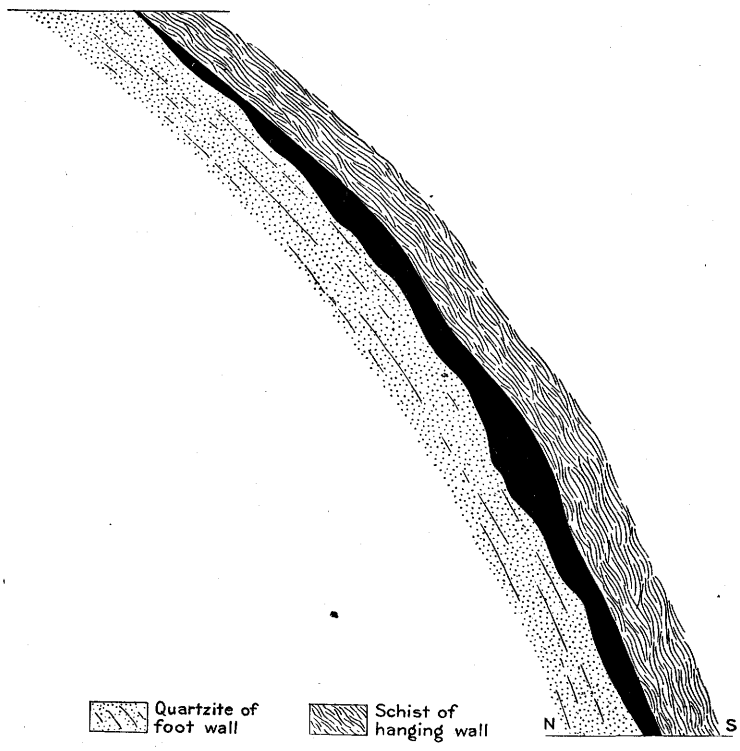

FIG. 22.—Ferris-Haggarty mine; idealized vertical north-south section across the ore body, showing convexity and irregular dip.

A certain amount of ore is found in north-south fractures in the quartzite country rock beneath the ore shoot, and a portion of the sulphides in the latter may have been formed by a replacement of the quartzite, but the main mass of the ore occurs filling the mass of broken or brecciated quartzite, the fragments of which are sharply limited against the ore and contain metallic minerals only in the form of veinlets with sharp walls (figs. 23, 24).

The sketch diagram (fig. 25) represents the relations of the vein to the inclosing rocks in the west end of Bonanza stope. The bottom of the section is 90 feet above the first mine level. In the foot wall north-south fractures are

prominently developed, but there is no marked horizontal bowing of the strata. The ore minerals are chalcocite with some chalcopyrite, and these form a matrix for brecciated fragments of quartzite. The foot-wall material is much fractured and seamed, while the overlying schist appears to be perfectly intact, though it is considerably crumpled.

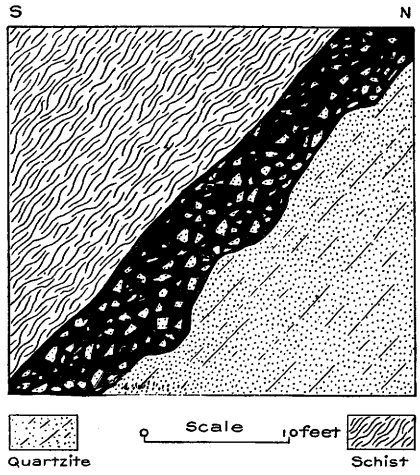

FIG. 23.—Ferris-Haggarty mine; face of stope west of old shaft, 90 feet above first mine level. The sketch shows the brecciation of the quartzite and irregularity of foot wall. At this place north-south fractures are strongly developed in the foot wall, but do not cut the overlying schist.

At several places in the mine the ore body was found to have more or less continuous bands of schist running through it, and in such cases the ore is found to be formed just under the bands of close-grained rock, while the quartzite above them is barren for some distance (fig. 26), indicating that the ores were deposited by ascending waters.

