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# ORE DEPOSITS OF THE NORTHERN PART OF THE PARK (INDIAN CREEK) DISTRICT, BROADWATER COUNTY, MONTANA

By

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# BROADWATER COUNTY, MONTANA

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## ABSTRACT

The Marietta mine (gold, silver, and some lead) is in the Elkhorn Mountains, 15 miles northwest of Townsend, Montana. The Slim Sam Formation (Late Cretaceous age), composed of tuff and sandstone, is present in the southwest part of the area mapped. The host rocks for the ore are the Upper Cretaceous Elkhorn Mountains volcanics, a thick series of interbedded andesitic flows, breccias, and conglomerates. Six small intrusive bodies composed of quartz diorite, porphyritic diorite, porphyritic quartz diorite, and biotite-augite porphyry are present within the area.

Propylitic alteration of the volcanic rocks is intense, and bleaching and silicification extend as far as 8 feet from the veins.

The major vein in the Marietta mine occurs in a fault that strikes northwest and dips flatly southwest. The vein has been explored about 2,500 feet along strike and 740 feet down dip. Ore width attains 9 feet in areas where the dip of the vein flattens.

The dominant vein minerals are pyrite, arsenopyrite, quartz, and carbonates. The paragenetic sequence is: (1) quartz, (2) pyrite, (3) arsenopyrite, (4) sphalerite, (5) chalcopyrite, (6) cubanite(?) and tennantite, (7) argentiferous galena, (8) carbonates (siderite, ankerite, and manganocalcite), (9) late quartz, pyrite, and calcite, (10) native gold. Pyrite, arsenopyrite, and quartz are the host minerals, containing microscopic grains of gold in microfractures.

Vertical zonation of the carbonate minerals is obvous. Siderite, emplaced at higher temperature, is restricted to the lower levels, whereas ankerite and manganocalcite are confined to the upper levels of the mine.

The most promising areas for future exploration are lateral extensions of the Marietta vein on the No. 4 level, extensions at depth of both the Marietta and Gold Dust veins, and northerly extensions of the Marietta vein on the surface.

# INTRODUCTION

The Marietta mine and the surrounding area is approximately 15 miles northwest of Townsend, Montana, in T. 7 N., R. 1 W., Broadwater County (fig. 1 and 2). This area is on the eastern flank of the Elkhorn Mountains, which extend eastward to the Townsend Valley. To the northwest, the Elkhorn Mountains merge into an unnamed mountain range (Boulder Mountains, limited usage) south of Helena, Montana. The Boulder River marks the southwest edge of the range, and the 46° parallel delimits the southern extent of the area studied. Access to the mine and the surrounding area is by the Indian Creek road, which is maintained throughout the year. An alternate route is available by way of the Beaver Creek road, south of Winston, Montana, to its confluence with Weasel Creek, then up Weasel Creek to its source, and across the divide into the area mapped. This route is not maintained throughout the year.

The main objective of this investigation is to make a detailed study of the geology of the Marietta mine and surrounding areas in order to explain or define the nature of mineralization in this area. It is hoped that the result of this study will facilitate future exploration within the district.

Reconnaissance geologic studies and mineral-deposit investigations of the area described in this paper have been made in the past. The earliest geologic work was done by Stone (1911, p. 75-98) in a mineral-examination and

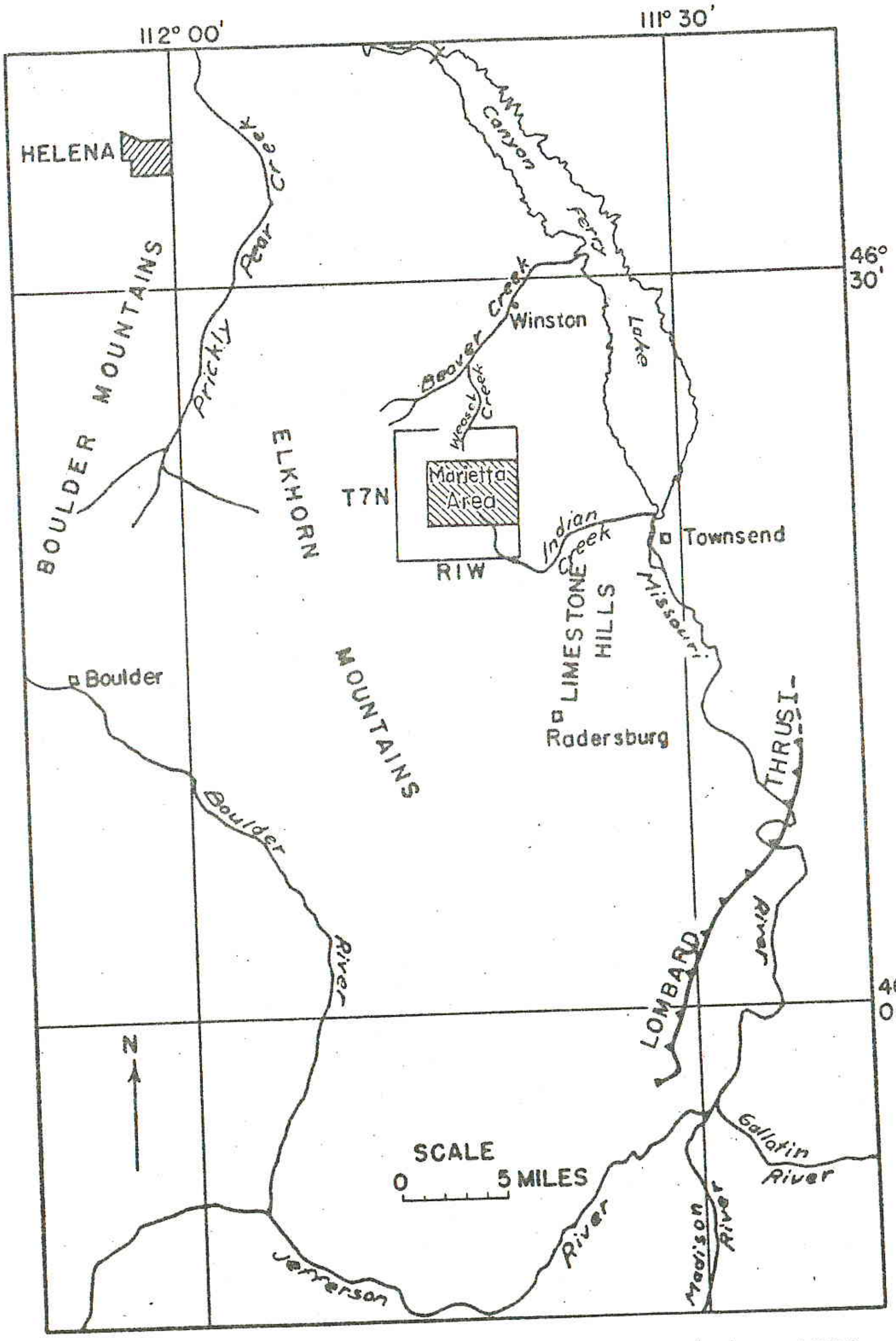

Figure 1.--Sketch map of Elkhorn Mountains area.

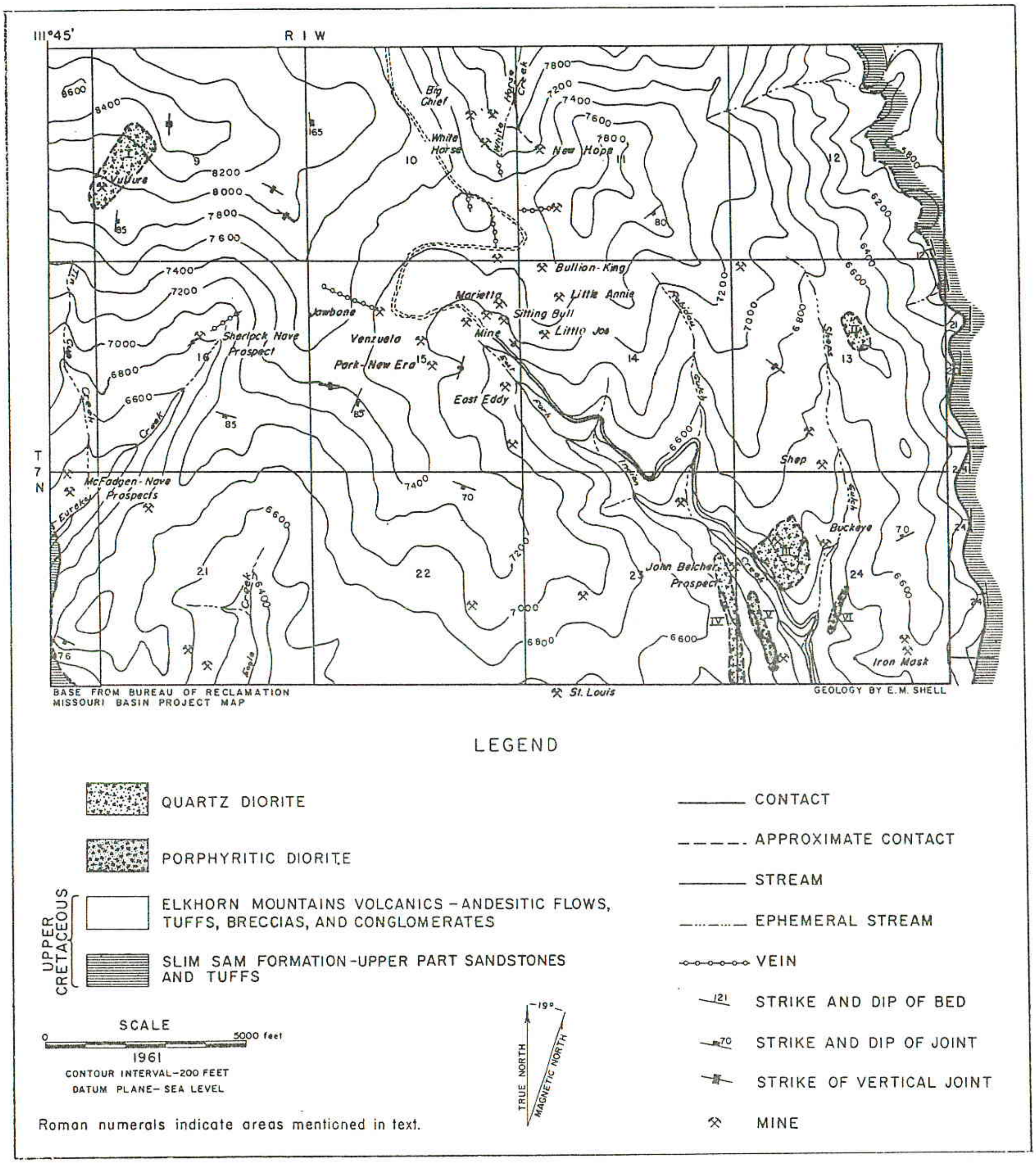

Figure 2.--Geologic map of Marietta mine area.

reconnaissance geologic mapping project of the Elkhorn Mountains. Knopf (1913) studied the ore deposits of the Helena mining region, which lies west and northwest of the Marietta area. Billingsley (1915) and Billingsley and Grimes (1918) studied the Boulder batholith and surrounding area, including the mineral deposits. The study encompassed the Marietta mine area, but the regional geology was not studied in detail and the Marietta mine was inaccessible. Corry (1933) did a reconnaissance study of the gold deposits of Broadwater, Beaverhead, Phillips, and Fergus Counties. Pardee and Schrader (1933) included the Marietta area in their study of the Greater Helena region.

The most extensive previous study of the Marietta mine was done by Reed (1951), but his work was curtailed considerably by inaccessibility of most of the mine. Klepper and others (1957) mapped the geology of the southern part of the Elkhorn Mountains and investigated the ore deposits in that area. Their paper is drawn upon extensively in the discussion of the relationship of the volcanic rocks common to both areas. Regional geological mapping, which included the Marietta area, was done by the U.S. Geological Survey during the summer of 1958, but geologic maps of the area were not available (Klepper, 1960, written communication). Sahinen (1959) compiled published information on the mineral deposits of the Helena mining region. Personnel of several mining companies have studied the mine, but their reports have not been published, and the results of these investigations are not available.

Approximately 50 days were spent in the field in June, July, and August of 1960, three weeks of which were spent mapping surface geology and the rest in collecting data and samples from underground workings.

Geologic data were plotted on aerial photographs having a scale of 1:20,000. A Missouri Basin Project topographic map having a scale of 1:20,300 and 20-foot contour interval was used in conjunction with the aerial photographs. Traverses were made along all ridges and most of the stream beds in the area mapped. All lithologic contacts were walked out.

The geology of the underground workings of the Marietta mine was plotted on Northern Milling Co. level maps on a scale of 1 inch equals 50 feet. A representative suite of ore and wall-rock samples was obtained by systematic sampling along drifts, crosscuts, and stopes. All accessible underground workings were mapped and sampled. Parts of the upper levels and some of the raises and stopes were inaccessible, owing to caving or waste filling.

