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GEOLOGY AND ORE DEPOSITS OF THE CLINTON MINING DISTRICT, MISSOULA COUNTY, MONTANA

by

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CONTENTS

ILLUSTRATIONS

TABLES

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ABSTRACT

Approximately 4 square miles of surface and all accessible underground workings in the Clinton mining district of western Montana were mapped and studied in detail. Discovered in 1878, the district has produced copper, silver, lead, and gold having a total value of approximately $100,000, principally from the Hidden Treasure and Cape Nome mines.

The main rock unit in the area is a late Cretaceous or early Tertiary granodiorite stock, which was intruded transverse to northwest-trending folds produced during Laramide orogeny. The stock cuts late Precambrian Beltian quartzite of the Missoula group and a diabase sill contained therein. After intrusion of the stock, dacite porphyry dikes were intruded along tensional fractures that cut all rocks in the district. Later tensional fractures provided openings along which ore minerals were deposited.

The ore deposits occur both in the granodiorite, as discontinuous fissure filling in veins that trend north and dip west, and in the adjacent quartzite, as lenticular replacement bodies in northeast-trending shear zones that dip southeast. In order of their paragenetic sequence, the ores in the granodiorite consist mainly of chalcopyrite, bornite, enargite, and chalcocite whereas those in the quartzite are chalcopyrite, tetrahedrite, and galena.

In the quartzite of the Hidden Treasure mine, significant mineralization occurs mainly where west-dipping splits converge upward with predominantly east-dipping veins. The structure of the ore bodies in the 4001 raise of the Hidden Treasure mine is complicated by four stages of movement, each of which cut and displaced previous mineralized structures.

Surface and underground vein exposures indicate that the best prospects for additional ore may be the zones of supergene sulfide enrichment like the one that accounted for most of the past production in the Hidden Treasure mine.

INTRODUCTION

LOCATION AND ACCESSIBILITY

The Clinton mining district (fig. 1) lies within the western part of the Garnet Range, 20 miles east of Missoula and 2 miles northeast of Clinton, Montana. It is situated in sec. 13 and 24, T. 12 N., R. 17 W., and sec. 17, 18, 19, and 20, T. 12 N., R. 16 W., Montana Principal Meridian. U. S. Highway 10 and the main lines of the Northern Pacific and the Chicago, Milwaukee and St. Paul railroads pass through Clinton. A county-maintained road affords access to most of the district except in the late winter and early spring months.

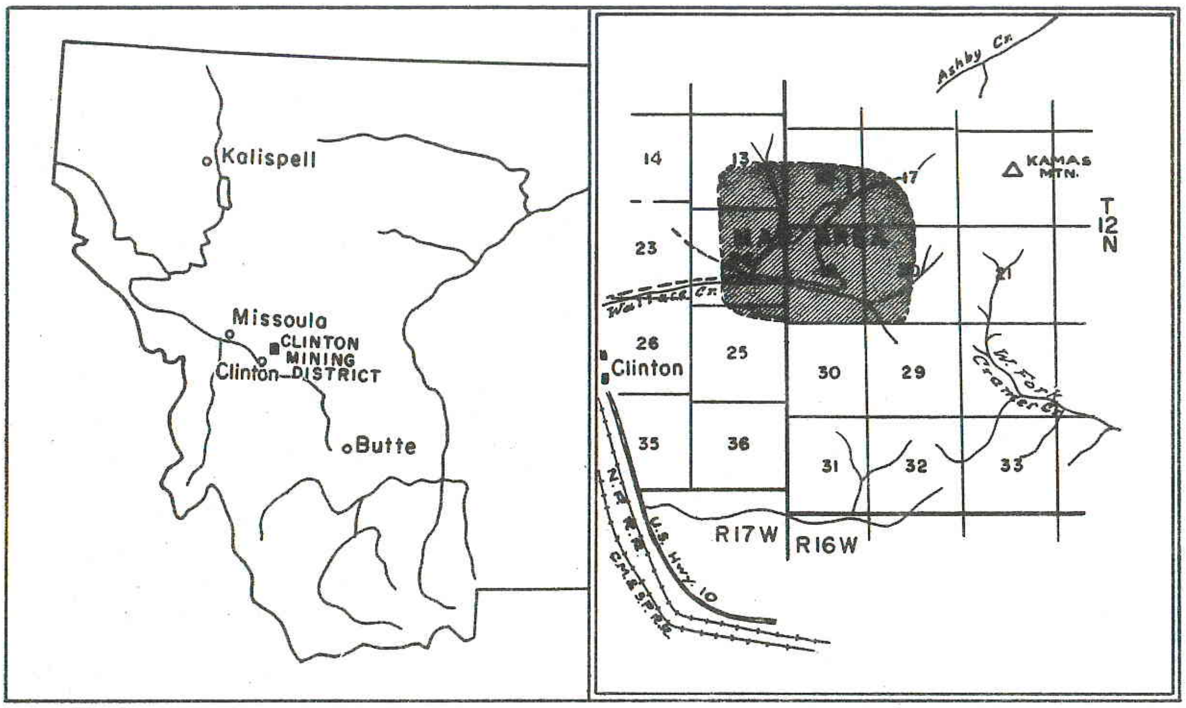


Figure 1.--Index map of Montana, showing location of the map area.

PURPOSE OF THE INVESTIGATION

The purpose of this study was (1) to obtain a detailed picture of the surface and underground geology of the Clinton mining district, (2) to work out the mineralogy and paragenetic relationships of the ore minerals, and (3) to determine the factors controlling ore deposition. It is hoped that this information can be used in the development of paying mines in the district.

PREVIOUS WORK

There is little published literature dealing with the geology of the Clinton district. Most of the reports are of a reconnaissance nature.

Rowe (1910) briefly described the general geology and the more important properties at a time when there was a great amount of activity and interest. His work is of particular value because most of the workings he visited are inaccessible at the present time. He presented a somewhat more optimistic description of the economic potential than was found during this investigation, however.

Pardee's reconnaissance of the western part of the Garnet Range (1918) gives a description of the geology and of the more important properties, but it is very general.

The geology of the upper levels of the Hidden Treasure mine was described by Piquette (1941) during an exploratory program in the upper adit level. He also described the surrounding geology, but added little to what had already been said by Rowe and Pardee.

In 1943, 1944, and 1945 the U. S. Bureau of Mines undertook a program of sampling and diamond drilling. Several properties were examined and extensive sampling was done on the Queen Mary and the Hidden Treasure claims. The results of this work were disappointing, however, and the project was discontinued (Britton, 1946).

Sahinen (1957) described several of the properties in the district; his report is based on a survey of previous literature and brief visits to some of the individual properties.

Reports by Brynie (1959), Matson and Leischner (1959), and Toler and Schryver (1958) are on file with the Department of Geology, Montana State University. They were submitted for a course in geologic problems, and cover local problems in mine mapping and sampling.

PRESENT STUDY

The field work for this study began in June 1958 and was conducted, as time permitted, through July 1959, while the writer was employed as a geologist for Hera Exploration Co. of Clinton, Montana. Field work directly related to the investigation totaled approximately 30 days.

The underground geologic mapping necessitated a transit survey of all the accessible mine workings and construction of base maps upon which the geologic data of selected portions of the mine were plotted. A scale of 1 inch equals 20 feet was chosen in order to show as much geologic detail as possible on a relatively small map.

Surface geological data covering appfoximately 4 square miles were plotted directly on vertical aerial photographs having a scale of 1:17,500. (Commodity Stabilization Service photographs dated August 11, 1955.) The final surface map (pl. 1) was prepared by transferring the geologic data to a planimetric base map constructed from the aerial photos by means of a K.E.K. stereoscopic plotter; this transfer removed distortion due to differences in elevation and enlarged the scale to approximately 1 inch equals 1,320 feet. Land net control was established by matching the planimetry of the base map with that of an aerial "strip tracing" on file at the Regional Offices of the U. S. Forest Service, Missoula, Montana.

Laboratory work involved making petrographic descriptions, identifying minerals in ore samples, and studying their textural and paragenetic relationships. Altogether 43 polished sections and 15 thin sections were prepared and studied. Photomicrographs were made of certain polished sections that best show mineral relationships.

ACKNOWLEDGMENTS

Many persons have contributed to the completion of this study. Appreciation is extended the offices and stockholders of Hera Exploration Co. who have generously given their permission to use company information. The writer gives special thanks to B. L. Hicks for his assistance in constructing the base maps, and to Gary G. Morrison for his help with the field work. Professors R. M. Weidman, A. J. Silverman, J. W. Hower, and R. A. Brodersen of the Geology Department of Montana State University offered valuable assistance and constructive criticism. E. M. Schell gave freely of his time to assist on mineralogical problems. A special acknowledgment is due the writer's wife, Bonnie, for her typing and suggestions.

HISTORY AND PRODUCTION

The Clinton mining district was discovered in 1878, when the first locations were recorded by J. D. Richards, James House, and S. F. Keim. There was little activity, however, until about 1905, when exploratory work was started in the Cape Nome mine. This seemed to draw interest to the entire district; between 1905 and 1912 several properties were being actively explored. Low metal prices and discouraging mineral showings resulted in virtual abandonment of the district for many years. During the flurry of activity between 1905 and 1912, underground workings totaling more than a mile in length were driven on the Cape Nome claim. This included sinking 500 feet of vertical shaft and driving nearly 5,500 feet of drifts and crosscuts on five levels. Considerable workings were also driven on the Hidden Treasure claim.

From 1912 to 1963, sporadic small-scale production and exploration have been carried on in the Hidden Treasure and Cape Nome mines. Some prospecting has been done in other parts of the district, but no other production is known.

In 1956 Hera Exploration Co. of Clinton, Montana, leased the Hidden Treasure, Cape Nome, and several other claims in the district. The company re-opened the 100-foot level of the Cape Nome mine and temporarily dewatered the shaft to the 300-foot level for examination. During the summer of 1958 small scale production was obtained from the lower adit of the Hidden Treasure mine.

In 1957 Clinton Mining and Milling Co. of Clinton, Montana, completed installation of a 50-ton-per-day bulk flotation plant on Wallace Creek. This mill was constructed to beneficiate ore produced from Hera Exploration Co. operations, as well as from other nearby properties. During three years of intermittent operation (to December 1960), the mill produced four carloads of copper concentrates, which were shipped to the smelter at Anaconda, Montana.

Early in 1959 Hera Exploration Co. undertook a program to extend the lower adit of the Hidden Treasure mine 2,600 feet to a point under the Cape Nome workings. In December 1960 this half-completed venture apparently was abandoned and attempts were being made to develop sufficient ore in the Hidden Treasure mine to operate the Clinton Mining and Milling Co. mill on Wallace Creek.

According to Pardee (1918), the total production of the district through 1917 did not exceed $25,000. Table 1 shows the production of the Clinton district from 1934 to 1960. No information is available for the period 1918-1934.

Table 1.--Production of gold, silver, copper, and lead in the Clinton mining district, 1934-60. Years 1934-55 modified from Sahinen, 1957, p. 33.