Genesis of the ore.—The reference of the Doane and Ferris-Haggarty copper ores to the same type of deposit is founded on the very close similarity in their mode of occurrence. In the latter the upper part of a bed of quartzite, striking nearly east and west and dipping south, has been greatly broken and brecciated along its contact with a thick overlying stratum of schist. The brecciation has been caused in part by

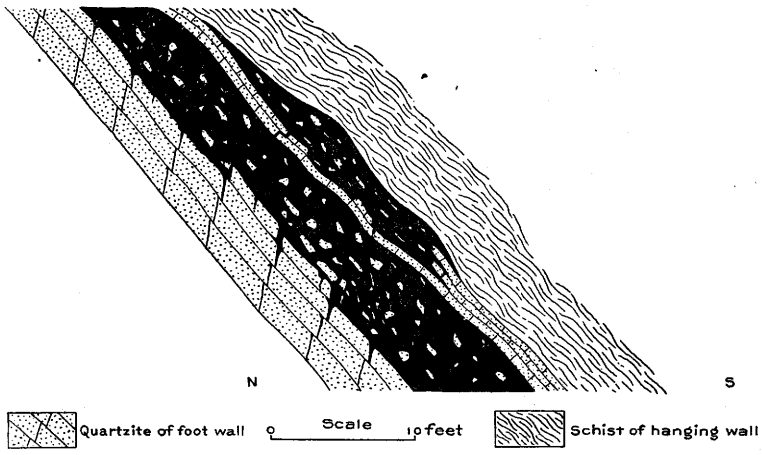

FIG. 24.—Ferris-Haggarty mine; idealized sketch of ore body as seen near old shaft at depth of 135 feet, showing false hanging wall and nature of brecciation.

movements essentially parallel with the bedding, and in part by movements along fractures transverse to the stratification. Cross fractures, which strike nearly north and south and dip steeply either to the east or to the west, are to be

observed in various parts of the mine, and in some cases they are filled with ore in the quartzite of the foot wall, but they do not break the continuity of the hanging-wall schist. The latter has almost invariably adjusted itself to movement in the direction of these fractures by bending, instead of by breaking. This being the case, and the schist being fine grained, it forms a capping over the open quartzite breccia which has been very impervious to the passage of water in circulation.

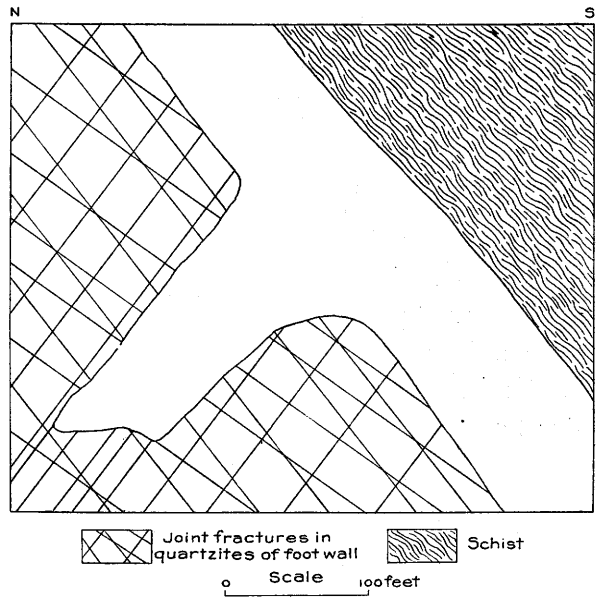

FIG. 25.—Ferris-Haggarty mine; north-south diagrammatic section through stope on first mine level near head of incline to second level, showing intersection of bedding and fissures, and an offshoot of ore into the foot-wall quartzite.