Laboratory investigations during the fall and winter of 1960-61 consisted of petrographic study of the different rock types and mineralogic study of ores under the microscope and by X-ray diffraction.

P.I. Raber, President, Northern Milling Co., Townsend, Montana, suggested the problem area and provided financial assistance for the work. E.F. Wieglenda, Superintendent, P.H. Sweeney, former company Geologist, and T. Lee, former company Engineer, Northern Milling Co. personnel, offered many valuable suggestions and criticisms. F.A. Crowley, Montana Bureau of Mines and Geology, Butte, lent five polished sections. A.J. Silverman, Geology Department, Montana State University, Missoula, gave freely of his time and advice in all phases of the study. Many problems were discussed with R.M. Weidman and the rest of the staff of the Geology Department, Montana State University. Uuno M. Sahinen, Montana Bureau of Mines and Geology, Butte, read the paper and offered helpful suggestions.

## PHYSIOGRAPHY

The eastern half of the area mapped is drained by the East Fork of Indian Creek and its tributaries; the Marietta mine is in a small basin near the head of Indian Creek. The southwestern part of the area is drained by Eureka and Eagle Creeks, tributaries of Crow Creek. A small portion of the northern part of the area drains into White Horse Creek (fig. 2). Water for milling is obtained from Indian Creek and from the mine. Springs are abundant throughout the area.

Maximum topographic relief within the area mapped is 2,600 feet. The highest point, near the northwest corner of the area, has an altitude of 8,600 feet (fig. 2). Most of the ridge tops are rounded by erosion. Outcrops of massive beds form cliffs as much as 100 feet high; gulches have steep walls; and talus slopes are common throughout the areas.

The average annual precipitation in the Townsend Valley, adjacent to the east side of the area mapped, is 11.5 inches, and the mean annual temperature is 42.1°F. Mountainous areas west of the valley receive slightly more precipitation. The temperature range is characteristic of the Northern Rocky Mountain physiographic province, which has a cool-temperate semiarid climate.

Timber in this area consists chiefly of conifers. The heavier stands of timber are confined to the north slopes, whereas the south slopes are only moderately timbered or grass covered. Small natural clearings in the timbered areas are common throughout the area. Most of the mine timbers used in the region are obtained from the surrounding slopes.

# GENERAL GEOLOGY

## SEDIMENTARY ROCKS

Parts of the Slim Sam Formation crop out in sparse patches in the southwest corner of the area. The east boundary of the map area was arbitrarily placed at the contact between the Slim Sam Formation and the overlying Elkhorn Mountains volcanics (fig. 2). According to Klepper and others (1957, p. 28), dark shales of Niobrara age grade upward into the Slim Sam Formation (fig. 3), which contains Late Cretaceous fossils.

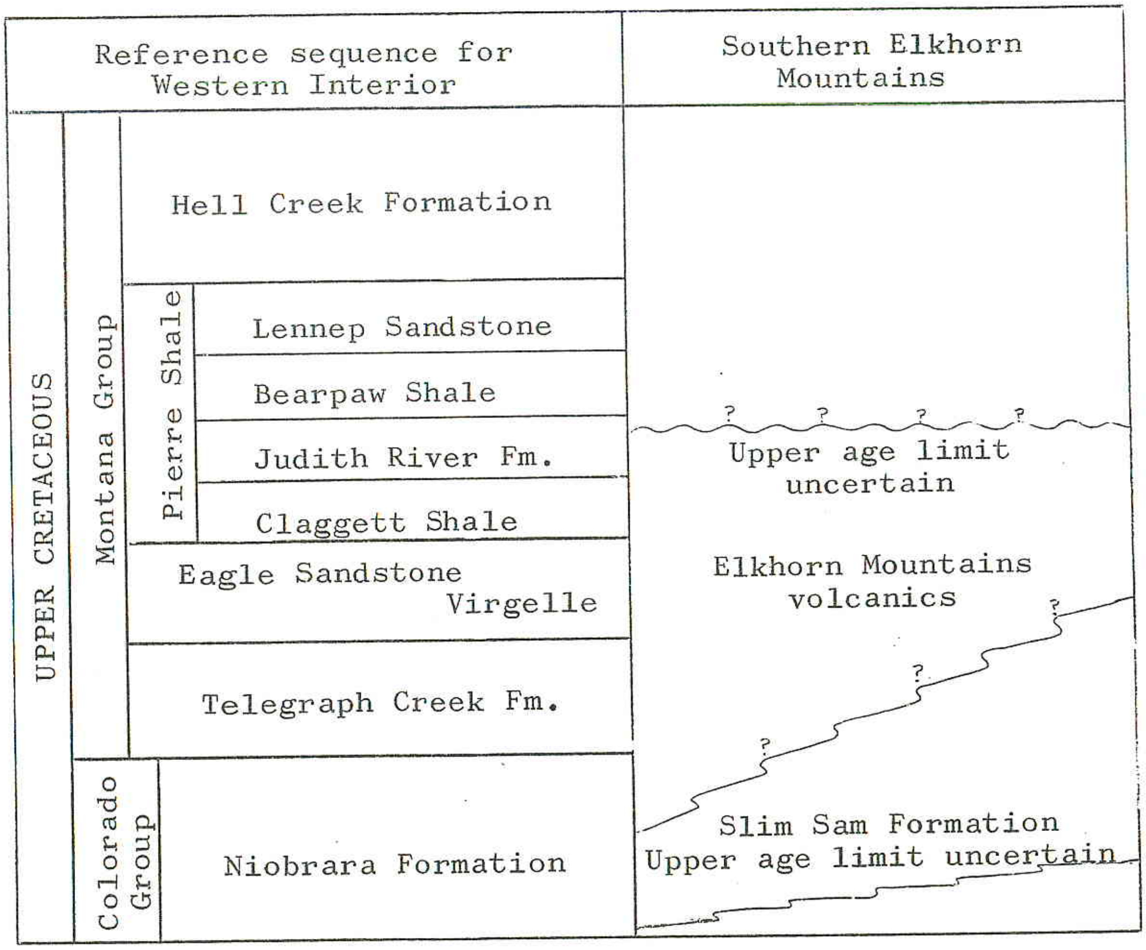

Figure 3.--Generalized partial stratigraphic column, west-central Montana (modification of fig. 3, Klepper and others, 1957, p. 41).

In the area mapped, the upper part of the Slim Sam Formation consists of three units, (1) at the bottom a gray, medium-grained tuff composed chiefly of angular feldspar grains in a quartz matrix, minor constituents consisting of micaceous minerals, rock fragments, and opaque minerals, (2) a greenish-gray, fine-grained, thin-bedded sandstone, and (3) at the top, a gray to greenish-gray, fine- to medium-grained tuff composed of feldspar, quartz, and dark minerals in a micaceous and clayey matrix. Volcanic components increase upwards as the Slim Sam Formation grades into the overlying Elkhorn Mountains volcanics.

The gradational contact is exposed on most of the spurs along the southern half of the east boundary. Farther north, where topographic relief and dip of the beds decrease, outcrops are few, and the contact was mapped chiefly on float. Klepper and others (1957, p. 29) measured three sections of the Slim Sam Formation in the surrounding area and found a maximum thickness of 1,182 feet.

The attitude of the Slim Sam Formation was not observable in the southwest part of the area, but to the west Klepper and others (1957, pl. 1) found that this formation dips generally eastward. Along the southeastern border of the area mapped, the Slim Sam Formation dips about 25° west but farther north the dip progressively decreases to near horizontal (fig. 2).

## ELKHORN MOUNTAINS VOLCANICS

Volcanic rocks, consisting of andesitic flows, volcanic breccias, conglomerates, and tuffs, conformably overlie the Slim Sam Formation in and adjacent to the area mapped. South and west of this area, these volcanics also contain lapilli tuff, welded tuff, crystal tuff, basalt flows, and some andesitic and related hypabyssal intrusive rocks that were not distinctive enough to map as separate units.

Klepper and others (1957, p. 31) named these rocks the Elkhorn Mountains volcanics and designated the area where they are found as the Elkhorn Mountains volcanic field. These volcanics are known to extend discontinuously from Townsend Valley westward to Deer Lodge Valley, and from Helena southward to Jefferson River. The Boulder batholith extensively intruded the volcanic rocks throughout the central part of the volcanic field.

Elkhorn Mountains volcanics more than 5,000 feet thick were mapped by Klepper and others, and the total accumulation in and around the Elkhorn Mountains is thought to be more than 10,000 feet (1957, p. 31). According to these authors, the volcanic rocks are divisible into three units on the basis of gross lithology. In the area of this study, the lithology of the volcanics corresponds most closely to that of the lower member, but part of the middle member may be present. To the southwest the lower member is on the order of 2,000 to 2,500 feet thick. The fact that underlying sedimentary rocks are found along the east and west sides of the area mapped also indicates that the overlying Elkhorn Mountains volcanic rock should be the lowest unit. Thickness of the volcanics in the area mapped was indeterminable, owing to the lack of bedding. Separation of the volcanics on the basis of lithology was unsuccessful because of variance in lithology over short distances (even within one outcrop), paucity of outcrops, and the lack of bedding in the volcanics.

### Tuffs

Tuffaceous rocks are prevalent in the area mapped. They are massive in outcrop and weather readily into rubbly fragments. The tuffs are varicolored in shades of red, green, gray, and brown, and consist of rock fragments, feldspar, quartz, and opaque minerals in an aphanitic groundmass. Streaks and clots of clay minerals and chlorite are evident in some of the tuffs.

In thin section the tuffs are seen to consist of a mixed aggregate of chlorite, calcite, altered feldspar, sericite, quartz, hematite, pyrite, brownish to gray argillaceous minerals, and glass fragments.

Chlorite and hematite seem to be mainly secondary, resulting from complete alteration of ferromagnesian minerals. Hematite forms rims around many of earlier ferromagnesian mineral grains. Pyrite in small amounts as anhedral to subhedral grains is partly oxidized to unidentified iron oxides or hydroxides.

Plagioclase grains are mostly subangular and as much as 1.5 mm in diameter. They are intensely altered to sericite, clay minerals, and calcite. The composition of the plagioclase could not be determined, owing to the intensity of the alteration.

Quartz grains as much as 1 mm in diameter are abundant. Glass is present as fragments and as part of the matrix in one thin section examined. The glass has been partly altered to clay minerals. Rock fragments, observable in hand specimens, were not encountered in thin sections.

In two thin sections of the tuffaceous rocks, small secondary veinlets of quartz and calcite were observed. A zeolite mineral was also present in one of the veinlets.

Propylitization, the type of alteration described in a later section, seems to predominate in the Elkhorn Mountains volcanic tuffs examined by the author.

### Volcanic Breccia and Conglomerate

Andesitic breccias and conglomerates are distributed over the entire area, but are generally more abundant near the east and west borders. Along the east boundary they are the major rock types stratigraphically above the Slim Sam Formation.

The breccias and conglomerates are massive in outcrop and form some of the ridges and cliffs in the area. They are varicolored in hues of red, brown, green, and gray. The only megascopic difference between the breccia and conglomerate is in the shape of the included material. In both rock types the included fragments range in size from microscopic to boulders 2 feet in diameter, and average about 6 inches (fig. 4). Most of the breccia and conglomerate is composed of andesite fragments set in an andesitic matrix, although occasional fragments of other rock types have also been incorporated. In general, the matrix material is darker than the included fragments.

Most of the incorporated material is erosional debris derived from pre-existing flows and incorporated in later flows. Some of the breccia and conglomerate fragments may have originated from mud flows, brecciation of a cooling lava flow, or explosion breccia.

Figure 4.--Andesitic conglomerate. Rounded fragments of andesitic material incorporated in an andesitic lava flow. A knife near the center of the picture indicates the scale.

## Andesite Flows

Andesite flows are abundant in the area, but they were not mappable as separate units. The flows are massive and thoroughly indurated and form cliffs 100 feet high. Many of the talus slopes are composed of angular andesite fragments. Most of the andesite is dark greenish gray but some is dark reddish gray.

Phenocrysts of pyroxene, as much as 3.5 mm in diameter, and smaller grains of altered plagioclase are the only minerals megascopically identifiable. Flow banding and bedding are conspicuously absent in the flows.

Most of the flows are altered so intensely that a reliable modal analysis was not possible. In order to obtain a semiquantitative mode of the relatively unaltered andesite, 500 points of a thin section were counted. The optically identified minerals are plagioclase, 70 percent; clinopyroxene, 8 percent; biotite, 5 percent; quartz, 5 percent; chlorite, 3 percent; epidote, 2 percent; orthoclase, 2 percent; opaque minerals, 5 percent; apatite, less than 1 percent; and traces of zircon.

The plagioclase occurs as lath-shaped, euhedral crystals as much as 1 mm in length and commonly displays albite twinning. Most of the grains are at least partly altered to sericite and calcite, and in some the alteration seems to be complete. Plagioclase composition could not be determined precisely, owing to alteration and complex oscillatory and normal zoning of individual grains, but it seems to range from $An_{35}$ to $An_{55}$.