Year	Ore, tons	Gold, oz.	Silver, oz.	Copper, lb.	Lead, lb.	Total value
1934	143	10	1,304	----	----	$ 1,817
1935	955	52	8,178	51,205	9,825	12,322
1936	411	--	25	22,761	----	5,710
1937	1,575	92	13,766	85,628	----	24,229
1938	415	16	2,707	23,306	----	4,594
1939	354	17	2,341	17,115	8,617	4,369
1940	26	3	443	3,230	----	785
1941	----	--	----	----	----	----
1942	19	1	69	700	----	169
1943	206	11	1,305	11,800	6,800	3,357
1944	212	6	1,004	8,000	----	2,004
1945	----	--	----	----	----	----
1946	----	--	----	----	----	----
1947	----	--	----	----	----	----
1948	50	1	439	2,800	1,480	1,305*
1949	----	--	----	----	----	----
1950	----	--	----	----	----	----
1951	----	--	----	----	----	----
1952	----	--	----	----	----	----
1953	----	--	----	----	----	----
1954	----	--	----	----	----	----
1955	----	--	----	----	----	----
1956	----	--	----	----	----	----
1957	300*	--	----	11,538**	----	3,000*
1958	600*	--	----	23,077**	----	6,000*
1959	250*	--	----	9,630**	----	2,500*
1960	----	--	----	----	----	----
Totals	5,641	212	31,718	270,775**	26,722	$72,381

*Approximation.

**Equivalent copper (total metallic assay value converted to copper percentage).

TOPOGRAPHY

The Clinton mining district lies on the south slopes of the Garnet Range. Elevations range from 3,467 feet at the town of Clinton to 6,365 feet at Kamas Mountain, which is the most prominent topographic feature in the district.

The northwestern part of the Garnet Range is characterized by steep slopes dissected by narrow V-shaped canyons having steep gradients. The upper slopes are more gentle and are probably correlative with a postulated mid-Tertiary erosion surface (Pardee, 1918, p. 163). Differential erosion of the less resistant Clinton stock has left a topographic low in otherwise relatively high ridges and mountains.

The area is drained by Wallace and Woodville Creeks, which converge and flow southwest into the Clark Fork River. These streams are perennial, but most of their tributaries are dry during the late summer and fall.

Near the confluence of Woodville and Wallace Creeks is a small lake. Originally it was formed as a result of a landslide, which dammed the valley with material from near the top of the ridge to the south. At present the lake is impounded by a man-made earth dam. It is estimated from profiles of the slide scar that approximately 1.4 million cubic yards of material slid into the canyon. The slide scar and the slide are old enough to support timber of the same species and size as that on the surrounding country. The lake has existed long enough to deposit a well-defined "flat" of sediment at its upper end.

CLIMATE AND VEGETATION

A semiarid, temperate climate, typical of the Northern Rocky Mountains, prevails in the area. Weather conditions are roughly comparable to those at Missoula, for which the U. S. Weather Bureau has provided the following figures. Annual precipitation averages 13 inches and rarely exceeds 20. Temperatures vary from extremes near -33°F in the winter to 105°F in the summer; the mean is 44°. Snowfall in normal years is heavy enough to impose transportation problems in the higher elevations during the late winter months.

The district is covered by coniferous trees and brush, except in lower valleys that have been cleared for farming and ranching. Trees in the wooded areas consist chiefly of fir and larch on the north-facing slopes and ponderosa pine on the south. Most of the larger trees have been cut by logging operations. Abundant trees of species and size usable for mine timbers are readily available on most of the mining claims.

GENERAL GEOLOGY

The Clinton mining district is located in a region of moderate structural deformation, characterized by northwest-trending folds and faults and a northeast-trending granodiorite stock.

The main rock unit of the area is the small granodiorite stock, which has intruded argillaceous quartzite of the Garnet Range Formation (Precambrian) and impure dolomitic limestone believed to be the Jefferson Formation (Devonian). The limestone occurs north of the mapped area. The effect of contact metamorphism is pronounced in the Garnet Range Formation, where dense hornfels extends as far as 600 feet from the contact. The limestone has been altered for as much as 100 feet from the contact to a white crystalline marble containing typical contact minerals.

A large diabase sill in the Garnet Range Formation was cut by both the granodiorite and more recent dacite porphyry dikes. Recent alluvium occurs along the principal stream valleys.

SEDIMENTARY ROCKS

Precambrian

Precambrian rocks are represented in the map area (pl. 1) by the Garnet Range Formation and the overlying Pilcher Quartzite, both in the upper part of the Missoula Group of the Belt Series. In general, outcrops are scarce; logging and mine-access roads provide the best exposures.

Garnet Range Formation.--Rocks of the Garnet Range Formation are exposed west, south, and east of the Clinton stock. The formation, which is very consistent lithologically, is composed mainly of thin-bedded greenish-brown and gray quartzite interbedded with thin reddish argillite layers. It is best recognized by the large amount of detrital mica flakes it contains and the distinctive brown weathered outcrops and talus slopes it forms. The thickness could not be determined, because neither the top nor the bottom of the formation is exposed in the map area. Montgomery (1958, p. 13) measured 5,500 to 6,000 feet exposed in the Nimrod area approximately 20 miles east. Nelson (1959, p. 55) measured thicknesses ranging from 1,800 to 3,800 feet in the vicinity of Sheep Mountain approximately 15 miles west of the area.

Pilcher Quartzite.--Rocks assigned to the Pilcher Formation crop out along the south side of Wallace Creek where they are in fault contact with the Garnet Range Formation. They consist mainly of reddish-orange medium-grained quartzite interbedded with yellow-green arenaceous argillite. This lithology is characteristic of the upper parts of the formation (Nelson, 1959, p. 56). A thickness of at least 300 feet is exposed, but total thickness could not be determined because the contacts in the map area occur along fault traces.

Devonian.--Rocks believed to be Jefferson Limestone, of Devonian age, occur north of the mapped area. They lie unconformably on the Pilcher Quartzite and consist mainly of flaggy impure dolomitic limestone. In weathered outcrop they are easily recognized, as they are characterized by a light-gray chalky surface. They form a fine reddish-brown soil upon decomposition. When freshly fractured, the rock is dark gray to black and is laced with small calcite-filled fractures.

Quaternary.--Recent stream-deposited alluvium floors the Clark Fork River valley and the lower reaches of Wallace Creek.

IGNEOUS ROCKS

Precambrian(?)-Cretaceous(?)

Diabase sill.--On both sides of the granodiorite stock, the sediments are intruded by a diabase sill 300 to 900 feet thick. The mapped outcrop extends from the southeast contact of the Clinton stock for a distance of more than a mile in the Garnet Range Formation. The Wallace Creek faults cut it into three displaced segments. It seems to dip roughly 60° southwest, conforming to the dip of the enclosing sediments.

Rocks of the Belt Series in many areas in northwestern Montana are intruded by diabase sills. In the Nimrod area directly east of the Clinton district, Montgomery (1958, p. 33) mapped a diabase sill that intruded the Garnet Range Formation. From its similarity with other intrusive bodies farther east, which intrude the Colorado Shale, and because it is partly covered by igneous flows of early and middle Tertiary age, he tentatively placed its time of injection as late Cretaceous. Ross and others (1955) show the age of other diabase intrusions in western Montana as Precambrian. The relationship of the Wallace Creek sill to the other rocks in the area does not permit a closer age determination than post-Garnet Range Formation and pre-intrusion of the granodiorite stock.

The texture of the sill is typically diabasic. It ranges from medium fine grained at the contacts to coarse grained near the center. Plagioclase and pyroxene make up approximately 80 percent of the rock. Minor amounts of amphibole, calcite, magnetite, and myrmekitic intergrowths make up the rest of the rock. Myrmekitic intergrowths are most common toward the top. Numerous lenses and layers of almost pure magnetite $\frac{1}{2}$ to 8 inches thick were observed in the lower third of the sill. Abundant veinlets of carbonate cut the sill but seem to be most common in areas of fracturing. They are probably of hydrothermal origin.

The average modal composition of the rock is as follows:

Plagioclase	40%	Amphibole	7%
Pyroxene	30%	Iron oxides	3%
Sericite	10%	Carbonate	2%
Myrmekite	8%		

In thin sections the rock is extremely "dirty" as a result of strong sericitization. This sericitization may be alteration caused by intrusion of the Clinton stock. Seven thin sections were prepared from samples taken at irregular intervals across the sill where it is exposed along Wallace Creek. From this limited study, it is not possible to determine what effect the intrusion of the stock had upon the sill.

Late Cretaceous-Early Tertiary(?)

Clinton stock.--The Clinton stock (common local name) is a small, hornblende granodiorite intrusion, $\frac{1}{2}$ mile to 1 mile across and nearly 5 miles long in a northeasterly direction. It is exposed from the middle reaches of Wallace Creek on the south slope of the Garnet Range to the main forks of Ashby Creek on the north, beyond the mapped area.

The mass is generally sheeted horizontally. The effect of weathering and erosion along the joint planes leaves cores of rounded boulders, which crop out above the surface of the ground in a characteristic spheroidal weathering pattern. In the map area the contacts are discordant. The western and southern intrusive contacts dip nearly vertically, but the southeastern and eastern contacts dip approximately 65° beneath the overlying sedimentary rocks, indicating that the stock may connect with the Garnet stock farther east.

The granodiorite is inequigranular and coarse grained and is composed mainly of quartz, plagioclase, K-feldspar (probably microcline), hornblende, biotite, and chlorite. Minor amounts of apatite and iron oxides are also present. The composition and texture seem to be uniform in the area mapped. No discernible difference in grain size can be seen when samples from near the contacts are compared with those taken from well within the main body of the stock.

In hand specimens the rock is light greenish gray. Dark-green hornblende in elongate crystals, some as much as 20 mm long, is abundant. Subhedral flakes of black biotite as much as 4 mm across are present in small amount. The light-colored constituents, which make up about 80 percent of the rock, consist of greenish plagioclase, faintly pink K-feldspar, and milky colored quartz.

Thin sections show that plagioclase is the most abundant mineral, constituting approximately 50 percent of the rock; it occurs in subhedral crystals 2 to 4 mm in length. Its composition, $Ab_{56}An_{44}$, places it in the range of andesine. Zoning of the plagioclase is common. Many of the crystals are extremely cloudy and others are almost unidentifiable, owing to sericitization. Both Carlsbad and albite twinning are present.

K-feldspar constitutes approximately 15 percent of the rock. It occurs in subhedral crystals, which average 4 mm but range to as much as 12 mm long. Where not obliterated by sericitization, multiple twinning can be seen.

Hornblende constitutes approximately 15 percent of the rock. Most of the prisms are euhedral. They range in length to 20 mm. Pleochroism is strong, from light brown to dark green. Partial replacement by biotite and later by chlorite is common.

Some of the crystals have been broken, and pieces whose broken ends can be matched are found near each other.

Quartz grains, which make up 15 percent of the rock, fill the interstices between the earlier formed minerals. Most quartz grains display undulatory extinction under crossed polarizing prisms. Biotite and chlorite plus minor apatite and iron oxides make up the remaining 5 percent of the rock.

Dacite porphyry dikes.--Numerous dacite porphyry dikes intrude all other rock units in the area and are, therefore, the youngest rocks present. All observations indicate that they were intruded before the time of vein deposition, however.

In outcrop the dikes appear dark brownish gray to light greenish gray; white euhedral phenocrysts of plagioclase as much as 10 mm long are embedded in a gray groundmass. Small flakes of biotite and prisms of hornblende can be seen megascopically. Plagioclase is replaced by epidote to some extent in all exposures investigated. It is believed that the "epidotization" is related to hydrothermal activity, for it is more prevalent in those dikes in which shearing can be observed. In some places the replacement is so advanced that the entire exposure has a pronounced greenish hue.

Four thin sections of these rocks were studied. The coarse-grained fraction consists of andesine ($Ab_{56}An_{44}$), hornblende, biotite, chlorite, and sericite, which make up approximately 50 percent of the rock. Little can be said about the aphanitic groundmass, because it is too fine grained and has been too strongly sericitized for identification of the original minerals by optical methods. Although no quartz or K-feldspar could be observed in the groundmass, they were detected by x-ray analysis.