From the relations which have been described in detail in the foregoing pages, and which are here briefly summarized, it is believed that the existence of the Ferris-Haggarty ore body depends upon the presence of the north-south cross fractures, the brecciated quartzite, and the overlying impervious schist. The cross fractures being in many places filled with ore are regarded as having been channels of easy circulation for ascending solutions. Since the fractures do not continue through the schist, the moving waters were completely deflected by the impervious stratum into the fractured rock beneath, along which they continued to ascend, and found conditions favorable for the deposition of their metallic contents.

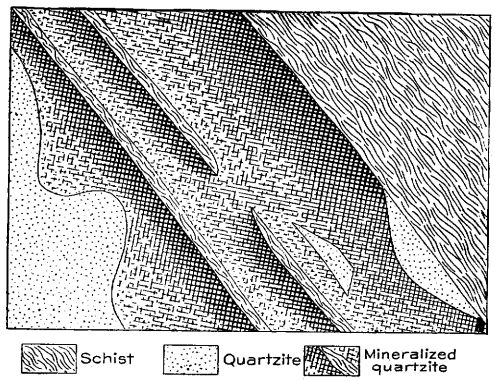

FIG. 26.—Ferris-Haggarty mine; diagrammatic section of ore body, illustrating the manner in which the richness of the ore increases just beneath layers of close-grained schist interbedded with the quartzite.

The occurrence of ore in these north-south fractures beneath the ore horizon, and the relation of the latter to them, suggests that they have been feeders for the main ore body, and while sufficient observations have not been made to prove the point, it is believed that there is a zone of excessive sheeting transverse to the strike of the rocks which inclose the ore body, and as wide as

its horizontal length. Outside of this zone parallel fractures exist, but they are probably few and widely spaced.

That the mineralizing waters were ascending and that the schist was practically not penetrated by them is shown by the clearness of the contact of ore and schist and the rarity with which any ore occurs in the material of the hanging wall. The same thing is brought out even more clearly in certain places where thin beds of schist occur within the mineralized part of the quartzite (fig. 26). In such cases the ore is mainly segregated beneath the different schist bands, and immediately above them little or no mineralization has taken place.

The basic gabbro rocks of the region are regarded as the source from which the deeply circulating waters derived their metallic contents.

The primary ore was chalcopyrite with perhaps some iron sulphide free from copper, and the rich ores which have been encountered have resulted from secondary concentration of originally leaner ores, through the action of surface waters percolating through the vein, dissolving copper from the upper portions and redepositing it lower down. Examination of the ore in the mine workings shows the gradual increase of primary chalcopyrite and the corresponding diminution of chalcocite as depth is attained, and it is probable that eventually the former will entirely replace the latter.

Future of the property.—The prosperity of the Ferris-Haggarty mine for the immediate future is practically assured by the existing ore reserves (see figs. 13, 14), and the conservative policy of developing and exploring while production is going on will doubtless be adopted.

The ore body itself will naturally be followed downward, and exploration of the ore-bearing horizon between the schist and quartzite toward the east may lead to the discovery that another zone of north-south sheeting has produced mineralization in it. Also the ground north of the present workings may contain ore bodies located beneath other slaty or schistose layers intercalated in the quartzite, and related to north-south fractures in a manner similar to the known deposit.

CHARTER OAK MINE.

The Charter Oak property is located a short distance north of the area shown on the Encampment special map, in sec. 24, T. 14 N., R. 85 W., about 6½ miles northwest of Encampment.

The country rocks in the vicinity are gneissoid or schistose granite and metamorphosed basic rocks related to gabbros, but having the composition of diorite. The greater part of these diorites are schistose, but occasionally they are massive. They are intrusive in the granite gneiss, and the contacts between them and the schistosity of the diorite follow the platy structure of the older granitic rock.

The mine is situated near the east side of a broad synclinal fold, the axis of which pitches northwest from the high hill about 1 mile to the southwest, in sec. 29, T. 14 N., R. 85 W. In this locality the influence of the fold may be noted