The clinopyroxenes consist of pigeonite and diopside in anhedral to euhedral grains generally about 1 mm in length. Depending on the orientation in the thin section, the individual grains are either slightly elongate or form eight-sided prisms. Twinning and zoning of the pyroxenes are common. Diopside, the dominant pyroxene, is biaxial positive and has a 2V of about 55° as determined with a universal stage. The $N_{Y}$ index is about 1.684. Pigeonite has a 2V of about 15°. Both minerals are partly altered to chlorite and epidote.

Biotite occurs as small anhedral grains filling interstices. It is the reddish-brown variety typical of basic volcanics and is partly altered to unidentified opaque minerals.

Orthoclase and quartz occur as small interstitial grains. They are poikilitic and enclose numerous euhedral crystals of apatite and occasional zircon grains. The orthoclase is partly sericitized.

## Alteration of the Volcanics

The alteration of the volcanics is principally propylitization, which is intense and geographically widespread throughout the area mapped. It is megascopically characterized by the obliteration of most of the original texture, by dark greenish color, by a high degree of induration, and by feldspar phenocrysts that are less translucent than normal. It is characterized microscopically by the alteration of the original minerals and by the abundance of epidote, clinozoisite, chlorite, sericite, carbonate minerals, pyrite, hematite, serpentine(?), and rare albite.

Silicification of the andesite, and argillization of the feldspars, evident throughout the area, are most conspicuous adjacent to mineralized areas.

Identification of some of the original minerals of the andesite was based on relic forms and remanents of primary minerals. Some plagioclase grains are complexly zoned (oscillatory and normal) and have a composition ranging from $An_{35}$ to $An_{55}$. Plagioclase is altered to sericite, carbonate, argillaceous material, and chlorite. The ferromagnesian minerals were more susceptible to alteration, as they have been almost completely altered to chlorite, epidote, clinozoisite, hematite, pyrite, and serpentine(?). Locally, hematite is abundant as an alteration product and gives the andesite a reddish cast. In the Marietta mine, ore seems not to be associated with andesite containing abundant hematite, but data are insufficient to determine the significance of this condition.

Almost all of the thin sections of andesite are cut by tiny stringers containing euhedral crystals of one or more of the following minerals: quartz, carbonate, epidote, clinozoisite, and one or possibly several zeolites. This may represent a late phase in the propylitic alteration.

## Age of the Elkhorn Mountains Volcanics

Klepper and others (1957, p. 32) have studied the age of the Elkhorn Mountains volcanics. A summary of their work is given below.

The beginning of the volcanic period is marked by andesitic detritus in the Slim Sam Formation, which contains fossils of Niobrara age. The Slim Sam Formation is believed to have been deposited rapidly, and in places it grades upward into the volcanics. Fossils found in a marly layer in a volcanic conglomerate that is believed to have been deposited at or near the end of the volcanic activity are judged to be Judith River in age. Also, the volcanics are the youngest rocks in the southern part of the Elkhorn Mountains that have been involved in the major episode of Laramide folding.

In summary these authors state, "The paleontologic, stratigraphic, and structural evidence indicates to the authors that the Elkhorn Mountains volcanics are almost certainly wholly Cretaceous in age. But the evidence is insufficient to indicate whether they range in age from very late Niobrara or Telegraph Creek time to an upper limit that cannot be fixed more closely than Judith River time, or younger, or are restricted in age to Judith River time." (See fig. 3).

## INTRUSIVE ROCKS

Six small intrusive bodies crop out on the surface (fig. 2), and two narrow dikes are exposed underground (pl. 1). Three of these bodies are slightly elliptical and half a mile or less in maximum plan dimension. The other three bodies are elongate and 100 to 300 feet in width. Exposures are poor; most contacts mapped on the surface are based chiefly on float. Significant amounts of float were observed in various parts of the area, suggesting that other intrusive bodies are also present, but was so scattered that no probable contacts could be postulated. Contact metamorphism of the intruded andesite seems to be negligible.

The intrusive rocks were emplaced after or possibly during extrusion of the Elkhorn Mountains volcanics. Some may be consolidated remanents of volcanic necks or plugs from which andesitic rocks were extruded.

Mineralogical and structural similarities of intrusive rocks mapped by Klepper and others (1957, p. 44) farther southwest indicate that these rocks are genetically related to the Elkhorn Mountains volcanics. These same authors suggest that the small plutons mapped in the southern part of the Elkhorn Mountains may be genetically related to the Boulder batholith.

The intrusive rocks of the area consist of quartz diorite, porphyritic diorite, porphyritic quartz diorite, and a biotite-augite porphyry. For convenience in referring to the location of the individual intrusive bodies, locality numbers (fig. 2) have been assigned:

| | |
|---|---|
| Locality I | Quartz diorite |
| Locality II | Quartz diorite |
| Locality III | Quartz diorite |
| Locality IV | Quartz diorite |
| Locality V | Porphyritic diorite and biotite-augite porphyry |
| Locality VI | Porphyritic quartz diorite |

Six thin sections, one from each of the major intrusive bodies, were studied in detail (table 1). Spatial association and mineralogical similarities suggest that the intrusives in the area mapped are genetically related to each other and to the surrounding extrusives.

Table 1.--Modal analyses of intrusive rocks.

| Rock type | Quartz diorite | | | | Porphyritic diorite | Porphyritic quartz diorite |
|---|---|---|---|---|---|---|
| Locality number | I | II | III | IV | V | VI |
| Plagioclase | 55.0 | 59.4 | 59.2 | 60.6 | 66.4 | 65.4 |
| Chlorite | 8.0 | 11.4 | 10.0 | 7.6 | 5.4 | 10.2 |
| Epidote and clinozoisite | 11.0 | 9.2 | 9.6 | 2.6 | 3.8 | 4.6 |
| Clinopyroxene | 1.0 | 6.6 | 4.2 | 2.6 | 12.6 | 5.4 |
| Hornblende | 3.0 | 1.4 | 1.2 | 4.8 | --- | 1.0 |
| Microperthite | 9.0 | --- | --- | 4.0 | --- | --- |
| Orthoclase | --- | --- | --- | 4.0 | --- | --- |
| Quartz | 8.0 | 7.0 | 10.0 | 8.0 | 1.0 | 7.6 |
| Biotite | 4.0 | --- | --- | 2.4 | 4.4 | tr |
| Opaque minerals | 1.0 | 4.2 | 5.6 | 2.6 | 5.2 | 5.4 |
| Apatite | tr | tr | tr | 1.8 | 1.0 | tr |
| Zircon | tr | tr | tr | --- | --- | --- |
| Total | 100.0 | 99.2 | 99.8 | 101.0 | 99.8 | 99.6 |

Note: Owing to alteration of the rocks, only 500 points were counted in each thin section. One thin section was prepared and studied from each of the above localities; therefore, these modes are semiquantitative.

## Quartz Diorite

The quartz diorite rocks are the major intrusive bodies in the area. They are easily recognized, as the color and texture contrast strongly with those of the andesites, and the quartz diorite forms coarse rounded fragments on weathering.

In hand specimen, the quartz diorites are light gray and fine to medium grained. Most of the major minerals are identifiable with the unaided eye and microscopically they interlock (fig. 5). A mode of each of the four quartz diorite bodies is given in Table 1.

Plagioclase is the dominant mineral in the quartz diorite. It occurs as anhedral to euhedral grains as much as 2 mm long. Composition of the plagioclase in the rocks ranges from $An_{33}$ to $An_{60}$. Oscillatory and normal zoning around a more calcic core is common (fig. 6) and indicates disequilibrium conditions during crystallization. The cause of disequilibrium is

Figure 5.--Thin section No. B-40. Quartz diorite from Locality IV; chiefly plagioclase laths (P), chlorite (C), and interstitial quartz (q). Crossed nicols, x 25.

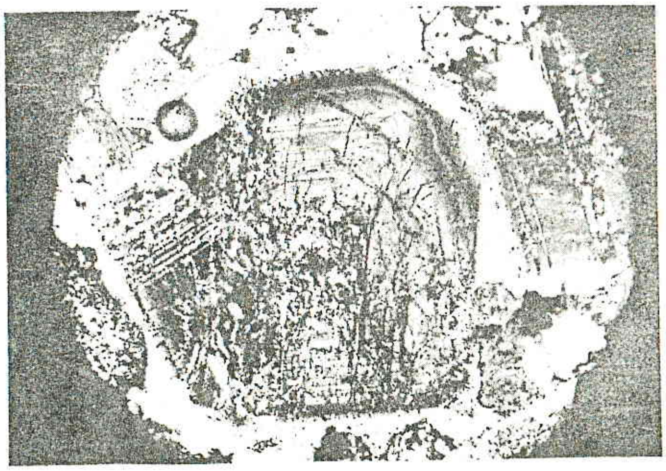

Figure 6.--Thin section No. SE-34. Oscillatory zoning of a plagioclase grain from quartz diorite at Locality III. Plagioclase chiefly surrounded by quartz and some epidote. Crossed nicols, x 75.

speculative. The quartz diorite of Locality I contains less than 1 percent myrmekitic intergrowth of quartz and plagioclase. A thin section of this rock also contains about 10 percent microperthite. Alteration products of the feldspars, in decreasing abundance, are sericite, clay, and calcite.

Pigeonite and a more calcic pyroxene are the two clinopyroxenes present in the quartz diorites. Many of the pyroxene grains are twinned, and hourglass zoning can be observed. The calcic pyroxene is more abundant than pigeonite. The optic angle of pigeonite ranges from 12° to 30°, and the mineral is slightly pleochroic. The presence of pigeonite in the quartz diorite indicates rapid cooling of the partly crystallized melt, probably by rapid upward intrusion into the near-surface rocks.

Pleochroic colors of the hornblende are generally light to dark green. The optic angle of the hornblende ranges from 70° to 90°, and 2V averages about 73°.

Biotite occurs as small euhedral grains as much as 1 mm long in quartz diorite from Localities I and IV. It is pleochroic from light to dark brown. Most biotite is altered to chlorite or rimmed by an opaque mineral.

Small, anhedral, interstitial grains of quartz, as much as 1 mm in diameter, are present in about equal amounts in all the quartz diorites. Apatite occurs as euhedral inclusions in most of the other minerals and as separate grains throughout the rock. Small, elongate, euhedral zircon crystals were observed in thin sections of the quartz diorite.

Opaque minerals consist chiefly of pyrite and the iron oxides magnetite and hematite. Most of the pyrite is euhedral grains as much as 1 mm in diameter. Hematite and magnetite are present as reaction rims around ferromagnesian minerals.

### Diorite and Porphyritic Quartz Diorite

The probable contacts of two elongate intrusive bodies (Localities V and VI, fig. 2) were mapped on the basis of float. The rock from Locality V is porphyritic diorite and that of Locality VI a porphyritic quartz diorite. These rocks are dark gray, and the fine- to medium-grained matrix contains numerous euhedral pyroxene phenocrysts as much as 6 mm long (fig. 7 and 8). Mineralogically, the porphyritic rocks differ from the quartz diorites (table 1) with respect to percentages of minor minerals. Alteration of these porphyritic rocks is analogous to that of the quartz diorite previously described.

The porphyritic rocks contain euhedral sericitized plagioclase ($An_{35}$-$An_{60}$) grains as much as 1mm long (fig. 7).

Figure 7.--Thin section No. SE-33. Porphyritic diorite from Locality V; clinopyroxene phenocrysts in a matrix of sericitized plagioclase laths. Crossed nicols, x 25.

Figure 8.--Thin section No. SE-41. Porphyritic quartz diorite from Locality VI. Partly altered clinopyroxene (Py), plagioclase (gray), quartz (white), chlorite (C), opaque minerals and holes in section (black), and small euhedral apatite (A). Crossed nicols, x 25.

Chlorite, epidote, and clinozoisite are present as alteration products. Hornblende, similar to that found in the quartz diorite, is present in the thin section from Locality VI. Biotite and quartz occur as small interstitial grains.

Some phenocrysts of pigeonite are also present in rocks from each locality. Seemingly, the clinopyroxenes were the first minerals to crystallize in the magma. Rapid cooling of the partly crystallized melt after its intrusion into the surrounding andesite prevented inversion of the pigeonite to orthopyroxene.

### Biotite-Augite Porphyry

A biotite-augite porphyry body intruded the andesite and porphyritic diorite at Locality V. The biotite-augite porphyry was not mapped separately, as only one outcrop several feet in diameter was observed near the southeast corner of Locality V. It is a dark-gray, fine-grained, porphyritic rock consisting of a submicroscopic crystalline groundmass, phenocrysts of biotite and augite, and subordinate amounts of plagioclase (composition undetermined) and orthoclase(?). Phenocrysts range in size from 0.25 mm to 2 mm and constitute about 20 percent of the rock. Biotite phenocrysts are most abundant and are rimmed by reaction rims of iron oxides and unidentified pyroxenes.

The texture of this rock and the presence of resorbed biotite phenocrysts indicate a period of early crystallization at high water pressure during which time the biotite phenocrysts developed. As a result of intrusion of the magma, the water pressure dropped rapidly, and biotite became unstable and was partly resorbed to iron oxides and pyroxenes. The submicroscopic texture of the groundmass also resulted from intrusion of the melt and subsequent chilling of the partly crystallized magma.