The andesine, which forms about 60 percent of the phaneritic portion, occurs as euhedral phenocrysts as much as 10 mm in diameter. Most of it is strongly sericitized and in some places it displays sutured edges that indicate that it was partly resorbed by the melt before solidification. Zoning can be observed in some crystals. Most of the crystals poikilitically enclose numerous small hornblende euhedra.

Hornblende phenocrysts, elongate prisms as much as 3 mm long, make up approximately 30 percent of the coarse-grained fraction, and biotite and chlorite approximately 5 percent, as small flakes 0.5 to 1 mm across. Epidote, in radiating fibrous crystal clusters, is found partly replacing the plagioclase and makes up approximately 5 percent of the rock.

No appreciable differences can be found in the mineralogy of the dark and light-colored porphyrys, which in some places crop out side by side. The difference in color may be attributable to a larger percentage of ferromagnesian minerals in the darker aphanite.

No chemical analyses of the porphyry and the granodiorite are available for comparison, but the phenocryst composition and the x-ray evidence of quartz and K-feldspar in the groundmass of the porphyry suggest that the dikes and the stock originated from a common magma source.

In general, porphyritic dike rocks are widely scattered throughout the district but they occur mainly in a well-defined zone a quarter of a mile wide located half a mile east of the granodiorite contact. Individual dikes range in width from 4 to 50 feet. Maximum lengths of about half a mile were traced. All contacts observed in the field are knife-edged. No difference in grain size near the edges of the dikes could be discerned, and no metamorphic effects could be found in the sediments.

The dikes in the main zone strike roughly N. 40° E. and dip nearly vertically. In other parts of the area the strike and dip of porphyry dikes varies somewhat at random. A small plug-shaped body of dacite intrudes the Garnet Range Formation a short distance east of the Hidden Treasure mine. Two dikes extend from its northern contact.

It is believed that the dikes were emplaced along tensional fault fractures. Some dikes are sheared, indicating the effects of later faulting.

METAMORPHIC ROCKS AND CONTACT METAMORPHISM

The effects of contact metamorphism caused by the intrusion of the Clinton stock can be seen in a zone of hornfels 600 feet wide in the Garnet Range Formation. This zone parallels the igneous contact, and as might be expected, is most intense near it.

The rock is light to dark gray mottled with dark spots. The mottling is caused by concentrations or clusters of very fine grained ferromagnesian minerals and sericite, which weather in relief, giving the rock a botryoidal appearance on weathered surfaces.

Under the microscope, thin sections of the rock show that it is composed essentially of quartz and fine-grained dark-green amphibole and scattered concentrations of fine-grained sericite. Small veinlets of chlorite fill fractures in some areas. Locally, abundant fine-grained pyrite has formed bands.

No contact effects associated with the diabase or the porphyry were observed.

STRUCTURAL GEOLOGY

Folds.--The Garnet Range Formation in the map area is exposed along the south limb of a broad overturned anticline that extends southeastward parallel to the grain of the regional structure. Pardee's map (1918, p. 172) indicates that the crest is located about a mile farther north and that the structure trends about N. 50° W. and plunges gently to the southeast.

Dips on the south limb are variable, and the structure is complicated by several northeast-trending minor folds, apparently caused by forces attendant to the intrusion of the Clinton stock. Beds near the lower portal of the Hidden Treasure mine have been slightly overturned to the south.

Faults.--Three interbranching, east-trending steeply dipping faults on which vertical movement is estimated to be several hundred feet were mapped along Wallace Creek (pl. 1). To the west, between two segments, a wedge of Pilcher Quartzite has been relatively downdropped into the Garnet Range Formation. To the east, a wedge of Garnet Range Formation containing the diabase sill has been relatively downdropped. Although the faults are concealed, the following evidence indicates their presence and position:

1. The steeply dipping Garnet Range Formation is brought into contact with the relatively flatlying Pilcher Quartzite along Wallace Creek.
2. The diabase sill has been offset in two places.
3. Zones of brecciation and gouge can be seen in road cuts.
4. Wallace Creek and the West Fork of Cramer Creek form a lineament, which can be seen on aerial photographs.
5. Numerous springs occur along the projected fault traces.

Several parallel lineaments, which seem to indicate subsidiary faults, can be seen on aerial photographs. They occupy a zone a quarter of a mile wide on the south side of Wallace Creek and extend for approximately 15 miles to the east along Wallace Creek and the West Fork of Cramer Creek. They are not shown on the accompanying geologic map (pl. 1).

Two sets of mineralized minor faults can be seen on the surface and in the underground workings. One set strikes northeast and dips vertically to 70° E. The other strikes north and dips 70° to 25° W. These structures are considered in more detail under the heading Ore Deposits.

Two other nonmineralized faults, which gave evidence of strong movement, were observed in the workings of the Hidden Treasure mine. They strike roughly N. 10° W., and dip 80° SW. At the time of the investigation, they were not sufficiently exposed to allow further observations; they are not exposed on the surface.

STRUCTURAL GEOLOGIC HISTORY

The structural geologic history of the Clinton mining district can be interpreted from the relationships of the igneous rocks and structural features in the mapped area. The first igneous activity resulted in the injection of a thick diabase sill in the Garnet Range Formation. This event must have preceded regional folding, because it seems improbable that the sill could have been injected concordantly in tightly folded rocks. After injection of the sill, compressive forces acting in a northeast-southwest direction deformed the entire area during the Laramide orogeny in late Cretaceous or early Tertiary time. These stresses formed northwest-trending folds and faults in western Montana.

To the north of the map area, the Garnet Range Formation was folded into a northwest-trending anticline. Igneous activity followed, resulting in the intrusion of the Clinton stock transverse to the regional structural grain. No definite age can be assigned to the stock, but on the basis of lithologic similarities it is tentatively correlated with other intrusions in western Montana (late Cretaceous or early Tertiary) for which age dates are available. Chapman and others (1955, p. 608), measured lead-alpha activity ratios in radioactive monazite and zircon from the Boulder batholith and the Philipsburg batholith. Based upon five samples, the average determination for the Boulder batholith was 68 million years, suggesting its time of emplacement at or near the end of Cretaceous. Based upon one sample, the age of the Philipsburg stock was found to be 50 million years or early Tertiary. Knopf (1950, p. 834-844), using Ar^{40}/K^{40} found an age of 78 million years for granodiorite from the Marysville stock at Marysville, Montana, suggesting emplacement in late Cretaceous.

Tension fractures post-dating intrusion of the Clinton stock were injected by magma, chemically similar, and probably genetically related to the granodiorite. This formed the dacite dikes of the district. The chronology of the formation of the large normal faults along Wallace Creek is not entirely clear. Presumably it was pre-mineralization, because extensions of the veins are not found south of the fault traces along Wallace Creek. Later tensional fracturing provided openings along which the mineralized veins of the district were formed.

Subsequent warping and uplift, coupled with active erosion, has exposed the stock and the mineralized veins.

ORE DEPOSITS

GENERAL CHARACTER

The ore bodies of the district are copper-silver, lead-gold deposits; the metals are listed in order of economic value. The results of mineralization in the sedimentary rocks (as seen in the Hidden Treasure mine) differ markedly from those in the granodiorite (as seen in the Cape Nome mine). These differences are probably attributable mainly to the differing chemical properties of the host rocks. There is also a distinct difference in the attitude of the main mineralized structures. In the sedimentary rocks the major veins strike northeast, parallel to the igneous contact, and the dip ranges from vertical to 70° SE. In contrast, the veins within the granodiorite strike predominantly north and the dip ranges from vertical to 60° W. Striations and fault gouge in most of the veins is evidence of pre- or post-mineralization fault movement. It seems likely that the structures were formed by tensional fracturing caused by contraction of the igneous body during cooling, and attendant release of stress in the adjacent sediments.

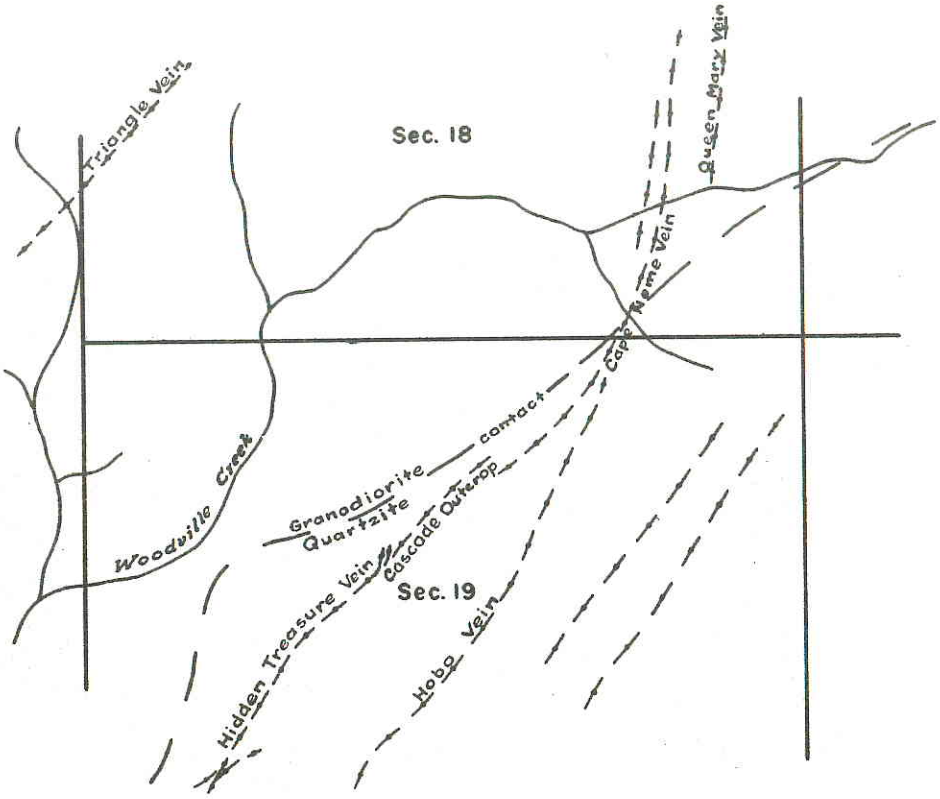


Figure 2.--Sketch map showing relative locations of veins in the Clinton mining district.

Mineralization in the sediments produced small, discontinuous, lenticular replacement bodies in shear zones. These replacement bodies average 20 feet in length and are rarely wider than 3 feet. No well-defined ore shoots are known. A zone of ore minerals in the Hidden Treasure mine seems to plunge steeply to the south, roughly parallel to the dip of the country rock.

In general, the mineralization in the veins within the granodiorite seems to be more nearly continuous. The veins contain fissure fillings as much as 7 feet wide and continuous for distances of 200 feet. Because little active mining has been carried on in the granodiorite and because most of the workings are inaccessible, relatively little is known of the details of the ore bodies there.

MINERALOGY

Classification of ore

Based upon mineralogy, five distinct types of ore can be recognized in the Clinton mining district. In general, they are developed dominantly in one or the other of the two vein types--replacement in the sedimentary rocks and fissure filling in the granodiorite.

1. Chalcopyrite-tetrahedrite ore:
   This type occurs in the Hidden Treasure mine and is the most common association in the sedimentary rocks. The veins strike northeast and dip vertically to steeply east.

2. Galena-chalcopyrite ore:
   This ore is dominantly galena, but contains minor amounts of chalcopyrite and tetrahedrite. It occurs within the sedimentary rocks of the Hidden Treasure mine in stringers that strike northwest and dip relatively gently to the southwest.

3. Galena-sphalerite ore:
   Only one ore of this type was noted, and it can hardly be called ore in a true sense, but it does represent a distinct type. It is composed of almost equal amounts of galena and sphalerite but includes minor chalcopyrite. It forms small stringers in a dacite dike approximately 1,200 feet east of the Hidden Treasure vein.

4. Chalcopyrite-bornite ore:
   This is the typical ore found in veins within the granodiorite. In the Cape Nome vein it locally contains depreciable amounts of enargite and chalcocite.

5. Oxidized ore:
This is a weathered product of the veins of the district. It consists of weathered gangue and country rock, the fractures and free surfaces containing the typical oxide minerals of copper and lead.

SULFIDE ORE MINERALS

Chalcopyrite.--Copper pyrite ($CuFeS_2$) is the most common ore mineral in the district and was identified in all the veins investigated. It forms irregular stringers and veins as much as 12 inches wide in the Hidden Treasure vein. It is intimately mixed with gangue minerals, but does form rare clotlike concentrations as much as 3 inches in diameter. In the sedimentary rocks it is associated with tetrahedrite and galena; in the granodiorite, with bornite and chalcocite. Chalcopyrite, in the Hidden Treasure mine, contains appreciable amounts of silver. Assays indicate that the ratio is approximately 4 ounces of silver for each percent of copper; very little gold is present.

Tetrahedrite.--"Gray copper" ($Cu_3(Sb,As)S_3$) is the second most abundant ore mineral in the chalcopyrite-tetrahedrite ores of the sedimentary rocks, but it was not noted in any of the veins within the igneous rocks. In the Clinton district it is recognized by its gray color and reddish-brown streak. It carries very little silver; assay results show a ratio of about 1 ounce of silver for each percent of copper present.

The tetrahedrite seldom is found in massive concentration, but rather as disseminations and fine veinlets. In some places it was deposited in openings as small perfectly formed tetrahedra. The largest single crystal observed was approximately $\frac{1}{2}$ inch across.

Galena.--Lead sulfide (PbS) is widely distributed throughout the veins in the sedimentary rocks, but only sparingly in the granodiorite. Its main occurrence is in the galena-chalcopyrite ores in narrow west-dipping stringers in the Hidden Treasure mine. Finely crystalline "steel galena" in the more prominent veins yields appreciable quantities of gold. Unfortunately, these occurrences are extremely small and sparse. In the galena-sphalerite ores, galena occurs as perfectly formed cubes.

Bournonite.--Bournonite ($PbCuSbS_3$) is found along galena-tetrahedrite borders.

Bornite.--"Peacock copper" (Cu_5FeS_4) is found only in the chalcopyrite-bornite ores in the granodiorite. It is closely associated with chalcopyrite in the veins, and in most places is accompanied by small amounts of chalcocite and enargite.

Enargite, var. luzonite.--Luzonite (Cu_3AsS_4) is found in most of the ore samples collected from the chalcopyrite-bornite ores of the Cape Nome mine. Megascopically, it is recognized by a dark-gray sooty appearance and submetallic luster. In polished section, it has a definite pinkish cast.

Chalcocite.--"Copper glance" (Cu_2S) occurs as a primary mineral in the hypogene zones of all the veins in the granodiorite. It is found as an important mineral consitutent of the chalcopyrite-bornite ores in the Cape Nome mine.

Pyrite.--Iron sulfide (FeS_2) is widely scattered in small amounts throughout the district, but in comparison with other similar deposits, it is notably lacking in abundance. Normally it is nearly white to pale yellow. It occurs in minute fractured grains in the veins and in small striated cubes scattered throughout the wall rock.

Sphalerite.--"Rosin jack" (ZnS) has been identified in the galena-chalcopyrite ores in the Hidden Treasure mine, but it is present in such small amount that it hardly deserves mention. In the Hobo prospect, east of the Hidden Treasure, spahlerite is nearly as abundant as galena, but this occurrence is unimportant from an economic standpoint because the deposit consists of a few small stringers, the largest of which are hardly an inch wide.

SECONDARY ORE MINERALS

In general, the depth of partial to complete oxidation extends 100 to 150 feet below the surface. Where fracturing has provided permeable pathways for downward-moving meteoric waters, local oxidation has been observed as much as 800 feet below the surface. A weak zone of supergene sulfide enrichment is found at the bottom of the zone of oxidation in the Hidden Treasure mine; its vertical extent averages 50 feet.

Cerussite.--Lead carbonate ($PbCO_3$) is found in minor quantities in the oxidized outcrops of some of the lead-bearing veins in the district. It exists as crusts on galena and as small brilliant white crystals in cavities.

Chrysocolla.--Copper silicate ($CuSiO_2 2H_2O$) occurs in the oxidized ores of all the veins in the district. Normally it is waxy green to blue green and forms crusts or scales in fractures and on free surfaces.

"Copper Pitch".--A brown to black impure copper oxide is found in fractures and free surfaces of the oxidized outcrop of the veins. It is mixed with various amounts of iron oxide and manganese oxide.

Covellite.--Copper sulfide (CuS) occurs as a supergene sulfide mineral coating galena and chalcopyrite in the workings of the Hidden Treasure mine, but is extremely rare.

Chalcocite.--Sooty copper glance (Cu_2S) occurs in small quantities in the upper workings of the Hidden Treasure mine, where it replaces chalcopyrite and tetrahedrite. It cannot be recognized megascopically except where it has been deposited along fractures as a thin steely gray film on chalcopyrite.

Malachite.--Green copper carbonate ($Cu_2CO_3(OH)_2$) is the most common of the secondary copper minerals in the district. It forms greenish stains or small crusts on the veins where they are exposed at the surface. Where openings are available, it forms as small clusters of radiating acicular crystals. Malachite can be found as far as 800 feet below the ground surface where fractures have provided water courses for meteoric waters.

Azurite.--Blue copper carbonate ($2Cu_2CO_3(OH)_2$) is scattered in the district, mainly very near the surface, where it forms thin bluish films in fractures. In some cavities it has been deposited as tiny crystals.

Native Copper.--Metallic copper (Cu) was identified in gravity concentrates during an attempt at milling oxidized ore from the Cascade outcrop. It is sparse, and unimportant from an economic standpoint.

Chalcanthite.--Blue vitriol ($CuSO_4 \cdot 5H_2O$) is found locally as a thin coating on the walls of old workings in the Hidden Treasure mine.

GANGUE MINERALS

Quartz.--Silica (SiO_2) is widely distributed in the ore deposits of the Clinton district. It forms the principal filling of all the veins. Most of it is gray to white and fine grained, and can be recognized as belonging to one of the several stages during which the quartz was introduced into the veins. Some of it, however, seems to be silicified inclusions of wall rock.

Barite.--Heavy spar ($BaSO_4$) is an abundant gangue mineral in the Cape Nome vein and is present in lesser amounts in most of the other veins of the district. On the 300-foot level of the Cape Nome mine, an intergrowth of massive barite and siderite was observed filling the entire width of the vein, which is as much as 7 feet wide in one place. Most of the barite is milky white and coarsely crystalline, but no individual crystals were found.

Siderite.--Iron carbonate ($FeCO_3$) is present in all the veins of the district and is especially abundant in the veins within the granodiorite. It is cream colored when fresh, but in weathered outcrop it is deep reddish brown. Where openings were available, it was deposited in perfect rhombs as much as $\frac{1}{2}$ inch across. Siderite was positively identified by x-ray diffraction.

Calcite.--Calcium carbonate ($CaCO_3$) is present in small amounts in all veins studied. It is a late-stage mineral of hypogene origin. In the Hobo prospect, east of the Hidden Treasure mine, it constitutes the principal gangue.

Hematite.--Specularite (Fe_2O_3) was one of the first primary minerals formed. It is found in thin seams so fine grained and so nearly pure that it strongly resembles graphite. As clots and stringers it is one of the most common gangue minerals in the more prominent veins, although it was not observed in the galena-chalcopyrite ore veins. The Triangle and Alladin veins contain hematite so abundantly that they might more properly be referred to as deposits of iron rather than base metals.

ENRICHMENT

When ore deposits, especially those of copper, are exposed to oxidization, sulphide minerals tend to break down into soluble and insoluble products. The soluble products are carried downward below the water table by meteoric waters and deposited as sulphides upon other sulphides, thereby forming a zone of supergene sulfide enrichment. In some districts this zone of enrichment is the only portion of the deposit rich enough to be mined.

One of the prime requirements for supergene enrichment is the availability of sulfuric acid and ferric sulfate, which take the metallic ions into solution. Most commonly, both solvents are derived from the decomposition of chalcopyrite and pyrite under weathering conditions.

Climatic conditions and the relative paucity of pyrite in the Clinton district may have hindered the formation of solvents adequate for strong supergene enrichment. A zone extending through a vertical distance of 20 to 100 feet below the ground surface has been somewhat enriched, and it produced most of the ore in the early days of mining. It is possible that a long time of exposure to erosion together with an actively declining water table have offset the relatively small sources of available solvents. Although the supergene zone does not constitute a bonanza-type deposit, it nevertheless is an important factor in the economics of the district, as the ores are as much as twice as rich as those in the hypogene zone.

In general there is no enrichment of the oxide zone, although local oxide "blooming" in some of the vein outcrops has caused appreciable apparent widening of the veins. Thus a narrow vein called the Cascade outcrop produced a greater mining width at the surface.

MINERAL ZONING

What might be described as lateral zoning of minerals can be found when comparing the ores of the Hidden Treasure and Cape Nome mines. Whether this is caused by differences in the composition of the wall rock (which in turn affected the chemistry of the ore solutions), or by differing pressure-temperature conditions during deposition, is not known. The former is suspected, mainly because of the fact that no bornite is found in the veins within the sedimentary rocks, but it is found in all adjacent veins in the granodiorite, which must have been mineralized under similar temperature-pressure conditions. Galena, which is abundant in the ores within the sedimentary rocks, is present in only very minor amount in the granodiorite. Thus, probably there is a chemical rather than a temperature-pressure cause for the mineral zoning.

HIDDEN TREASURE MINE

Development

The development work of the Hidden Treasure vein has been accomplished largely through adits, known as the No. 1 tunnel (at 4,263 feet elevation) and the No. 2 tunnel (at 4,000 feet elevation). The ore bodies have been stoped considerably above the upper tunnel, but are almost unexplored between the two levels. About 1,800 feet of drifts and crosscuts have been driven on the upper level, and about 2,900 feet on the lower level. The two levels are interconnected by a vertical two-compartment raise and a "doghole" raise, which connects with the original discovery shaft. (Refer to vertical section shown on fig. 3.)

Ore Bodies

The ore bodies in the Hidden Treasure mine are principally copper and silver, but contain minor amounts of lead and gold. They occur as discontinuous lenses (as described under Ore Deposits) along a northeast-trending, steeply dipping shear zone known as the Hidden Treasure vein. The strike of the zone is irregular, but it averages N. 40° E., and the dip ranges from vertical to 70° SE. The width ranges from 3 to 40 feet. Mineralization has taken place as fissure filling but predominantly as replacement of the brecciated country rock within the shear zone.

Data collected during geologic mapping indicate that ore is concentrated where west-dipping splits converge upward with the predominantly east-dipping shear zone. Figures 4, 5, and 6 are geologic maps of portions of three levels of the Hidden Treasure mine. Note the relationship of minerals with west-dipping splits.