### Dikes

Two hydrothermally altered dikes that have intruded the andesite are exposed in the Marietta mine (pl. 1). These dikes are observable on the No. 4 and 5 levels of the mine. Both dikes are about 2.5 feet wide, trend northwest, and are nearly vertical. Another dike, similar in appearance but extensively weathered, is observable in a shallow drift several hundred yards west of the portal of the No. 5 level.

Microscopically the dike rocks consist of a complex aggregate of quartz, chlorite, epidote, clinozoisite, sericite, pyrite, calcite, and clay minerals. The original minerals are preserved in only a few grains.

# STRUCTURE

## Folding and Faulting

In the absence of any definite criteria for establishing the stratigraphic relationships of the Elkhorn Mountains volcanics, only a few of the structural features could be delineated.

The dominant structural feature within the area mapped is a broad, north-trending syncline. Indirect evidence for this syncline is the presence of a broad, elongate, north-plunging domal structure west of the area mapped (Klepper and others, 1957, pl. 1) and west-dipping strata east of the area (fig. 2). Minor folds were found superimposed on major folds to the west and southwest by these same authors and also to the southeast (Freeman and others, 1958, pl. 1). Therefore, it is reasonable to assume that minor folding also occurred within the area mapped. Stone (1910, p. 78) was one of the first to observe that the major folds generally have a northerly trend. In the southern part of the Elkhorn Mountains, Klepper and others (1957, p. 60) found some of the volcanics deformed as intensely as the underlying sediments, indicating that the folding and faulting culminated after the accumulation of the volcanics.

Previous mapping in adjacent areas of the Elkhorn Mountains and Townsend Valley has established a northwesterly trend for the major faults. The northwest-trending faults mapped by Freeman and others (1958, p. 525) in the Limestone Hills are believed to be subsidiary structures of the Lombard Thrust (for location of the Limestone Hills and trace of the Lombard Thrust, see fig. 1). According to Reed (1951, p. 14), many of the known centers of mineralization in the Elkhorn Mountains are confined to the intersection of northwest-trending faults and intrusive stocks.

Reed (1951, p. 44) mapped a northwest-trending fault about one mile south of the Iron Mask mine and believes that this fault continues into the upper Indian Creek basin, which contains the Marietta and related veins. Substantiating evidence for this fault is the linear pattern of Indian Creek in the area mapped (fig. 2).

Faulting on a small scale is prevalent in the Marietta mine and adjacent areas (pl. 1). Most of the productive lodes were localized in some of these faults. Postmineralization faulting in the Marietta mine produced displacement measurable only in inches wherever it could be determined. Detailed discussion of the structure observed underground is reserved for a later section.

### Joints

Two sets of northwest-trending joints are present within the area mapped. One set is nearly vertical (fig. 2); the average dip of the other set is about 20° southwest.

An analysis of the joints, specifically in the vicinity of the Marietta mine, was attempted but no satisfactory conclusions as to their origin or their relationship to the veins could be obtained from the available data.

## ORE DEPOSITS

The northern part of the district has produced notable quantities of gold and silver, and lead is an important by-product (table 2). The only operating property in the area at present is the Marietta mine. Figure 18 shows the patented and some of the unpatented claims in the Marietta mine area. Most of the ore deposits in the area occur in andesites, but some minerals are in and adjacent to the intrusive bodies other than the quartz diorite at Locality II.

All veins observed in the area are emplaced along well-defined faults. The Marietta vein trends northwest and dips southwest about 30°. The trend of most of the other veins in the area (wherever the attitude could be determined) is either northeast or northwest and the dip is generally shallow.

## MINING HISTORY AND PRODUCTION

According to Stone (1911, p. 76) gold placers on Wilson Creek (T. 7 N., R. 2 W.) and other creeks were extensively worked in 1858. Soon thereafter placer gravels were discovered on Indian Creek. The large influx of prospectors into this part of Montana was caused by the discovery of placer gold in Last Chance Gulch (present site of Helena, Montana) on July 14, 1864. Numerous lodes were staked in the Elkhorn Mountains in the 1860's. Reed (1951, p. 43) states that lodes in the Park (Indian Creek) district were discovered in the late 1870's. The Marietta mine was intensively prospected and developed during the period 1880-1906. In the late 1890's, a small tonnage of unusually rich lead-silver ore was produced from the White Horse mine. The Iron Mask mine was intermittently prospected and developed during the period 1904-40. From 1943 to 1947, the Iron Mask property produced most of the metal output of the Park (Indian Creek) district. The Marietta mine was operated intermittently from 1906 to 1951. Stone (1911, p. 89) states that a mill and cyanide plant were built and unsuccessfully operated in the Marietta mine area sometime prior to 1910.

Since 1951 the Marietta mine has been the principal metal producer in the Park (Indian Creek) district. In 1958 Northern Milling Co. acquired the property (fig. 18), and active mining and exploration work begun then is continuing at the present time (1962). In 1959 a 200-ton-per-day selective flotation mill was erected on the property to concentrate ore from the mine. On September 2, 1960, the Department of Interior approved an OME loan to Northern Milling Co. for a lead-zinc exploration program. At the present time (1962) this exploratory work is in progress.

The following chronological account of mines and production of ore in the Park (Indian Creek) district is compiled from annual volumes of The Mineral Resources of the United States (1905-1931) and Minerals Yearbook (1932-1960). Only the names of the larger producing mines were available in these references, and the ensuing notes are restricted to mines described in this report. (For location of these mines see fig. 2.)

1905.--A 50-ton cyanide plant was constructed to treat ores from the Park-New Era group.

1906-08.--The Park-New Era property reported production during the period.

1909.--No specific properties noted from the northern half of the Park (Indian Creek) district.

1910.--The Park-New Era property reported production.

1911.--No specific properties noted from the northern half of the Park (Indian Creek) district.

1912-13.--The Marietta mine is listed as a producing mine.

1914-16.--No specific properties noted from the northern half of the Park (Indian Creek) district.

1917.--The Iron Mask mine produced ore.

1918.--Operation of the Iron Mask mine by the Bamar Copper Co. produced several shipments of lead ore.

1919-22.--No specific properties noted from the northern half of the Park (Indian Creek) district.

1923-24.--Production was reported from the Iron Mask property.

1925-26.--No specific properties noted from the northern half of the Park (Indian Creek) district.

1927.--The Creden Corp. operated the Iron Mask mine for a short time and shipped four cars of lead-zinc ore to Butte, Montana, for custom milling.

1928-30.--Small lots of lead-zinc ore were shipped from the Iron Mask property to Butte for custom milling.

1931.--One car of lead ore from the Gold Dust property was shipped to the East Helena smelter.

1932.--No specific properties noted from the northern half of the Park (Indian Creek) district.

1933.--Gold ore was shipped from the Marietta property; lead ore was produced from the Park-New Era and Little Annie mines.

1934.--The important producers of gold ore in the district included the Marietta mine; lead ore was shipped from the Little Annie mine.

1935-36.--No specific properties noted from the northern half of the Park (Indian Creek) district.

1937.--The major producing mine in the district was the Marietta mine. Gold ore shipments were also noted from the Jawbone and St. Louis mines, and ore was shipped from the Iron Mask and Park-New Era mines.

1938.--The Marietta mine was again listed as the chief producer in the district, shipments amounting to 266 tons of gold ore and 117 tons of lead ore. Gold ore was also shipped from the Little Joe and St. Louis properties. Shipments of lead ore were noted from the Iron Mask and Park-New Era mines.

1939.--Lessees of the Marietta mine shipped the largest amount of ore from the district, 257 tons of gold ore and 502 tons of lead ore. Among the other producing properties in the district were the Iron Mask and Venzuela mines.

1940-41.--The leading producing property in the district was the Marietta mine, which shipped gold and lead ore.

1942.--The major producer in the district was the Marietta mine, from which 112 tons of gold ore and 269 tons of lead ore were shipped to the smelters.

1943.--The Iron Mask property, operated by the Broadwater Zinc and Lead Co., treated about 1,200 tons of lead-zinc ore in a 50-ton-per-day flotation mill on the property. In addition, 1,612 tons of silver ore was shipped to smelters from the property. Gold ore, amounting to 215 tons and containing 316 ounces of gold and 924 ounces of silver, was produced and shipped from the Marietta mine.

1944.--Zinc ore (4,885 tons) was shipped to the East Helena smelter from the Iron Mask mine by the Broadwater Zinc and Lead Co. In addition, 291 tons of zinc-lead concentrate was obtained by treatment of about 1,000 tons of ore from this property. Some production was also recorded from the Marietta mine.

1945.--The Broadwater Zinc and Lead Co. produced 4,429 tons of zinc ore from the Iron Mask mine.

1946.--The Broadwater Zinc and Lead Co. milled 4,825 tons of zinc-lead ore from the Iron Mask mine; it yielded 1,062 tons of zinc concentrate and 317 tons of lead concentrate. Production from the Marietta mine amounted to 54 tons of gold ore.

1947.--Substantial production of lead, zinc, and silver ore was noted from the Iron Mask mine.

1948.--No specific properties noted from the northern half of the Park (Indian Creek) district.

1949.--The Iron Mask mine was operated until June 10, 1949, by Boyles and Mosier and during this time 1,400 tons of zinc-lead ore was treated in the flotation mill on the property. The Marietta mine was operated by lessees and shipped 429 tons of ore containing 658 ounces of gold, 1,671 ounces of silver, 370 pounds of copper, 13,452 pounds of lead, and 7,916 pounds of zinc.

1950.--The Marietta mine, operated by lessees, shipped some gold ore. Among the other properties in the district that recorded production was the Lookout property (location of claim on fig. 18).

1951.--The principal producer in the Park (Indian Creek) district was the Marietta mine.

1952.--Active throughout the year was a Defense Minerals Exploration Administration contract on the White Horse property operated by Al and Jewell Dance. A total of 108 tons of gold ore was mined from the Marietta mine by the operators, Al Dance and Harry Q. Anders.

1953.--Gold ore was shipped from the Marietta mine during the year.

1954.--The Marietta mine shipped 500 tons of ore; recoverable content was 935 ounces of gold, 3,183 ounces of silver, 600 pounds of copper, 17,400 pounds of lead, and 13,200 pounds of zinc. Small production of lead ore was also noted from the Phoenix mine.

1955.--The Marietta mine, operated by Al Dance and Harry Q. Anders, produced a substantial tonnage of gold ore. Development and exploration were reported as 100 feet of drifting, 1,500 feet of diamond drilling, and 100 feet of raisework.

1956.--Forminco, Inc., lessees, operated the Marietta mine, which was the largest producer in the county. Lead ore and concentrates were shipped from the Iron Mask mine.

1957.--Production was noted from the Marietta mine, operated by Al Dance and Harry Q. Anders.

1958.--Northern Milling Co. reported that a sizable tonnage of gold ore was produced from the Marietta mine.

1959.--The leading gold ore producer in the county was the Marietta mine, operated by Northern Milling Co.

1960.--A sizable tonnage of gold ore was produced from the Marietta mine, operated by Northern Milling Co.

The total value of production from the Park (Indian Creek) district compiled on Table 2 is $2,324,732. This includes about $472,500 for placer gold and silver recovered during this period. Therefore, the lode production for the period 1905-60 is about $1,852,232. Pardee and Schrader (1933, p. 186) list $802,200 as the value of lead, zinc, copper, silver, and lode gold produced from the Park (Indian Creek) district for the period 1864-1928. Adding this figure to the total production figures from Table 2 (excluding the value of placer production) for the period 1928-60 gives a grand total of $2,564,016 as the value of metals produced in the Park (Indian Creek) district for the period 1864-1960.

## MARIETTA MINE

### Vein Structures

The Marietta, Gold Dust, and Rabidau veins are the three mineralized structures developed in the Marietta mine (pl. 1). Andesite flows are the host rock for the veins. The only intrusive rocks present in the mine are the two basic dikes previously described (pl. 1).

The Marietta vein is the most persistent and economically the most important. It strikes about N. 10° W. and dips about 30° SW. Near its southern extremity, on the Intermediate and No. 3 and 4 levels (pl. 1), the vein strikes about N. 40° W. and dips about 20° SW. The strike length of the Marietta vein is about 2,500 feet and its known vertical extent is about 410 feet (Section A-A', pl. 1). It has been discontinuously mined and explored from the surface for a distance of 740 feet down dip. On the No. 5 level the vein structure is strong and sulfide width attains 4 feet. From the sill of the No. 5 level to the bottom of a 25-foot winze near Station 518 (pl. 1), however, sulfide width decreased to about 1 foot. At the bottom of this winze the tenor of the ore decreased below the cutoff point, and the winze was temporarily abandoned. Exploratory work below the No. 5 level has not progressed far enough to determine whether mineable ore is present at greater depths. Width variations of the vein are common throughout the mine.