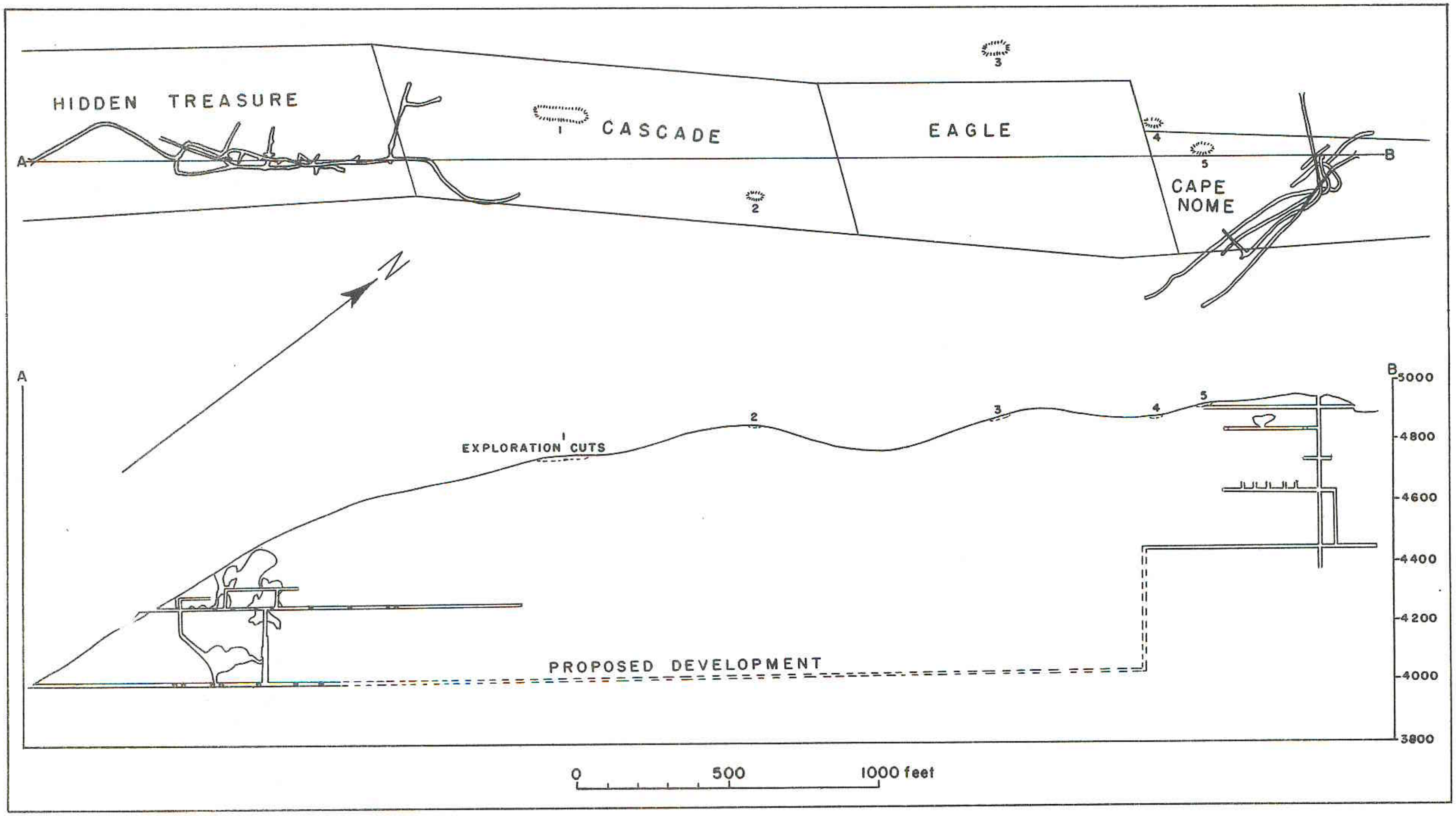


Figure 3.--Vertical longitudinal section, Cape Nome and Hidden Treasure mines.

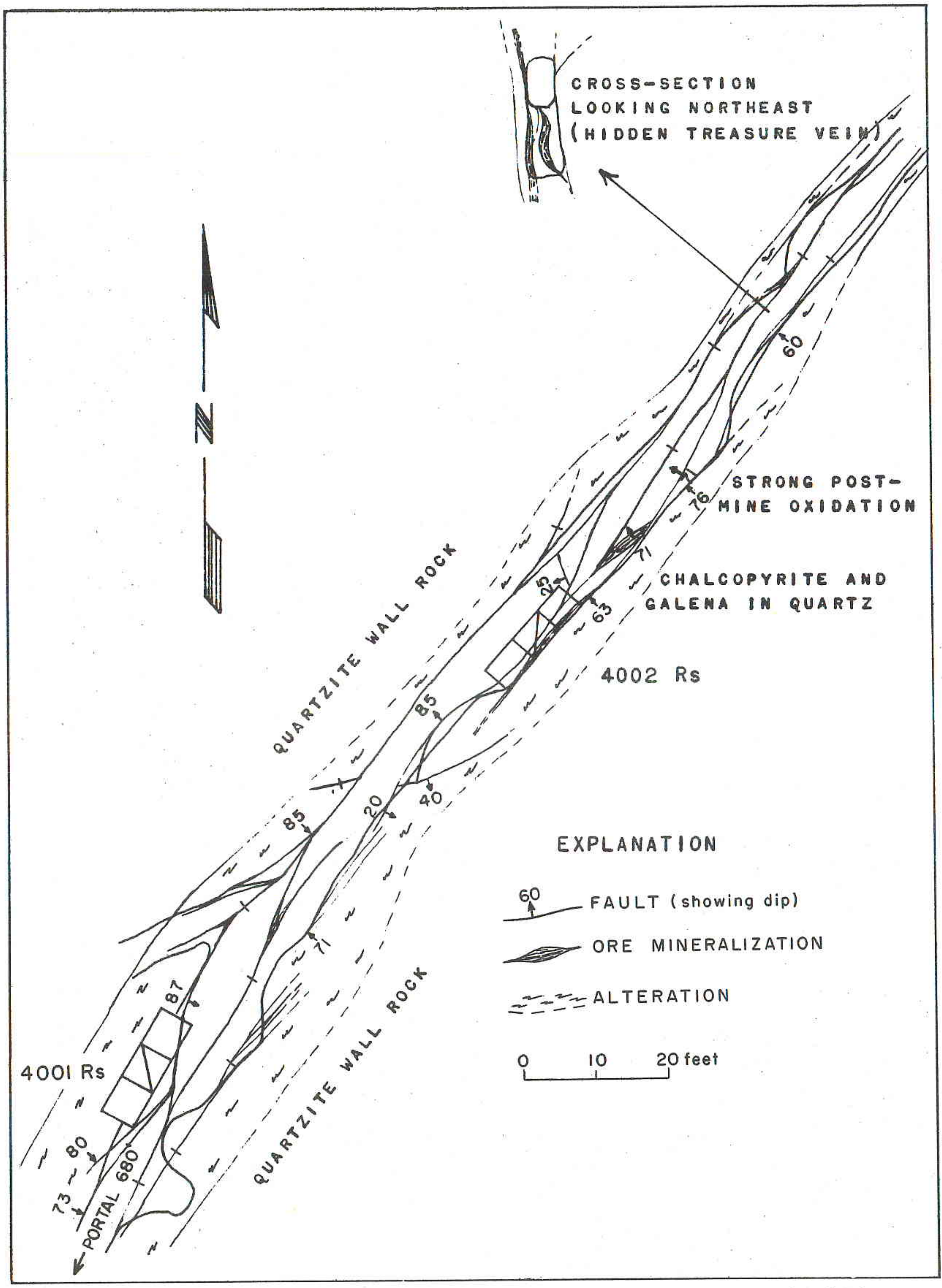


Figure 4.--Geologic map of part of lower adit level, Hidden Treasure mine.

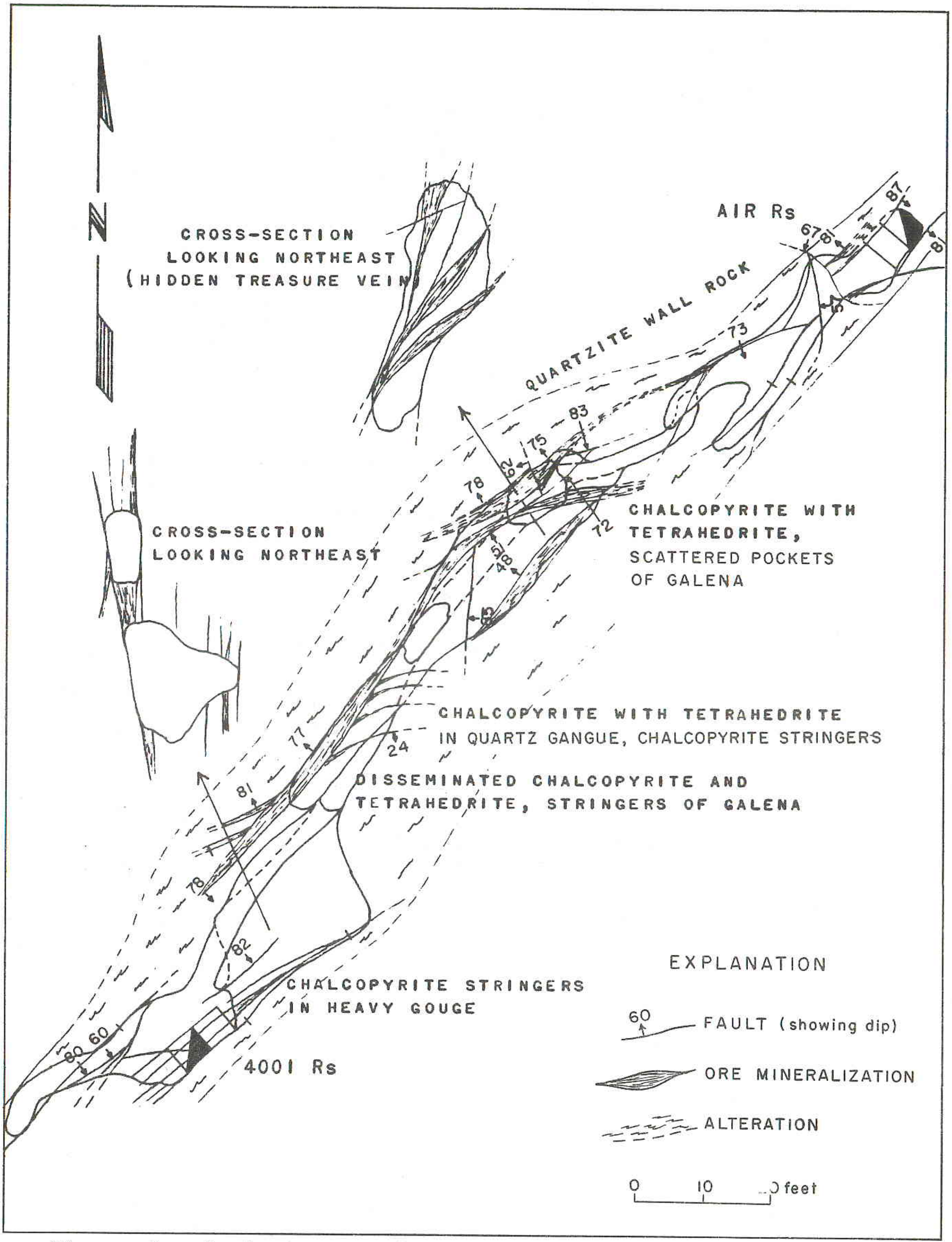


Figure 5.--Geologic map of intermediate level, Hidden Treasure mine.