The explored northern extremity of the Marietta vein is accessible on the surface and on the No. 3, 4, and 5 levels of the mine (pl. 1). On the surface the vein structure, observed in pits and bulldozer cuts, consists of sheeted andesite, iron oxides, and sparse partly oxidized pyrite. Some material from the northernmost surface pit shown on Plate 1 was assayed by Mr. T. Lee of Northern Milling Co. and showed a trace of gold and silver (1960, personal communication). At the northern extremities of the No. 3 and 5 levels

Table 2.--Production of gold, silver, lead, zinc, and copper, from lode mines in the Park (Indian Creek) district.[a]

| Year | Gold |  | Silver, Troy oz. | Lead, lb. | Zinc, lb. | Copper, lb. | Total value |
|---|---|---|---|---|---|---|---|
|  | Troy oz. | Value |  |  |  |  |  |
| 1908 | * | $ 5,313 | 2,939 | 27,374 | --- | 8,901 | * |
| 1909 | * | 7,007 | 552 | 6,246 | --- | 1,750 | $ 7,790 |
| 1910 | * | 5,412 | 2,957 | 111,304 | --- | 734 | 11,999 |
| 1911 | * | 4,882 | 1,736 | 40,276 | --- | 822 | 7,717 |
| 1912 | * | 2,554 | 1,192 | 24,763 | --- | 1,953 | 4,723 |
| 1913 | * | 4,193 | 375 | 8,218 | --- | --- | 4,781 |
| 1914 | * | 3,529[b] | 144[b] | 3,988 | --- | --- | 3,765[b] |
| 1915 | * | 2,587 | 2,927 | 58,853 | --- | --- | 6,837 |
| 1916 | * | * | * | * | --- | * | * |
| 1917 | * | * | * | * | --- | --- | 2,669 |
| 1918 | * | 749[b] | 2,360[b] | 58,362 | --- | --- | 7,253[b] |
| 1919 | * | 1,486[b] | 35[b] | 245 | --- | 655 | 1,660[b] |
| 1920 | * | * | * | * | --- | * | 1,565[b] |
| 1921 | * | 895 | 238 | 3,543 | --- | 141 | 1,310 |
| 1922 | * | * | * | * | --- | * | * |
| 1923 | * | 1,033 | 4,045 | 75,292 | 14,944 | --- | 10,637 |
| 1924 | * | 1,918[b] | 1,906[b] | 32,655 | 12,240 | 1,023 | 6,736 |
| 1925 | * | 934 | 1,689 | 7,282 | --- | --- | 2,739 |
| 1926 | * | * | * | * | * | * | 1,306[b] |
| 1927 | * | 726 | 1,182 | 23,267 | 49,232 | 1,329 | 6,187 |
| 1928 | * | 336 | 492 | 13,621 | 4,548 | 353 | 1,742 |
| 1929 | * | * | * | * | * | * | * |
| 1930 | * | * | * | * | * | * | * |
| 1931 | * | * | * | * | * | * | * |
| 1932 | * | 2,263[b] | 819[b] | 5,667 | --- | 238 | 2,679[b] |
| 1933 | 351 | * | 2,963 | 38,703 | --- | 2,031 | 11,699 |
| 1934 | 833 | * | 5,459 | 78,189 | --- | 750 | 42,788[b] |
| 1935 | * | * | * | * | * | * | * |
| 1936 | 753 | * | 4,505 | 70,625 | --- | 1,398 | 33,273[b] |
| 1937 | 1,352 | * | 6,439 | 78,935 | --- | 859 | 133,946[b] |
| 1938 | 1,147 | * | 9,866 | 123,761 | --- | 204 | 54,618[b] |
| 1939 | 2,120 | * | 17,932 | 300,574 | --- | 4,087 | 103,387[b] |
| 1940 | 1,780 | * | 11,752 | 173,920 | --- | 655 | 258,789[b] |
| 1941 | 1,373 | * | 8,671 | 145,600 | --- | 1,300 | 363,719[b] |
| 1942 | 1,114 | * | 3,607 | 62,800 | --- | 300 | 162,218[b] |
| 1943 | 590 | * | 11,437 | 188,400 | 66,000 | 2,600 | 50,729[b] |
| 1944 | 257 | * | 27,623 | 426,200 | 848,500 | 2,400 | 159,787 |
| 1945 | 59 | * | 14,895 | 207,000 | 1,012,400 | 2,000 | 147,610[b] |
| 1946 | 137 | * | 27,828 | 411,000 | 1,117,000 | 3,500 | 265,913[b] |
| 1947 | 75 | * | 9,358 | 168,200 | 315,200 | 1,300 | 114,387[b] |
| 1948 | 50 | * | 127 | 2,700 | 4,200 | --- | 23,254[b] |
| 1949 | 729 | * | 5,392 | 83,800 | 131,300 | 1,100 | 60,937[b] |
| 1950 | 1,067 | * | 2,443 | 34,600 | 5,100 | 700 | 45,097 |
| 1951 | 698 | * | 1,917 | 16,000 | 8,000 | --- | 30,424 |
| 1952 | 358 | * | 1,619 | 3,206 | 8,247 | 94 | 12,403 |
| 1953 | 170 | * | 602 | 2,400 | 1,000 | --- | 6,924[c] |
| 1954 | 942 | * | 3,291 | 20,000 | 13,600 | 600 | 40,334[c] |
| 1955 | 1,041 | * | 7,313 | 93,200 | 29,100 | --- | 60,520 |
| 1956 | 844 | * | 2,624 | 22,800 | 15,500 | 600 | 37,873 |
| 1957 | 216 | * | 856 | 5,800 | 6,500 | 300 | 10,008 |
| 1958 | * | * | * | * | * | * | * |
| 1959 | * | * | * | * | * | * | * |
| 1960 | * | * | * | * | * | * | * |
| Total | 17,956 | $45,817 | 214,107 | 3,259,369 | 3,662,611 | 44,677 | $2,324,732 |

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[a] Compiled from "Mineral Resources of the United States" and "Minerals Yearbook," 1905-1960. Production figures prior to 1908 were not given for individual districts.

[b] Includes placer production.

[c] Production combined with two other districts, but indications are that most is from the Park (Indian Creek) district.

*Figures not available.

the Marietta vein pinches down to about 4 inches. Near Station 430 on the No. 4 level, the vein increases in dip, curves to the west, and pinches from 4 feet to about 1 foot. Four drill holes (about 50 feet in length) and a raise in this area failed to reveal a northerly continuation of the structure, but near the end of the 424 N. drift the structure reappears and continues northward.

The Gold Dust vein on the No. 4 and 5 levels of the mine trends about N. 60° E. and dips about 40° SE. It has been explored about 600 feet along strike on the No. 5 level (pl. 1). The eastern extremity of the structure seems to split into several small horsetail veinlets. A small shoot, approximately 10 feet thick, was present where the Gold Dust and the Marietta veins intersect on the No. 4 level. A detailed study of the Gold Dust vein on the No. 4 and 5 levels was not feasible, owing to inaccessibility of the stopes and part of the drifts.

The following information on development work on the Gold Dust vein, completed from the fall of 1960 to February 1962, has been compiled from data submitted by E.F. Wieglenda Superintendent, and from company maps. This work is still in progress and consists of all development north of Station M-6 (pl. 1) comprising about 860 feet of drifts and crosscuts, a 117-foot raise near Station M-14, and a stope about 65 feet high, just west of the raise. The ore-bearing structure was exposed on the Mason level in April 1961, and is believed to be the downdip extension of the Gold Dust vein from the No. 5 level of the Marietta mine. The vertical distance between these two levels is about 300 feet. Minerals present on the Mason level are similar to those on the No. 5 level. The width of the vein ranges from 4 inches to 4 feet. At the top of the raise near Station M-14, the vein is 12 to 18 inches wide and dips 61° SE. Thirty-five samples, most of which were taken at 10-foot intervals along the strike of the vein, assayed an average of 0.52 ounce gold (from a trace to a maximum of 2.59 ounces), 0.76 ounce silver (from 0.01 to a maximum of 4.10 ounces), 1.9 percent lead, and 0.53 percent zinc. Additional exploration in this area is probably warranted to determine the extent of this structure.

A small and economically unimportant structure known as the Rabidau vein occurs near the portal of the No. 4 level. It strikes N. 60° E. and dips about 35° SE. It consists of 5 inches to 2 feet of oxidized ore, gouge, and sheeted andesite. The vein has been explored about 180 feet along strike (pl. 1).

The Marietta vein has easily recognizable foot and hanging walls. A gouge seam, in places 8 inches wide, characteristically is near or adjacent to one of the vein walls. The andesite wall rock is silicified, bleached, and pyritized for a distance of 6 to 8 feet on each side of the vein. Stringers of sulfides, quartz, and carbonates are common for considerable distances from the vein.

The veins in the Marietta mine are of the fissure-fill type. Minor amounts of pyrite, arsenopyrite, quartz, and carbonates are disseminated in the andesite adjacent to the veins. Local brecciation of the andesite during formation of the vein structure and mineralization is shown by occasional pieces of andesite breccia found within the vein material. The breccia has been only partly replaced by sulfides and gangue minerals.

Mineral ratios change rapidly and inconsistently along both strike and dip of the vein. Where the vein is narrow, some of the ore minerals are absent, and two or three minerals constitute the entire vein. Parts of the vein are banded with monomineralic or bimineralic bands of sulfide and gangue minerals (fig. 9). None of the banded ore represents simple crustification of a single open structure, but suggests repeated reopening of the vein during mineralization.

In the Marietta mine a few vugs were found to contain small crystals of quartz and some pyrite and calcite. One vug contained a small cluster of marcasite(?) crystals about half an inch in diameter, but this is an oddity, as no other marcasite was observed.

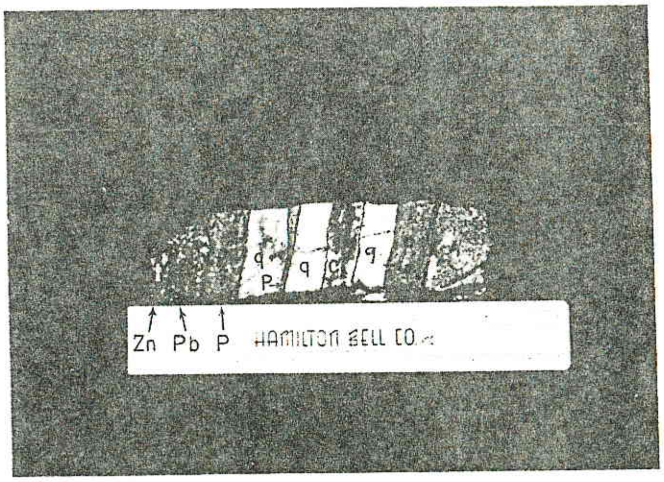

Figure 9.--Banded ore from 503 stope. Contains sphalerite (Zn), andesite (A), galena (Pb), pyrite (P), siderite (C), and quartz (q).

## Ore Shoots

The Marietta and Gold Dust veins randomly pinch and swell, ranging in width from several inches to about 3 feet. Where the dip of the Marietta vein decreases, the vein is enlarged to form shoots having a maximum width of about 9 feet. The largest and economically most important shoot occurs between the No. 3, 4, and 5 levels of the Marietta mine. The entire area has been stoped, with the exception of pillar supports, for a horizontal distance of about 400 feet. Sulfides, gangue, and variable gold were continuously present in this area in widths ranging from 6 inches to 9 feet. Between the No. 3 and 4 levels the shoot was very discontinuous. In this area sulfides and gangue attained widths of about 6 feet, and the gold and silver was irregularly distributed. Pinching and swelling of the vein, both laterally and vertically, has determined the position of the commercial ore bodies. Only the wider parts of the vein have been amenable to mining.

Numerous smaller shoots were present in the Marietta mine, as shown by many discontinuously stoped areas. Most of the stopes are now filled with waste and are inaccessible.

The ore bodies of the Marietta mine have been localized chiefly by premineralization faults of two ages. Older faults provided channels for movement of the ore solution and for deposition, and one of two younger sets of crosscutting faults probably acted as dams to the movement of ore-forming fluids.

The Marietta and Gold Dust veins are in the older faults. Almost horizontal postmineralization movement along the Marietta structure is indicated by slickensides in the ore and in the associated gouge seam. In general, the dip of the structure increases towards the surface (Section A-A', pl. 1). Ore width attains 9 feet between the No. 4 and 5 levels where the dip of the structure decreases. Between the No. 3 and 4 levels the structure is slightly steeper, and ore width does not exceed 6 feet. The dip further increases between the No. 2 and 3 levels, and the maximum width of ore is only about 3 feet. This strongly suggests that the Marietta structure had a thrust component of movement, which provided open space for ore deposition where the dip decreased. The ore bodies of greater width in the Gold Dust vein most probably were formed in a similar manner, but they were not studied in detail.

On the assumption that premineralization movement was similar to postmineralization movement, it follows that the Marietta structure is the result of a strike-slip fault with a thrust component of movement. Petrographic studies of andesite from both sides of the Marietta vein failed to reveal any major compositional differences.