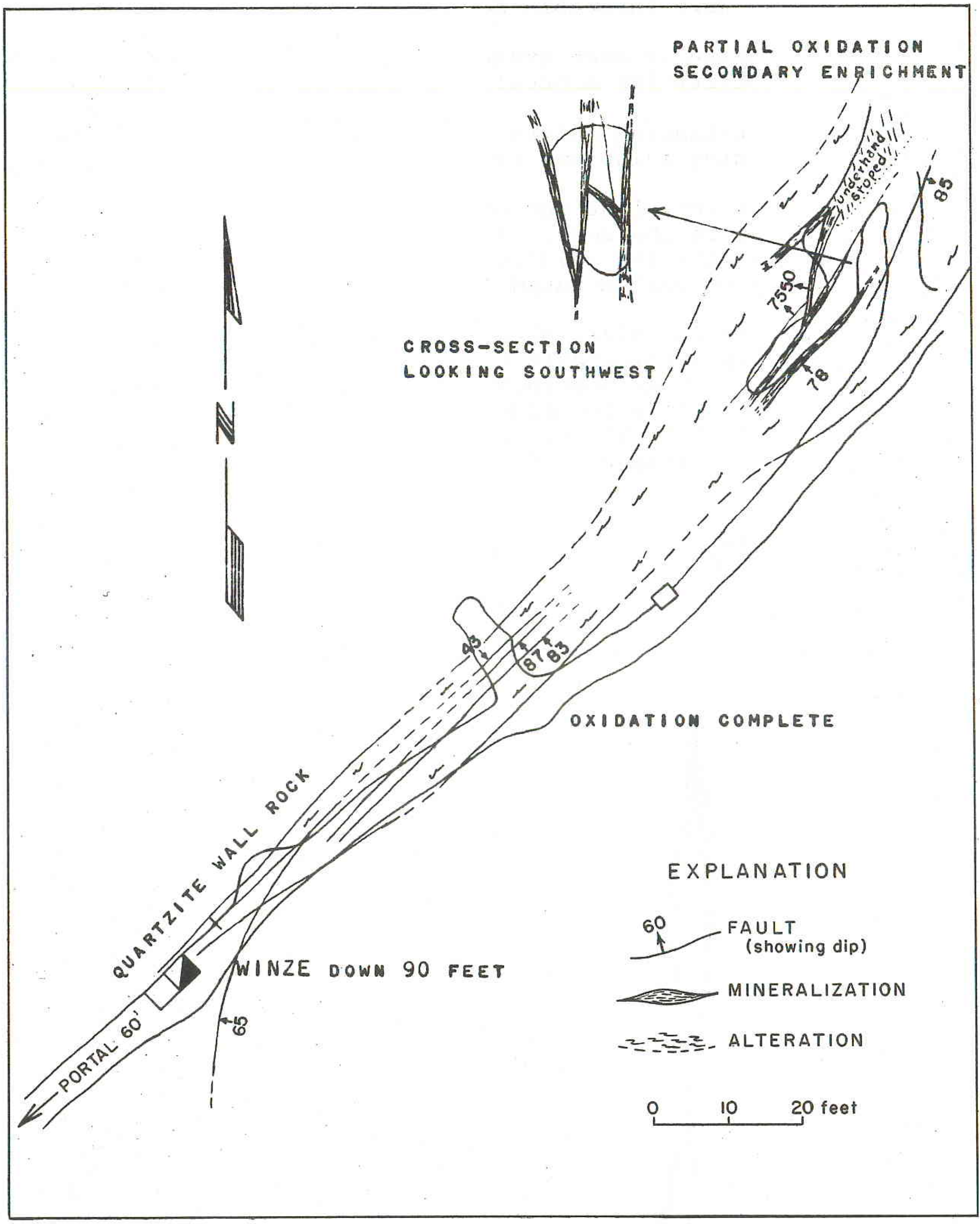
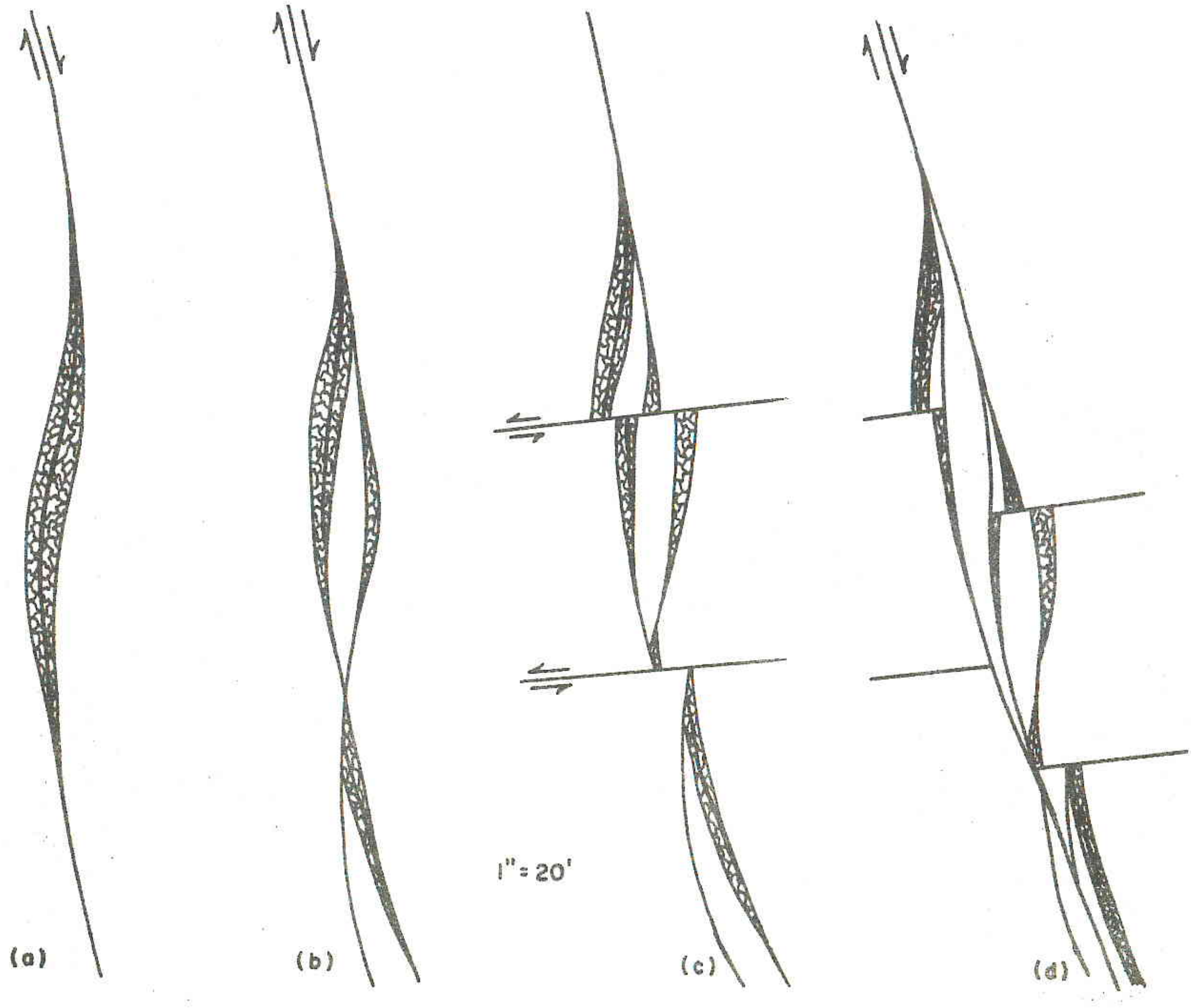


Figure 6.--Geologic map of part of upper adit level, Hidden Treasure mine.

This convergence may reflect some or all of the following local conditions, which were favorable for mineralization:

1. Brecciation is more pronounced, allowing greater permeability for mineralizing solutions.
2. The west-dipping splits were the main conduits for ore-forming solutions from depth.
3. Gouge is prevalent where the more radically divergent splits join the zone. This gouge may have filtered the mineralizing solutions, causing the metallic ions to be concentrated and precipitated.

The localization, size, shape, and continuity of the ore bodies are directly attributable to the effects of multiple stages of faulting. Four distinct stages were recognized and mapped in the Hidden Treasure mine. Figure 7 is a sequence of idealized cross sections of the ore body in the 4001 raise, showing the inferred stages of development.



Paragenesis

A microscopic study of polished ore samples revealed a definite sequence of deposition and gave an indication of the structural history during and after the deposition of ore. The following sequence was determined:

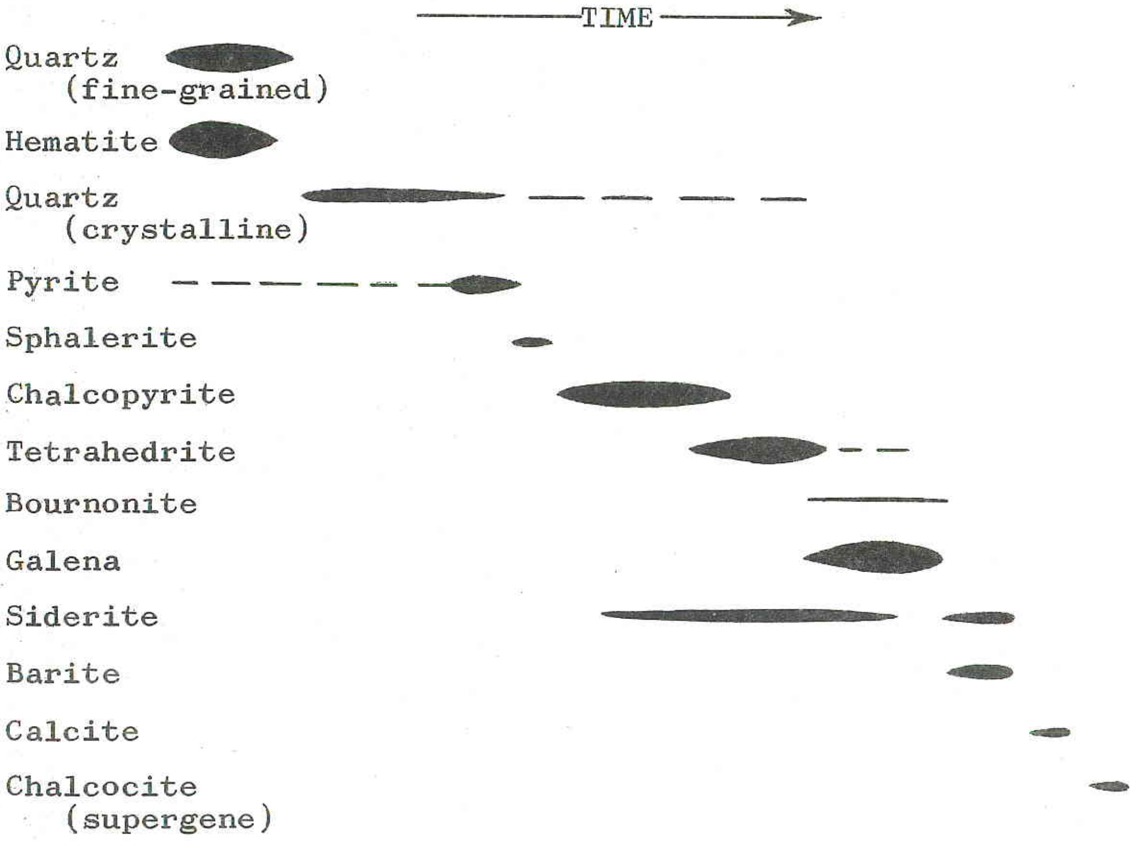


Figure 8.--Paragenetic diagram showing the sequence of deposition of minerals of the Hidden Treasure mine.

Figure 7.--Sequence of idealized cross sections of vein in 4001 raise of Hidden Treasure mine, viewed from southwest.