The younger, steeply dipping, sets of faults trend either northwest or northeast, almost perpendicular to the Marietta structure (pl. 1). They are premineralization, as mineralization continues through the faults without displacement, but they show some minor postmineralization strike-slip or dip-slip movement. Northwest-trending faults at both the north and south ends of ore shoots contain gouge and probably acted as dams, preventing the horizontal spread of ore solutions rising vertically along the main ore channels of the Marietta vein. Some of the northwest-trending faults can be projected through several levels of the mine. The northeast-trending faults seemingly did not affect localization of ore.

Ore-shoot formation at vein intersections was found only where the Gold Dust vein intersects the Marietta vein on the No. 4 level, where a small pod of ore was present (pl. 1). This shoot had a vertical extent of only about 10 feet and was confined to a small area between the No. 4 level and Sub levels.

## Mineralogy

The mineralogy of the different veins is strikingly similar. The only exceptions are small amounts of pyrrhotite in a polished section of the White Horse ore, and a small amount of molybdenite in a specimen obtained from a pit along the trend of the Marietta vein.

Relatively high-grade oxidized ore was mined from the B level of the Marietta mine during early periods of development. This level is inaccessible at present. Oxidation in the accessible parts of the mine has not been extensive, as only small quantities of azurite, malachite, and supergene covellite were formed.

Production records from 1901 to about 1951 were compiled by Reed (1951, p. 48) and indicate that the average recovered metal content from the Marietta mine has been 1.24 ounces gold and 7.5 ounces silver per ton, and 4.8 percent lead.

More than 100 ore samples and about 40 rock samples from the area mapped were assayed for beryllium with a berylometer. All registered less than the 0.05 percent minimum sensitivity of the instrument.

Throughout the Marietta mine pyrite, arsenopyrite, quartz, siderite, manganocalcite, and ankerite consitute most of the vein material, galena and sphalerite being secondary in abundance. Calcite, chalcopyrite, tennantite, cubanite(?), and native gold are minor constituents.

Pyrite is widespread in the veins but locally may be present only in microscopic quantities. It is generally intensely fractured. These fractures are filled by later arsenopyrite, sphalerite, galena, gold (fig. 10), chalcopyrite, and carbonates (siderite, ankerite, and manganocalcite). According to P.H. Sweeney and T. Lee (1960, personal communication), gold content increases in areas of fractured and friable pyrite. In local areas a decrease in gold content seems to be inconsistently related to pyrite that is coated with a film of black clay. An X-ray diffractometer pattern shows that the black clay is probably a mixture of kaolinite and chlorite. Megascopically, most of the pyrite appears massive; however, euhedral cubic crystals ranging from microscopic to 1.5 inches in diameter are common.

Arsenopyrite is present throughout all of the veins in varying proportions. Most of the fractured arsenopyrite also contains higher than average gold values. Fractures in the arsenopyrite are filled by the later minerals, sphalerite (fig. 11), galena (fig. 10 and 12), chalcopyrite, carbonate minerals, and gold. Arsenopyrite in turn fills fractures in pyrite. Most of the arsenopyrite is massive, but euhedral elongate crystals as much as 1.5 inches long are common, and many are arranged parallel to each other and perpendicular to the vein walls, indicating a fissure-filling process of mineralization. Small needles and rhombic crystals of arsenopyrite are commonly observed in polished sections (fig. 13).

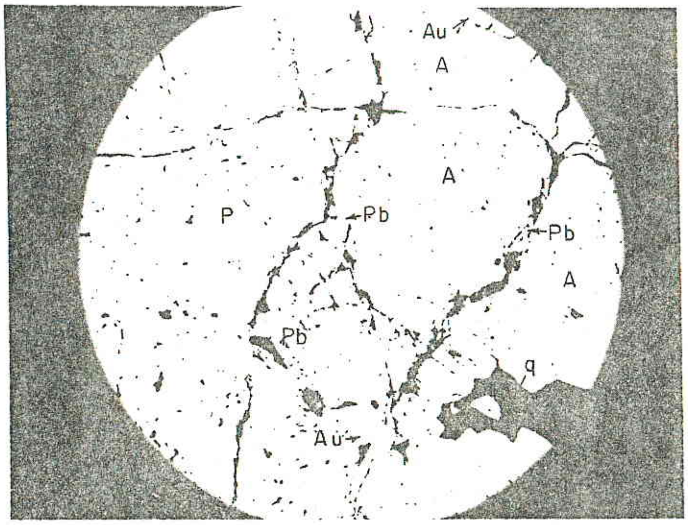

Figure 10.--Polished section No. M-5-8 from No. 5 level. Galena (Pb) and quartz (q) filling fractures in and replacing pyrite (P) and arsenopyrite (A). Gold (Au) also present as fracture filling. x 60.

Figure 11.--Polished section No. M-5-8 from No. 5 level. Quartz (dark gray) filling fractures and replacing arsenopyrite (A) and pyrite (P). x 60.

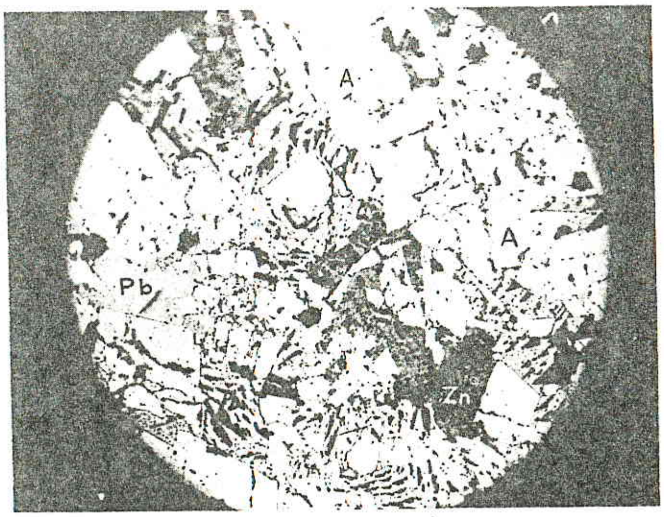

Figure 12.--Polished section No. M-4-28 from No. 4 level. Fractured arsenopyrite (A) being replaced by sphalerite (Zn) and galena (Pb). x 60.

Sphalerite occurs in small quantities in all the veins. Generally it is fine grained, but cleavage faces 0.25 inch in diameter were observed. The color ranges from dark reddish black, which is abundant, to reddish brown, which is sparse. The dark iron-rich sphalerite has a dark-red internal reflection under the microscope, and the lighter colored iron-poor sphalerite has a yellow internal reflection. The dark and light sphalerite grains are intimately intergrown, and no evidence for a depositional time difference could be observed. Sphalerite replaces and veins the earlier arsenopyrite (fig. 12), quartz, and pyrite.

Chalcopyrite is not visible in hand specimens of any of the vein material, but was observed to be microscopically widespread in 24 of the 30 polished sections studied. It is contained either as inclusions in sphalerite (fig. 14), as irregular grains and veinlets in or adjacent to earlier minerals, or both.

The chalcopyrite occurrence and texture were studied in detail to determine mode of occurrence. Less than 50 percent of the chalcopyrite is present as inclusions in sphalerite. Chalcopyrite grains and veinlets are present along sphalerite grain boundaries, where replacement commonly occurs. Both the darker and lighter sphalerite contain chalcopyrite inclusions but not all sphalerite grains contain visible chalcopyrite, and distribution of chalcopyrite in sphalerite is not systematic. A small percentage of the chalcopyrite inclusions are narrow, elongate rods showing a preferred orientation in the sphalerite (fig. 14). Some of these elongate inclusions have matching walls. Baker (1960, p. 393) noted in his study of exsolution chalcopyrite in sphalerite that the ends of the elongate inclusions are enlarged, suggesting that the ends of the rods drained chalcopyrite from a larger area. He also found abundant tiny irregular chalcopyrite grains throughout the sphalerite, and these were especially numerous close to the elongate inclusions. With few exceptions, the ends of the rodlike inclusions tend to pinch out rather than show enlargements. Very few of the criteria for exsolved chalcopyrite given by Baker were noted in the present study. It was concluded that there is not enough reliable evidence to determine whether the chalcopyrite-sphalerite relationship is due to replacement, exsolution, coprecipitation, or a combination of two or all three of these processes.

Microchemical etch tests indicate that minor amounts of cubanite(?) are present in the Marietta vein. Cubanite(?) grains are visible only under magnifications of x250 or greater, and are invariably associated with a small grain of chalcopyrite. The associated grains fill fractures in pyrite and arsenopyrite.

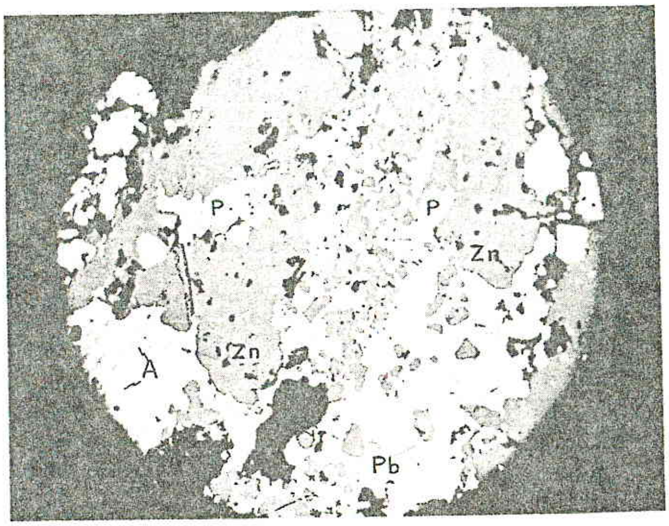

Figure 13.--Polished section No. M-4-3 from No. 4 level. Galena (Pb) replacing sphalerite (Zn). Tiny grains in sphalerite are chalcopyrite. Note euhedral outline of arsenopyrite (A) and some of the pyrite (P). x 60.

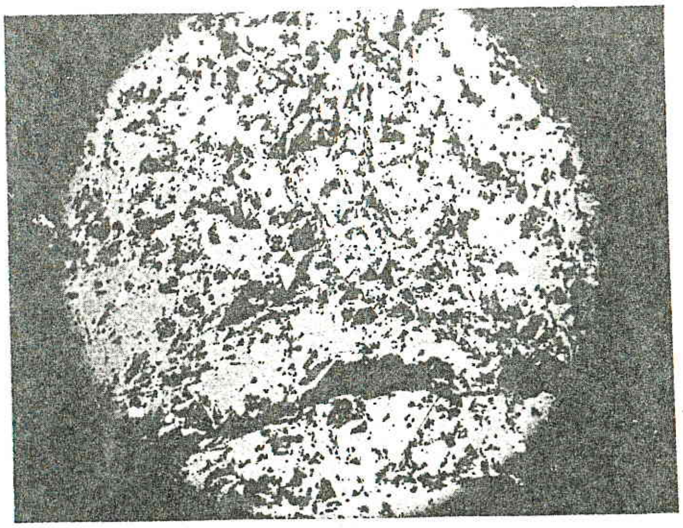

Figure 14.--Polished section No. M-4-3 from No. 4 level. Chalcopyrite (white) in sphalerite (dark gray) as oriented and randomly distributed inclusions. x 60.

Tennantite was identified in five of the polished sections studied. It occurs in very minor quantities as grains less than 0.1 mm in diameter as inclusions in galena (fig. 15), pyrite, and arsenopyrite. Tennantite is apparently earlier than galena, as shown by corrosion of the tennantite grains.

Galena generally occurs as finely crystalline masses throughout the veins. In the larger shoots, coarse galena having curved cleavage faces 0.5 inch across are common. Metallurgical tests performed on the ore during design of the mill confirmed that the galena is argentiferous, but silver minerals were not observed in the polished sections studied. Galena fills fractures in, and replaces, pyrite, arsenopyrite (fig. 10, 12, and 15), spahlerite (fig. 13), and quartz.

Native gold is present as extremely fine particles, chiefly in microfractures in pyrite and arsenopyrite (fig. 10). Rarely, specks of gold are observable in microfractures in quartz and as small grains in contact with chalcopyrite. About 80 to 85 percent of the gold in the ore is present as free gold and the rest is incorporated in the pyrite and arsenopyrite (Sweeney and Lee, 1960, personal communication).

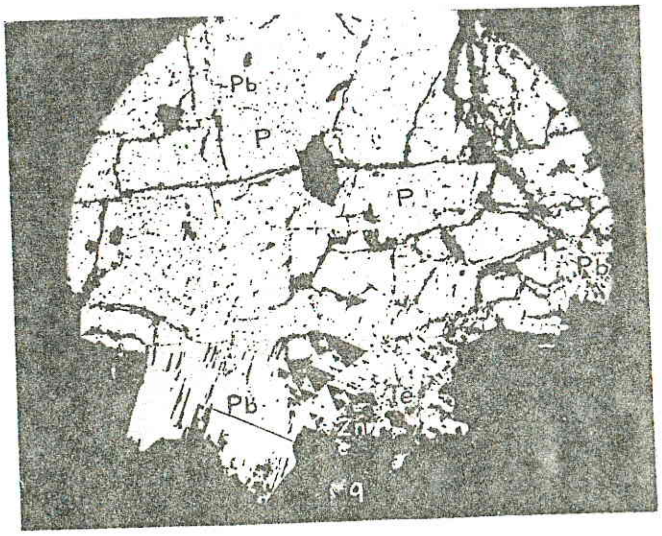

Figure 15.--Polished section from Cotter drift (Cot. Dr.). Galena (Pb) replacing pyrite (P) and possibly corroding tennantite (Te), quartz (q), and sphalerite (Zn). x 60.

Quartz is abundant throughout the veins and most is massive and milky white (fig. 9). Clear euhedral crystals, ranging from microscopic size to 1 inch long, are common in vugs, hand specimens, and polished sections. Most of the massive quartz and some of the euhedral quartz is fractured and has been replaced by the other vein-forming minerals. Later-stage quartz also has replaced most of the late minerals (fig. 10 and 11).

X-ray diffraction studies revealed that siderite, ankerite, manganocalcite, and calcite are the carbonate minerals present in the Marietta mine. Siderite is the most abundant; it is light tan and fine to coarsely crystalline. Ankerite and manganocalcite are fine grained and chalky. Both these minerals are white but most manganocalcite has a slight pinkish cast. Siderite, ankerite, and manganocalcite replace and vein galena along cleavages and by outward incipient replacement from carbonate veinlets (fig. 16). Calcite is not abundant and is found only as small crystals in vugs or on cleavage planes of galena and is therefore presumed to be a late mineral.

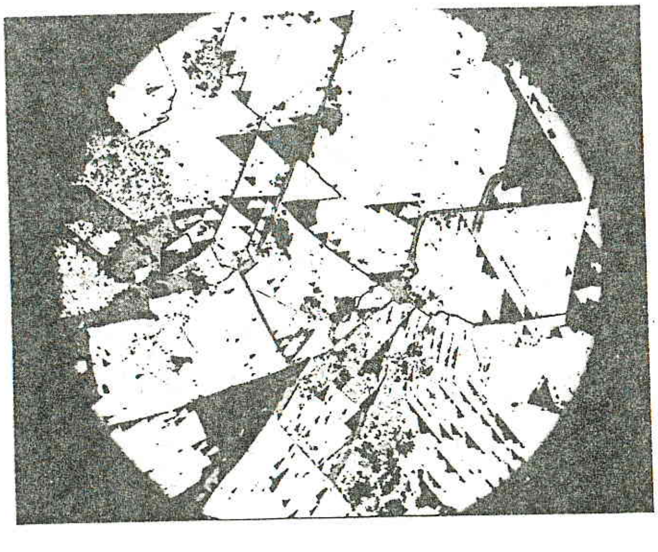

Figure 16.--Polished section No. M-4-58 from No. 4 level. Siderite (C) replacing galena (Pb) along cleavages. Siderite grains disseminated outward from veinlets. Black triangular pits are in galena. x 60.

## Paragenesis

The paragenetic sequence of the vein-forming minerals in the Marietta mine is summarized in Figure 17. Quartz was the first mineral deposited in the veins, then pyrite, and later arsenopyrite, but fracture filling and replacement textures in polished sections of the ore (fig. 11) indicate considerable overlap of quartz, pyrite, and arsenopyrite. Quartz and pyrite seem to have been deposited in small amounts throughout the entire mineralizing period, as shown by crosscutting relationships with all other minerals.

Movement along the vein structure fractured the early quartz, pyrite, and arsenopyrite. These fractures were then filled by sphalerite, which also replaced the host minerals. It could not be determined whether chalcopyrite replaced, exsolved from, or coprecipitated with sphalerite, or if a combination of these processes occurred.

Owing to the paucity of cubanite(?) and tennantite, their relative position in the paragenetic sequence could not be definitely determined, but they seem to have been deposited after sphalerite but before galena.

Galena is the next mineral in the paragenetic sequence. It has replaced and has filled fractures in all the major older minerals. The carbonate minerals (siderite, ankerite, and manganocalcite) were deposited after galena. A paragenetic sequence for these carbonate minerals was not postulated, owing to lack of evidence. The carbonate minerals have vigorously replaced galena (fig. 16) and older minerals (quartz, pyrite, arsenopyrite, and sphalerite).

The carbonate minerals have been partly replaced by a late stage of pyrite and quartz, which are also present as euhedral crystals, partly filling vugs. The early stage of quartz is generally milky white whereas the late stage consists chiefly of clear euhedral crystals. Calcite is also a late-stage mineral and can be observed only in vugs and as films on cleavage planes of galena.

A late fracturing of the vein minerals preceded the deposition of gold, which probably was the last mineral to be deposited. Fractures that contain gold can be followed through all major earlier minerals except late quartz and calcite.

## Mineral Zoning

The carbonate minerals, siderite, ankerite, and manganocalcite, are vertically but not horizontally zoned in the Marietta vein. There is no apparent vertical or horizontal zonation of any of the other minerals.

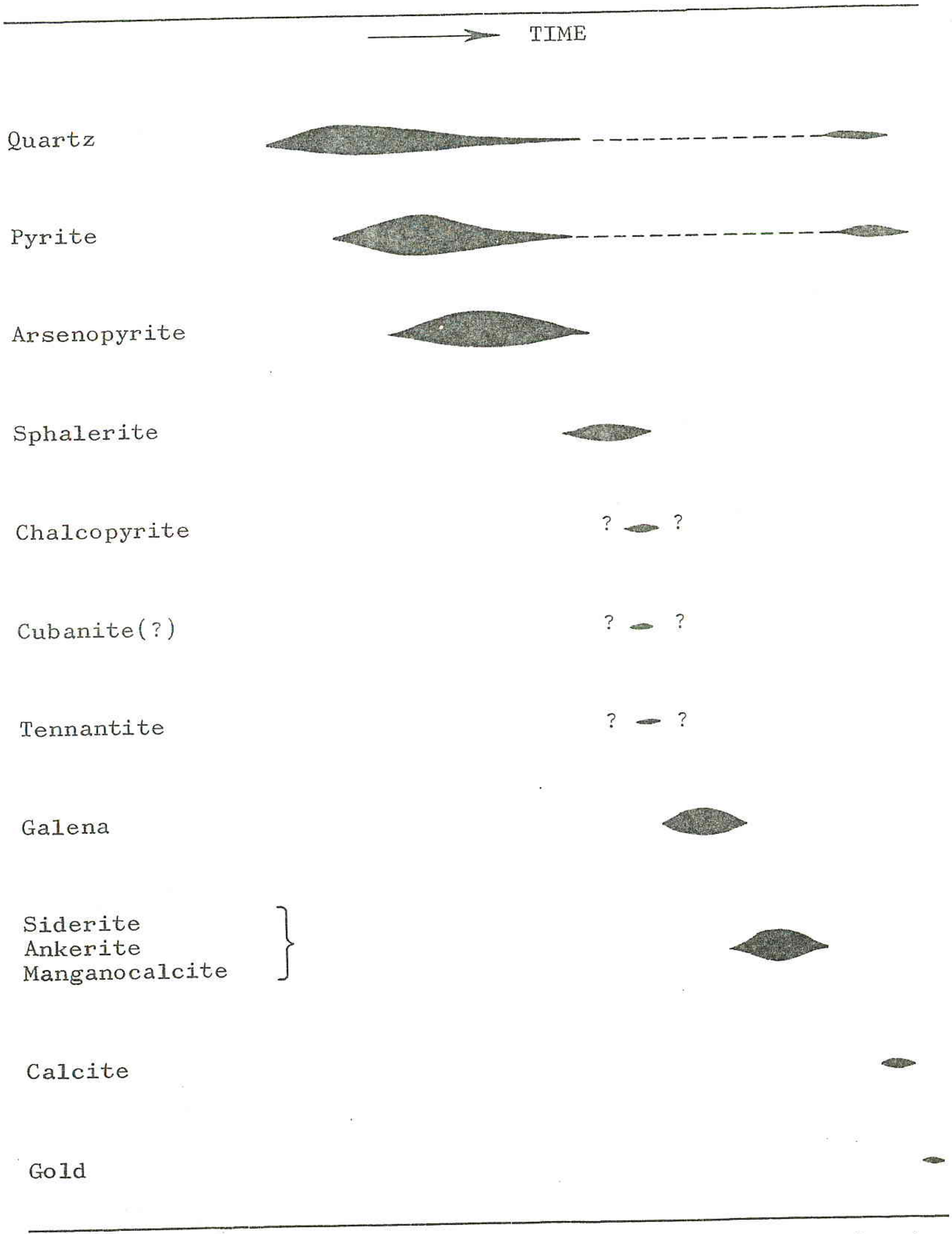

Figure 17.--Paragenetic diagram and relative abundance of vein-forming minerals in the Marietta mine.

Ankerite and manganocalcite were studied by X-ray diffraction, owing to their megascopic similarity. As siderite is megascopically identifiable, only those samples that possibly contained one of the other carbonate phases were studied by X-ray diffraction. The 28 carbonate mineral samples studied by X-ray diffraction included 7 samples from the No. 5 level, 5 samples from the No. 4 level, and 16 samples from the No. 3 level of the Marietta mine.

Siderite is the dominant carbonate mineral on the No. 4 and 5 levels of the mine. Two samples from the No. 5 level contained manganocalcite. One sample from the 421 stope, about 10 feet above the No. 4 level, contained ankerite. The rest of the carbonate samples X-rayed from the No. 4 and 5 levels of the mine contained only siderite. X-ray diffraction patterns of 16 samples from the No. 3 level showed one occurrence of siderite, one of siderite and manganocalcite, three of manganocalcite, four of ankerite and manganocalcite, and seven of ankerite.

In summary, siderite is more plentiful in the lower levels whereas ankerite and manganocalcite are almost confined to the No. 3 level of the Marietta vein. Lack of samples above the No. 3 level prevented a study of the carbonate phase in this area.

## OTHER NEARBY MINES

Very little information can be obtained about other veins in the area mapped, as most of the underground workings are either completely inaccessible or only partly accessible. Therefore, detailed study of the minerals present was not possible. Suites of rock and ore collected from mine dumps and from drifts show a similarity to those of the Marietta deposit. Polished sections were discussed in a previous section. Except as noted, all the following described mines were developed in an andesitic host rock.

### Jawbone

The Jawbone workings (fig. 2 and 18) are inaccessible. Several dumps in the vicinity attest to considerable development of this claim. Pieces of intrusive rock, similar in appearance to the dikes found in the Marietta mine, were observed on the Jawbone dumps. The structure on this claim seemingly was stoped to the surface, as numerous pits form a linear pattern that strikes N. 65° W. According to Corry (1933, p. 20) "lenses" 12 feet wide were mined in these workings.

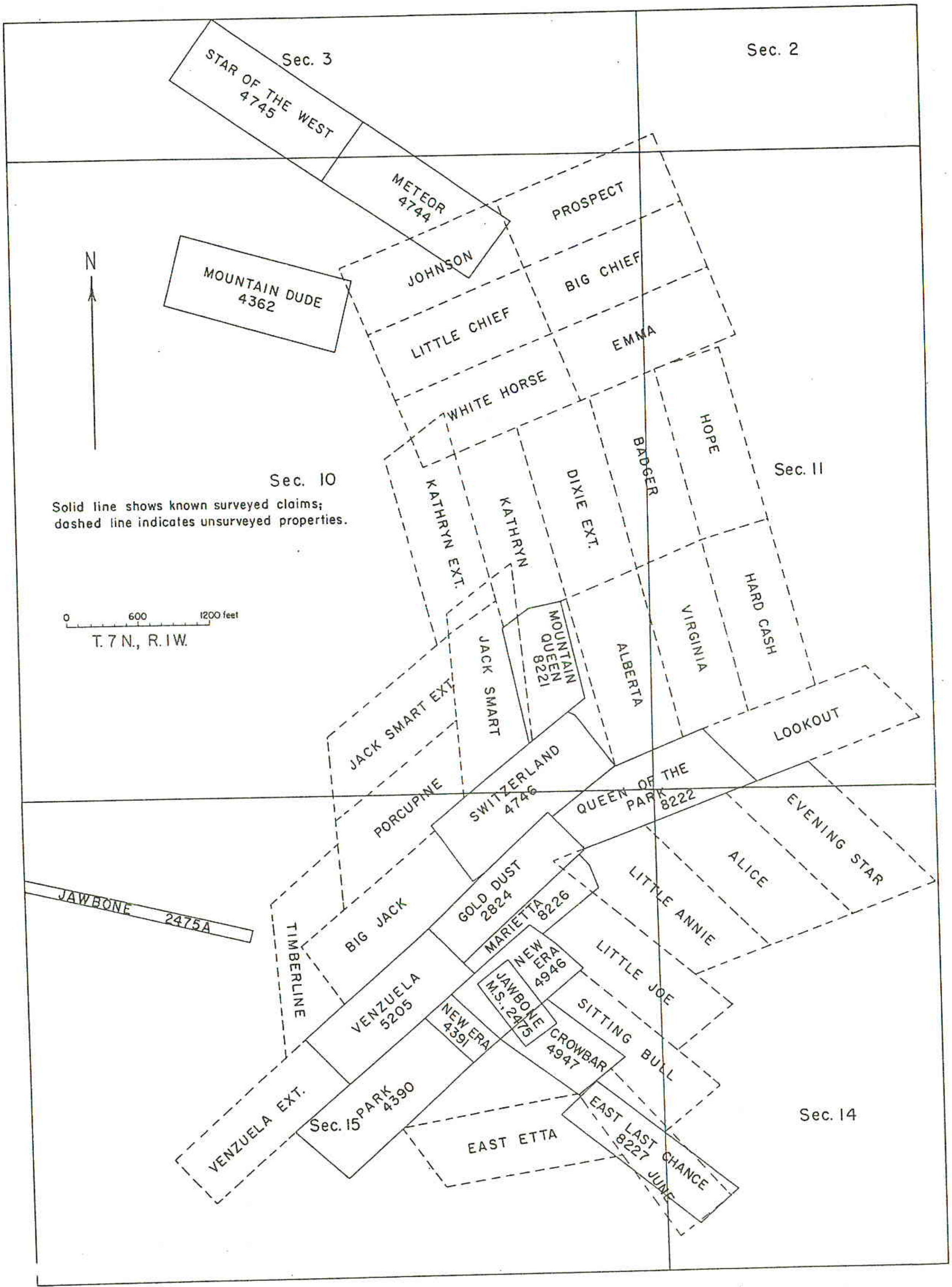

Figure 18.--Mining claim map of Marietta mine area.