(a) Faulting along curved plane produced an opening, which was partly filled with gouge and brecciated wall rock. Mineralizing solutions penetrated all open spaces; minerals cemented the crushed wall rock.
(b) Faulting along another curved plane cut diagonally through the vein, dividing it into three segments. Vein minerals introduced along this fracture filled all available openings and replaced wall rock for a short distance.
(c) "Flat faults" cut across the vein. Their dip ranges from 25° to 60° W. (Apparent dip is shown--dip is somewhat toward reader.) Observed displacement ranges from 3 to 36 inches, and maximum displacement probably does not exceed 10 feet. "Gouge ore" indicates post-mineralization movement.
(d) Faulting along a third curved plane again produced openings, and provided a conduit for mineralizing solutions. Vein minerals filled the openings and replaced the adjacent wall rock.

The first mineral deposited was hematite, which was introduced by early stage hydrothermal solutions after the formation of primary fractures. This stage also produced silicification of the wall rock and cementation of the zones of brecciation (fig. 7a). Seemingly a small amount of pyrite was also deposited at this time.

Subsequent movement brecciated the vein filling and reopened the fractures, making way for a new wave of solutions. Crystalline quartz and then pyrite were deposited along fractures in the wall rock and earlier vein filling (fig. 7b). Sphalerite was deposited locally. There is no evidence of replacement during this stage of mineralization.

A change of conditions brought widespread deposition of copper in the form of chaclopyrite. It replaced quartz, hematite, and pyrite to some extent, and nearly obliterated any traces of the earlier formed sphalerite. Siderite deposition began in this stage and overlapped the next. Tetrahedrite followed, and it replaced hematite, chalcopyrite, pyrite, and wall rock, locally for a distance of 6 inches outward from the guiding conduit fractures.

The next stage, in which galena was deposited, seems to have been preceded by movement that widened the veins to allow fissure filling locally. Bournonite is found as a common mineral (probably resulting from the reaction of galena with tetrahedrite) along galena-tetrahedrite boundaries. Bournonite replaced tetrahedrite. Galena replaced all the earlier formed ore minerals.

Repeated movement formed openings along which siderite and barite were introduced. Both these minerals were deposited primarily as fracture filling, but some replacement by siderite can be found locally.

Late-stage tetrahedrite was deposited locally in vugs as perfect crystals on siderite.

Post-mineral movement is indicated by slickensides on ore minerals and by "drag ore" completely surrounded by fault gouge. Calcite can be found in small, late-formed fractures that cut the other minerals.

Secondary chalcocite had replaced chalcopyrite and tetrahedrite in samples taken from the enriched zone above the upper adit of the Hidden Treasure mine.

Alteration

In the sedimentary rocks bordering the Hidden Treasure vein, alteration is indicated by strong bleaching of the wall rock. This is caused by sericitization and silicification of the metamorphosed Garnet Range Formation. The intensity of the bleaching seems to be proportional to the intensity of mineralization and could be used as a guide in the search for ore. The halos of alteration extend outward from the veins for distances of 1 to 20 feet. Between the zones of alteration most of the rock is fresh, except where cut by subsidiary fractures. Alteration is most intense in the hanging walls of the veins.

Microscopic observations comparing fresh with hydrothermally altered material showed that alteration caused removal of pyrite and amphibole and introduction of sericite and quartz.

CAPE NOME MINE

Development

The development workings of the Cape Nome mine consist of two adits and a two-compartment vertical shaft from which crosscuts and drifts have been driven on three levels. (Refer to the vertical longitudinal section on fig. 3, which shows the relationships of these workings.) Underground workings aggregate nearly 6,000 feet. They are described as follows:

1. Upper tunnel.--This is an adit, which was driven southward on the Cape Nome vein for approximately 800 feet. At the time of the investigation, it was caved and inaccessible.

2. Lower tunnel.--(100-foot level shown on fig. 9.) This is also an adit, consisting of a crosscut for approximately 300 feet east to the Cape Nome vein and 350 feet of drift to the south. Another crosscut was driven west for 90 feet from the end of the drift.

3. Cape Nome shaft.--A well-timbered vertical two-compartment shaft has been sunk to a depth of 500 feet. A sump extends 15 feet below this.

4. 200-foot level.--A station was cut and a drift extended approximately 75 feet southward at a point 200 feet below the shaft color. It explores a weak structure not exposed in any of the other workings.

5. 300-foot level.--From the 300-foot level of the shaft, a crosscut was driven east for 108 feet to the Cape Nome vein. From this point, a drift extends south along the vein for approximately 420 feet. The workings to this depth were examined briefly in 1958 during an attempt to dewater the Cape Nome shaft.

6. 500-foot level--The workings on the 500-foot level consist of a crosscut driven east for 124 feet to the Cape Nome vein. A drift along the vein extends approximately 800 feet to the south. A raise on the vein

connects the 300- and 500-foot levels near the end of the crosscut. Rowe (1910, p. 1101) reports that the Speculator Mining Company of Butte, Montana, extended a drift from the 500-foot level of the Cape Nome shaft approximately 1,800 feet to the north.

Ore Bodies

The ore bodies of the Cape Nome mine occur along a series of north-striking faults that dip near vertical to approximately 60° W. The major structure in the mine is the Cape Nome vein, which has been explored for nearly 1,000 feet along its strike and to a depth of 500 feet. Little is known of the vein on the 500-foot level, but according to old reports, it is "still strong and well mineralized". During the course of this investigation, parts of the lower tunnel not covered by timbering were mapped in detail and the 200- and 300-foot levels were examined briefly.

The Cape Nome vein as seen in the lower tunnel (fig. 9) dips nearly vertically, and width ranges from 5 to 12 feet. Fissure filling is not continuous, but consists of lenticular bodies 30 to 50 feet long and as much as 3 feet wide. Oxidation of the vein in the lower tunnel has changed most of the primary sulfides (chalcopyrite, bornite, chalcocite, enargite, pyrite, and galena) to secondary carbonates and oxides, except where the enclosing gangue has protected them from oxidation.

The crosscut of the lower tunnel also cuts another vein approximately 150 feet from the portal. Because the vein does not crop out at the surface, it is known as the Blind lead. It strikes nearly parallel to the Cape Nome vein but dips west at an average angle of 65°. Width ranges from 4 to 8 feet. Mineralization filled fissure along the footwall in short lenticular bodies of greater vertical than horizontal dimensions. The greatest width of mineral observed was slightly less than 3 feet.

The ore minerals of the Cape Nome mine comprise chalcopyrite, bornite, chalcocite, and enargite. Secondary malachite, azurite, and sooty chalcocite coat fractures and free surfaces in vugs. The gangue is quartz, siderite, and barite. Minor post-mine chalcanthite occurs locally.

During the brief examination of the Cape Nome vein on the 300-foot level in 1958, a reconnaissance was made through accessible workings, and samples were collected for laboratory study. Although no map was made and few measurements taken, the following brief description can be given: The vein width ranges from 3 to 7 feet. Fissure filling by quartz, barite, siderite, hematite, and copper sulfides in most places seems to be continuous over the entire width. The vein dips nearly vertically near the shaft, but toward the southern limit of the accessible workings it dips approximately 70° W.

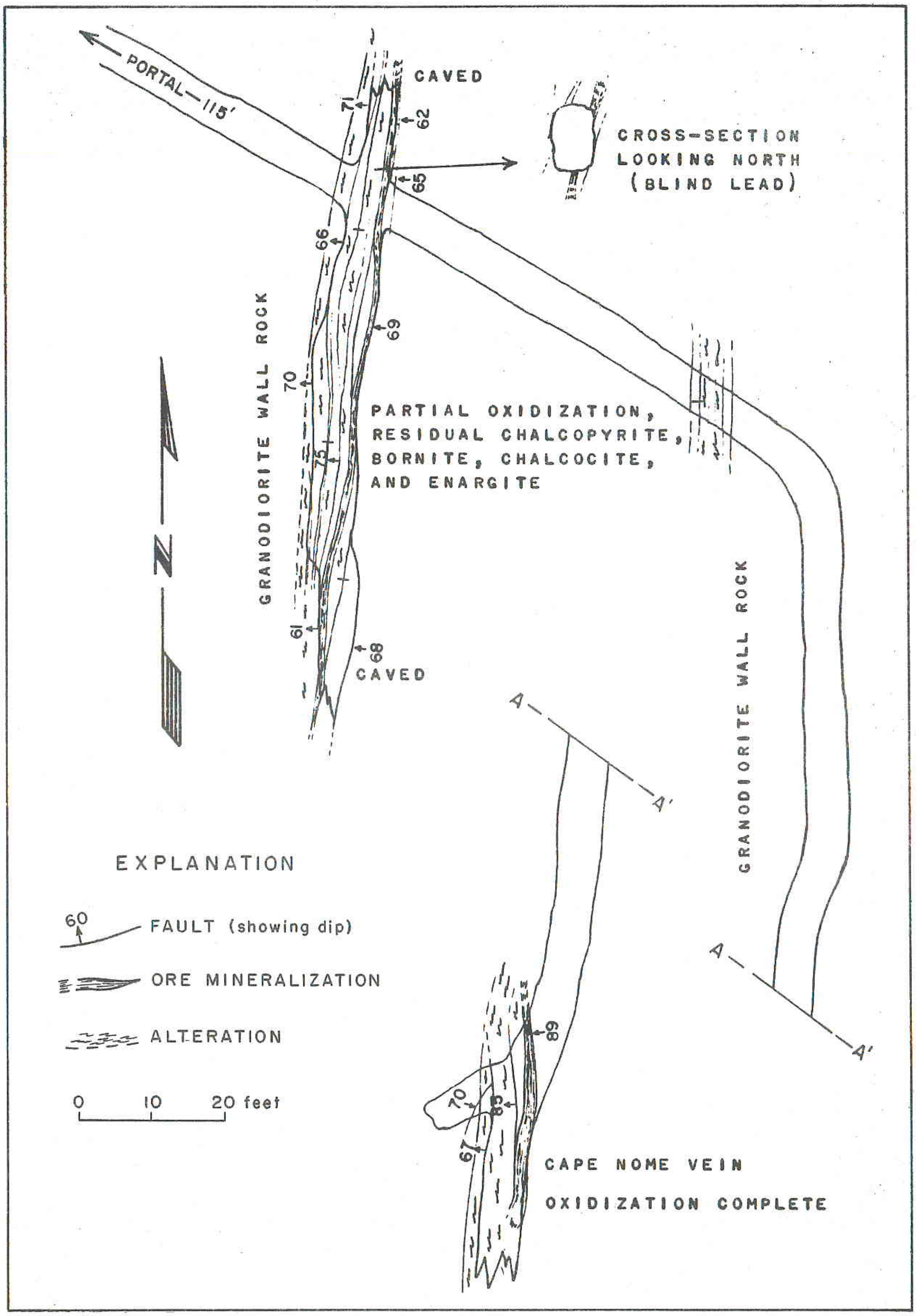


Figure 9.--Geologic map of part of 100-foot level, Cape Nome mine.

The wall rock on this level is much "tighter" than on the upper levels, and evidence of hydrothermal alteration even in close proximity to the vein cannot be seen megascopically. The ore minerals occur in disseminated blebs and narrow stringers; no massive sulfide bodies were observed. Partial oxidation of the sulfides was found locally.

Paragenesis

The following is a paragenetic diagram of the minerals of the Cape Nome mine:

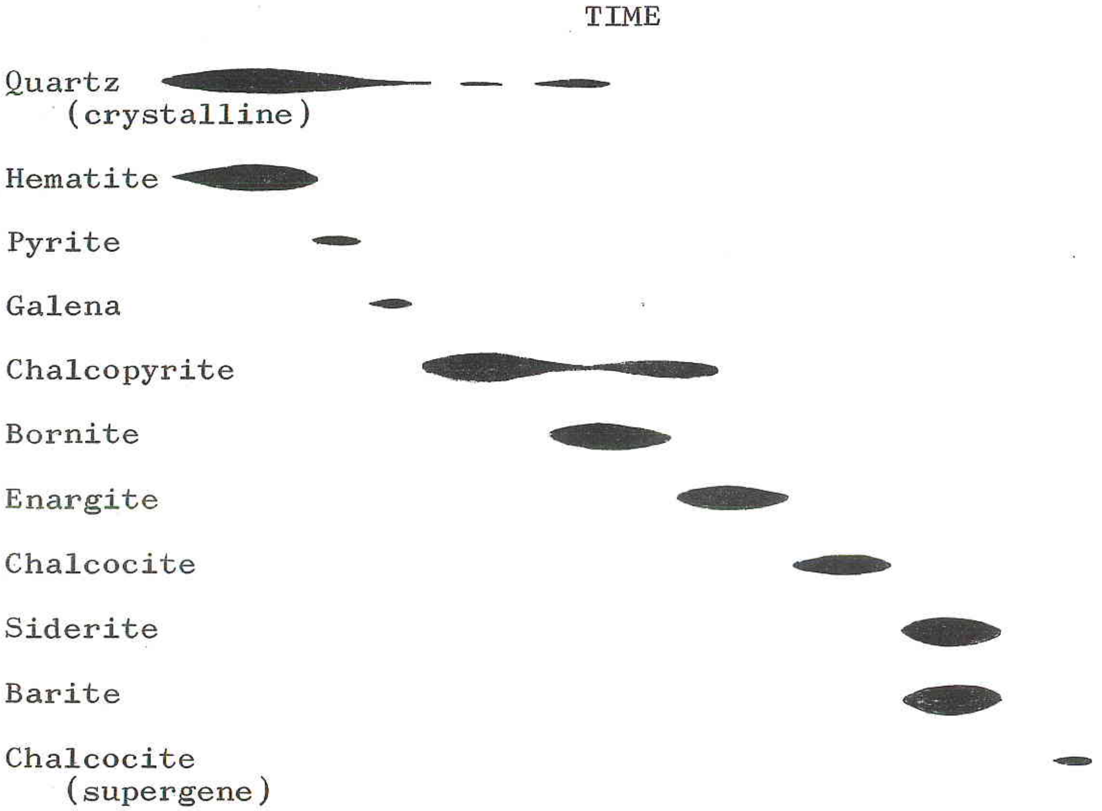


Figure 10.--Paragenetic diagram showing the sequence of deposition of minerals of the Cape Nome mine, based on samples from all accessible workings.

The sequence of deposition of the ores of the Cape Nome mine begins with the introduction of silica along primary fractures in the granodiorite. This stage seems to correlate with the crystalline quartz stage of mineralization in the Hidden Treasure vein. Considerable open space for crystal growth is shown by the abundant euhedral quartz crystals of this stage. Abundant hematite was introduced with the quartz. Sparse pyrite deposition followed.

Movement that resulted in slight widening of the fissures was followed by local deposition of galena, then by deposition of chalcopyrite from copper-bearing solutions. Bornite followed and replaced chalcopyrite. Either a renewal of conditions that precipitated chalcopyrite occurred, or there was an overlap. This stage was accompanied by slight fracturing. Chalcopyrite was deposited again in the fractures and replaced bornite in fine needle-shaped penetrations along cleavage planes.

A change of conditions governing the precipitation of the sulfides was followed by deposition of enargite (var. luzonite). Enargite cut by chalcopyrite indicates that chalcopyrite deposition overlapped into this stage. Enargite cuts both the bornite and the chalcopyrite but seems to replace the bornite preferentially.

Mild fracturing was accompanied or followed by deposition of primary chalcocite. Veinlets cut all the previous minerals. Where they cut the boundary from chalcopyrite into bornite, they swell slightly, indicating a preference for replacement of bornite.

Reopening of the veins was followed by widespread introduction of siderite and barite. Where open spaces were available, the siderite forms cockscomb-shaped crystal clusters. In most places, the siderite and barite were deposited separately, but locally they are intimately intergrown, forming an interlocking texture. The siderite is also found replacing all the ore minerals. It forms fine hairlike threads in the center of chalcocite veinlets that were evidently reopened during a late stage of fracturing. Secondary copper minerals are found replacing all the sulfides along late-formed fractures.

Alteration

In the granodiorite, alteration is weak in the footwalls, but in the hanging walls it is so intense that heavy timbering is required to hold the ground during mining operations. In the upper levels of the Cape Nome, the alteration has softened the wall rock enough to increase permeability, thus allowing surface waters to penetrate and superimpose the effects of weathering on the hydrothermal alteration.

The intensity of alteration seems to be inversely related to the amount of dip of the veins. Where the dip is nearly vertical, no alteration halo can be seen megascopically, although a thin section shows some silicification, strong sericitization of the feldspars, and chloritization of the biotite. Epidote, probably as a hydrothermal alteration product, has been deposited along joints and shear planes. As the dip decreases, alteration increases, especially in the hanging wall. This may be due to retardation of hydrothermal solutions along factures of less dip, or to an increased amount of fracturing in the hanging wall, which therefore carried relatively greater amounts of hydrothermal solutions. Along the Blind lead in the lower tunnel of the Cape Nome, alteration is pronounced for distances of 12 feet into the hanging wall of the vein. The dip is approximately 65° W.

Along the Cape Nome vein on this level, alteration is confined to a narrow zone approximately 1 foot wide on each side of the vein. Here the dip is approximately vertical.

OTHER DEPOSITS

Surface exploratory work throughout the district has exposed numerous promising-looking deposits, most of which are within the granodiorite. The individual veins seen on the surface are characterized by a central zone of iron discoloration and by bleaching, which extends outward on each side. Discoloration is almost everywhere bounded by thick seams of clayey gouge, probably formed by fault movement, and is compounded by weathering, which caused the downward migration and concentration of hydrothermal alteration products of the wall rock. Most of the veins are 1 to 5 feet wide, but a few are as much as 12 feet wide. Measurements of surface exposures must be accepted with caution because "blooming" of the vein outcrops as a result of weathering is common.

Rowe (1910) described several other properties during a time when the district was active. The following descriptions are included to provide a more nearly complete treatment of the entire district in this report:

The Triangle Group.--This group consists of eleven claims, the most important of which are the Triangle and the Grass Widow. There are two veins on the Triangle and the Grass Widow. These two claims are the ones most developed. The main vein has been drifted upon for 540 feet, to a depth of about 400 feet below the outcrop. The vein or fractured zone is in the granite and has several stringers of high-grade copper ore running parallel with it. One of these stringers or seams assayed 15.4 percent copper, 0.24 ounce gold, and 3.2 ounces silver. It is said that the vein in the present face of the tunnel is 14 feet wide and samples taken from the face gave 2 percent copper, 5 ounces silver, and 0.02 ounce gold.

The Grass Widow vein has been opened by two small drifts, one 50 feet and the other 75 feet long. Although the writer did not visit the vein, it is stated in the company's report that it is 5 to 8 feet wide, thoroughly impregnated with chalcopyrite, azurite, and malachite, and assays from these were as much as 26 percent copper, and some gold and silver. A crosscut from the Triangle tunnel 513 feet along to the Grass Widow vein has been run, and a drift of 170 feet run on the Grass Widow vein where this crosscut from the Triangle cuts it.

The Alladin Group.--This group lies directly north and east of the Cape Nome and has running through it the same vein as the Cape Nome ground. There are three claims in this group, the Alladin, Sovereign, and "A" Ex.

Before 1907, the property was developed by a few prospect tunnels and shafts, but in 1907 the Speculator Mining Co. of Butte, Montana, took a lease and bond on the property and began to develop it from the 500-foot shaft level of the Cape Nome shaft. The company did 1,700 to 1,800 feet of drifting on a vein, crosscut to the west and a few feet to the east, but seemingly did not strike the Cape Nome vein proper before time for taking up the bond expired and therefore did not take over the property. The writer visited the underground workings on the Alladin ground at the time the company was operating, and believes that a crosscut to the east, not longer than 300 feet, would cut the Cape Nome lead. It seems probable that when this lead is struck, good ore will be encountered. The surface indications and those in a shallow shaft point to an ore shoot on the Cape Nome vein, as it continues in the Alladin territory. This, when cut by a crosscut from the main drift of the Speculator tunnel, would yield considerable stoping ground.

ECONOMIC POTENTIAL

GENERAL CONSIDERATION

The fundamental factors to be kept in mind when considering the economic possibilities of a mining district are the available quantity and quality of ore and the profit that can be gained from its extraction. The profit depends upon prevailing metal prices and mining efficiency and is beyond the scope of this paper. Therefore, this discussion is confined to the size of the deposits, the depth to which they may be expected to continue, the metal content, and the probability of discovering new ore.

SIZE OF DEPOSITS

Little can be said definitely about the size of the ore bodies of the district, except that those thus far developed have proved to be small.

The development and exploration work in the lower levels of the Hidden Treasure mine (to December 1960) has not indicated any ore bodies large enough or rich enough to be of any importance. Most of them are narrow, discontinuous lenses, which probably do not contain more than 200 tons of commercial ore. The exception may be the relatively narrow zone of supergene sulfide enrichment. The outlines of the old workings in the Hidden Treasure mine indicate that minable ore bodies of perhaps several thousand tons were removed from this zone by early-day mining operations.

The Cape Nome vein seems to have more continuity than any of the other veins investigated, but whether there is continuity of ore is not known.

DEPTH OF MINERALIZATION

The type of mineralization and the environment in which it occurs in the Clinton mining district suggest deposition under mesothermal conditions. The vertical range for deposits such as these are usually measured in several hundreds or thousands of feet. The development work on the veins is not yet sufficient to demonstrate the ultimate vertical range of mineralization in the district, but in the Hidden Treasure vein, the intensity of fracturing and primary mineralization seems to be consistent over a vertical range of at least 700 feet. Certainly the most promising prospect of developing ore bodies is in the zone of supergene sulfide enrichment. This zone is in the area between 20 and 100 feet below the ground surface. It has been almost ignored in the recent past because of attempts to develop paying production from the hypogene zone.

TENOR OF THE ORE

Several generalizations can be made in regard to the tenor of the ore as found in the different workings of the mines of the district. They are as follows:

1. The ore from the hypogene zone of the Hidden Treasure mine has averaged slightly less than 2 percent equivalent copper. Assay results across the vein may run as much as 10 percent equivalent copper, but because of the nature of the vein, it is necessary to mine barren waste rock along with the ore, thus causing dilution.

2. Ore mined from the supergene sulfide zone of the Hidden Treasure mine averaged nearly twice as rich as that from the hypogene zone. In some areas it was mined over widths of 10 feet.

3. Owing to the differing mineralogy, the hypogene ore of the veins within the granodiorite is of slightly better grade than hypogene ore in the sedimentary rocks. This ore can be mined with less dilution than that from the replacement bodies of the sedimentary rocks because it is confined mainly to fissure filling.

SUGGESTIONS FOR PROSPECTING

It is believed that the success of future mining ventures in the district will depend to a great extent upon the scope of the operation. The district does not seem to be favorable for a large mining operation, but rather one that can efficiently exploit numerous small and scattered ore bodies with shallow workings. Efforts should be concentrated in the sedimentary rocks near the granodiorite contact and within the stock itself, especially near its southeastern edge. Bulldozer trenching has proved to be one of the most efficient ways to determine the continuity of the veins on the surface. A small-diameter diamond drill should be used to confirm suspected ore bodies beneath the surface. The supergene sulfide zone should be explored on all the known veins, especially in the Hidden Treasure and Cape Nome mines.

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