## Park New-Era

The Park New-Era group (fig. 2 and 18) encompasses the Jackson workings (three levels), the Kane tunnel, and the Cotter drift (pl. 1). Seemingly a single vein was developed and mined in this group. It strikes about N. 45° E. and generally dips 50° to 60° SE. Reed (1951, table 8) lists production from the Park New-Era group at 11,348 tons of ore, from which 3,251 ounces of gold, 7,453 ounces of silver, 14 pounds of copper, and 76,108 pounds of lead were recovered. Indicated grade as calculated from sample and assay data obtained from a company map is 0.4 ounce gold, 2.5 ounces silver, 1.7 percent lead, and 4.5 percent zinc.

Vein widths of 4 feet were observed in the accessible parts of the workings, but the average width is probably about 2 feet (pl. 1). During 1960, the Kane tunnel, the 5th level, and the main level of the Jackson workings were inaccessible. The Mason tunnel (pl. 1) was rehabilitated in 1960, therefore the Cotter drift is accessible and the 4th level of the Jackson workings was partly accessible through the Wizemiller raise. Considerable stoping was evident but no commercial quantities of ore were observed. The Mason tunnel, developed as an access tunnel for the Cotter drift and Jackson workings early in the history of the mine, does not crosscut any commercial ore. Some of the faults in this tunnel, as throughout the area, are slightly mineralized and contain quartz, carbonate minerals, and pyrite.

## Little Annie

An inclined shaft, developed on the vein, allowed partial access to the Little Annie mine (fig. 2 and 18) in 1960. All ore is oxidized down to the present water level, which is about 220 feet down the 30° inclined access shaft. In 1960 about 200 feet of a crosscut 90 feet above the water level was accessible. The vein in this part of the mine strikes about N. 80° E., dips 30° NW., and is generally less than 2 feet wide. Reed (1951, p. 49) states that the indicated grade of the ore from the mine, based on company records, is 1.28 ounces gold, 14.0 ounces silver, and 7.0 percent lead. Total reported production from 1894 to 1936 was 600 tons of ore.

## Little Joe

Within several hundred yards of the Little Annie mine is the Little Joe prospect (fig. 2 and 18). Approximately 500 feet of drift was accessible in 1960. The vein strikes N. 70° E. and dips about 25° NW. It is 6 inches wide or less and contains chiefly quartz and oxidized sulfides.

### Bullion King

The Bullion King lode (fig. 2) is on the Queen of the Park claim (fig. 18). None of the underground workings are accessible. According to Reed (1951, p. 48) this lode was a shallow, steeply inclined chimney and had a plan area of about 25 square feet. Its long axis plunged northwest. This same author (p. 49) states that company records showed that 340 tons of ore produced from this lode during the period 1896-1919 had an indicated tenor of 12.0 ounces silver per ton and 55.0 percent lead.

### White Horse, Big Chief, and New Hope

The White Horse workings (fig. 2 and 18) are believed to be an extension of the Marietta vein, as indicated by a line of small prospect pits that can be followed from the B level adit northward, along the trend of the Marietta vein, into the area of the White Horse workings. None of the workings in the area were accessible. Widespread pyritization and bleaching and sheeting of the andesite is observable in the White Horse, Big Chief, and New Hope area. An outcrop of massive quartz about 300 feet long and 20 to 30 feet wide is present in the Big Chief locality.

The following has been condensed from Reed's account (1951, p. 51, table 12) of the prospects. In 1949 an adit had attained a length of 300 feet on the White Horse property and prospecting was still active. Previously, the old workings probably exploited a small lenticular ore body consisting principally of lead ore.

The New Hope prospect was developed on a structure that seems to persist for several hundred feet along a trend N. 25° W., and dips 30° NE. A sample obtained from a shallow cut contained 0.04 ounce gold and 0.5 ounce silver per ton, and 0.3 percent zinc. No production was reported from the New Hope and Big Chief properties.

### Vulture

The Vulture prospect is in the northwest part of the area mapped (fig. 2). Numerous workings are present both in the andesite and quartz diorite but none of them are accessible. According to Reed (1951, table 12) a vein that strikes N. 50° E. and dips 40° NW., consisting of galena, limonite, scant chalcopyrite, and drusy quartz was mined in this area. Less than 1,000 tons of ore was produced. The indicated grade is 0.23 ounce gold, 5.7 ounces silver, and 5.5 percent lead. The output prior to 1901 was said to contain 50 percent lead and 75 ounces silver per ton.

## Shep

None of the underground workings of the Shep prospect (fig. 2) are accessible. The following account of this prospect is condensed from Reed (1951, table 12). Old stopes in the mine, opened by a shaft, were mined out to widths of 2.5 feet on a vein that strikes N. 25° W. and dips 79° SW. The ore consisted of limonite in quartz gangue and had a reported value of $50 per ton. Production from this mine was less than 100 tons.

## Buckeye

The Buckeye workings (fig. 2) are entirely caved. Bulldozed cuts in the area exposed pyritized, bleached, and sheeted andesite. According to Reed (1951, table 12), a vein that strikes N. 55° W. and dips vertical contained pyrite, galena, sparse sphalerite, and ankerite, but produced less than 200 tons of ore. On surface exposures the width of the vein ranges from 0.5 to 2.5 feet.

## Phoenix

The exact location of the Phoenix prospect is unknown. Several abandoned workings are present both in the andesite and quartz diorite and probably are all part of the Phoenix prospect (fig. 2). According to Reed (1951, table 12), a vein 1 to 1.5 feet wide was explored by a shallow shaft and three short adits. The strike of the vein is N. 25° W. and the dip is 75° NE., and the indicated horizontal length is about 400 feet. This was a lead prospect, and recorded production was less than 100 tons.

## Iron Mask

The Iron Mask property (fig. 2) was one of the larger producers in the area mapped. In 1960 the property was inactive and inaccessible. Oxidized galena, sphalerite, pyrite, and carbonate minerals, including copper carbonates, and quartz were observed on the dumps. In 1910 Stone (p. 89) reported that this mine had a shaft probably deeper than 200 feet and that the ore was mostly oxidized iron and galena in quartz. Available production figures for the Iron Mask property are noted in the chronological account of the mines in a previous section of this report.

The following account on this property has been condensed from Reed's report (1951, p. 46, table 8). The principal vein strikes N. 15° W., dips 75° to 85° NE., and ranges in width from 1.5 to 4 feet. A parallel vein structure had been exposed but not developed about 15 feet west of the major vein. The principal vein was developed by a series of raises and stopes for about 600 feet horizontally from a 2,300-foot crosscut adit, which penetrated the vein about 570 feet below the outcrop. The recovered metal content of the ore averaged 4.0 percent lead, 7.4 percent zinc, 0.2 percent copper, 0.005 ounce gold, and 4.9 ounces silver per ton.

Another structure that strikes N. 10° E. to N. 10° W., dips 77° E., and ranges in width from 1 to 5 feet, was explored for a horizontal distance of 350 feet. This vein was penetrated near the portal of the crosscut tunnel.

### St. Louis

The St. Louis prospect (fig. 2) was developed by a shaft, but it was inaccessible in 1960. Minerals observed on the dump were pyrite, galena, arsenopyrite, sphalerite, and quartz. Reed (1951, table 12) states that the St. Louis structure strikes N. 85° W. and dips steeply. Indicated grade is 0.37 ounce gold, 1.6 ounces silver, and 0.3 percent lead. Production is listed at less than 500 tons of ore.

Numerous other abandoned mines and prospect pits are present in the area mapped. The location of the more extensive workings are shown on Figure 2. Most of the prospect pits and abandoned mines show minerals similar to those of the Marietta mine but obviously in noncommercial quantities.

## SUMMARY

The geology of the numerous veins in the area mapped seems to be similar to that of the veins in the Marietta mine. Some of the outlying veins, however, are associated with exposed intrusive rocks. The association of the ore deposits with intrusive and extrusive rocks throughout the Elkhorn Mountains suggest that the mineralization in the Marietta mine is genetically related to the magma from which the intrusive and extrusive rocks in the area originated.

Knopf (1931, p. 11) states that the ore deposits of the Helena mining region are replacement-fissure lodes commonly enclosed in andesite or intrusive rocks and containing pyrite, arsenopyrite, galena, and sphalerite as the principal sulfides, and tourmaline as one of the gangue minerals, but tourmaline is not an ubiquitous mineral throughout the region. Pardee and Schrader (1933, p. 196) agreed with Knopf and further stated that a characteristic zonal trend in the region is the increase in the proportion of quartz to sulfides with depth. The Marietta mine generally fits these descriptions with the exception of a lack of tourmaline and a lack of quartz-sulfide zoning, although deeper exploration of the Marietta mine may reveal quartz-sulfide zonation.

The Marietta ore is generally similar to the "typical epithermal deposits" described by Schmitt (1950, p. 192). In epithermal deposits the lodes are generally enclosed in altered andesitic rocks of about the same age and occupy faults in which fissure filling predominates over replacement. Texture and minerals present are similar to Marietta ore. The Marietta mine, however, contains more sulfides and less quartz than the "normal" epithermal deposit. Increasing fissure complexity upward, and downward termination in a barren zone, common in epithermal ore deposits, are not observable in the Marietta area, owing to erosion and to lack of exploration at depth.

Igneous activity and associated ore deposition in the Boulder batholith area can be divided into three periods (Billingsley and Grimes, 1918, p. 288): (1) an early andesite period (Late Cretaceous), (2) a granite period (Early Tertiary), and (3) a rhyolite period (probably Oligocene). During the granitic period the Boulder batholith and the largest number and the most varied types of ore deposits were emplaced. The Indian Creek region is listed as one of the districts that was mineralized during the granitic period (Billingsley and Grimes, 1918, appendix B).

Mineralization in the Marietta area is believed by the author to be genetically related to the magma from which the Elkhorn Mountains volcanics and associated basic intrusive rocks in the area originated. This phase of igneous activity occurred during the andesite period, and therefore it is reasonable to assume that the mineralization in the Marietta area was stimulated by this igneous activity. Numerous epithermal ore deposits throughout the world are genetically associated with basic extrusive rocks, and specifically with altered andesites similar to those of the Marietta area. Examples of these epithermal deposits are the San Juan district (Moehlman, 1936); the Pachuca silver district, Mexico (Wisser, 1937); and the Tonapah mining district, Nevada (Nolan, 1935).

## SUGGESTIONS FOR PROSPECTING IN THE MARIETTA AREA

The Marietta and Gold Dust veins below the No. 5 level, and the northerly extension of the Marietta vein on the No. 4 level, are the areas that are most likely to contain undiscovered ore. The Marietta structure extends a minimum of 400 feet farther north on the surface and B level than the known northern extent of the structure on the No. 4 level (pl. 1). The difference in elevation between the B and No. 4 levels is about 245 feet. Therefore, one may expect the structure to continue northward on the No. 4 level. Exploratory drifting on, and raising from, the No. 4 level seems to be the most feasible method of exploring north of the present extent of the No. 4 level.

Current exploratory work on the Mason tunnel level consists of northward drifting to explore a possible westerly and deeper extension of the Little Annie vein (fig. 2), and the Gold Dust and Marietta veins at depth (pl. 1).

Further exploratory work on the surface may prove fruitful, especially along the trend of the Marietta vein. Heavy soil cover and lack of outcrops would entail removing the overburden by relatively inexpensive methods.

The exploratory work described in this section will involve high capital risk, but it is generally agreed that mining exploration must be venturesome, within reasonable economic limits, if new ore bodies are to be found.

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