Geology and Ore Deposits of the Arabia District
Pershing County, Nevada

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Geology

by

Donald James Decker

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The thesis of Donald James Decker is approved:

Anthony L. Payne
Thesis Advisor

Earle W. Kersten, Jr.
Department Chairman

Deborah J. Brien
Dean, Graduate School

University of Nevada
Reno

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ABSTRACT

The Arabia District has produced lead-silver antimony ore in two periods of activity since discovery in 1859. Total metal production at 1971 prices would total nearly one million dollars. Of this, antimony is of the most value, followed by lead and silver. The district is located 15 miles north of Lovelock, Nevada on the east flank of the Trinity Range.

The oldest rocks exposed are part of the Grass Valley Formation of Upper Triassic Age. This formation consists of mudstone, limestone, volcanic wacke, quartz wacke, and slate. The sedimentary rocks were intruded and domed by quartz diorite and granodiorite in Late Cretaceous time. Tensional fractures in the hood zone of the intrusives produced planes of weakness in which later quartz-sulfide veins were formed.

Three types of alteration are observed in the district: contact metamorphism, hydrothermal alteration, and supergene alteration. The hydrothermal alteration is divided into sericitic, intermediate argillic, and propylitic facies, zonally related to the veins.

Hypogene mineralization occurred in two stages and consisted primarily of quartz, calcite, pyrite, jamesonite, pyrrhotite, and arsenopyrite. This was followed by two stages of supergene alteration, which contributed materially to enrichment of the ore.

Following deposition and enrichment of the ore, a
volcanic sequence at least several hundred feet in thickness was deposited, started in Miocene, possibly continued into Pliocene time.

The orebodies display structural and lithologic control. The veins have been subjected to at least five periods of deformation of which the third contributed to supergene enrichment. The veins have been highly oxidized, and enrichment has occurred in the oxidized zone. The ores consist of bindheimite and stetefeldite principally, both of which carry values in silver. Supergene sulfide enrichment at depth may be present. This is indicated by minor supergene sulfides in some workings, as well as favorable mineralogy for its development.

Potential areas for further exploration are pointed out in the vicinity of the West Workings, where many small veins might present a bulk mineable deposit. Also pointed out is a possible faulted extension of the Montezuma Vein which should be explored for, as well as a parallel vein which could be tested. Another potential target is the downward extension of the Electric, Jersey, and West Workings veins which could carry supergene silver sulfides.
INTRODUCTION

The Arabia District is a deep epithermal or shallow mesothermal mining camp which has produced lead, antimony and silver in two main periods of activity. The district is comprised of a cluster of small mines located in a region of antimony mineralization particularly well exposed in the Humboldt, West Humboldt, and Trinity Ranges.

Location

The Arabia Mining District is located in the Trinity Range, fifteen miles north of the community of Lovelock, Nevada on the western edge of the Humboldt River Valley, within Pershing County. Access to the district is most easily gained by leaving Interstate 80 (See Figure 1) at Oreana or Woolsey and proceeding on Poker Brown Camp Road to the northwest. The Arabia District is about 1 mile off the Poker Brown Camp Road, a total of eight miles from Interstate 80. Good graveled and dirt roads allow access at all seasons of the year.

Previous Work

The earliest account of the district is by Hague (1870), in which the 40th Parallel Survey Party described their visit to the district. Considerable historical emphasis has been placed on the Oreana Smelter, constructed in 1865. In 1917, Knopf (1917) visited and described the district; his work is principally a description of the Montezuma Mine and an
Figure 1

Location of the Arabia Mining District
outline of areas deserving of further investigation. Various other references mention the Arabia District, but the data primarily derives from these previous publications. Lawrence (1963) described the various properties in the district in detail, and mapped many of the workings in a descriptive inventory of Nevada's antimony deposits. Pershing County has been mapped on a reconnaissance basis by Tatlock (1969), no particular detailed emphasis having been placed on the Arabia District. The William Company of San Francisco is active in the district, in an apparent search for antimony.

History

The ores of Arabia were discovered by George Lovelock in 1859, for whom the nearby community is named. Organization of the district was accomplished in 1863. The productive record of Arabia has been confused by being included with statistics of the Trinity District, six miles to the southwest (See Figure 1).

The first development centered around the Montezuma Mine, which became a significant producer. Later, the Electric and Jersey Mines were opened, as well as the West Group and the centrally located Jaxrace Jewel prospect. The Electric Mine has the most extensive workings and probably surpassed the Montezuma in production.

Various small companies operated the mines sporadically before 1870, and a smelter was built in 1865 near the Salinas Ranch, four miles to the south (See Figure 2), the first
Figure 2 Oreana Smelter: This photo was taken by Mr. Timothy O'Sullivan, official photographer of the 40th Parallel Survey Party in 1869. Note the stacks of cordwood and oxen drawn wagons. Remains of the smelter can still be found.
smelter in the United States to ship lead to the general market (others had produced lead for local consumption) (Lincoln, 1923, p. 22). The completion of the transcontinental railroad in 1864 was a major impetus in development of the district.

After 1870, no production is recorded until 1919, although Knopf (1917) indicates the district was being revived at the time of his study. The work was spurred by the high prices for lead, antimony, and silver brought about by World War I. The major portion of production after 1917 was mined by lessees, so accurate statistics are not available. Figure 3 shows an approximation of the production from the district. The latest recorded production was in 1944, and the district has lain idle since.

Considering this metal production at 1971 prices, Arabia is in the one million dollar class of mining camp. Most value was produced in antimony, followed by silver, lead and gold. Minor copper production (736 pounds) has been reported.

Acknowledgments

Space is lacking to acknowledge the writer's indebtedness to everyone who contributed direct support in the thesis program, or offered encouragement through undergraduate and graduate studies.

Dr. A. L. Payne is due thanks for suggesting the thesis topic. Bear Creek Mining Company is gratefully acknowledged for financial support. Mr. L. B. Wright is acknowledged for
### PRODUCTION HISTORY

<table>
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<td>*</td>
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<td>750,000&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>1870&lt;sup&gt;*&lt;/sup&gt;</td>
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<tr>
<td>1917</td>
<td>36.7</td>
<td>6,746</td>
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<td>1918</td>
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<td>51</td>
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<td>27.6</td>
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<td>159,129</td>
<td>862,000</td>
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* None reported
1 Estimated by the author

Gold and Silver in ounces.
Lead and Antimony in pounds.
drill logs provided as well as discussion concerning the
district. Messrs. D. L. Stevens, Paul Holmes, and Wayne
Kemp, graduate students, at the Mackay School of Mines
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the laser microprobe.

Thanks are due my wife, Suzanne, who provided constant
encouragement as well as many hours of typing and preparation
of illustrations.
AREAL GEOLOGY

The sedimentary rocks in the Arabia District and the surrounding region are part of the Winnemucca Sequence (Tatlock, 1969) of Triassic and Jurassic age. To the east, in the Humboldt Range, this sequence has been subdivided into several stratigraphic units by Silberling and Wallace (1969), consisting of the Star Peak Group from bottom to top; which includes the Prida and Natchez Pass Formations, overlain by the Grass Valley, Dun Glen, Winnemucca, and Raspberry Formations (See Figure 4). The rocks of the Arabia District are tentatively correlated with the Grass Valley Formation (Silberling, 1971), which was laid down in a marine basin with a coastline to the east.

In Cretaceous time, following folding of the sedimentary rocks, the Trinity Range was intruded by granodiorite stocks. One of these stocks, at a point 6 miles west of the Arabia District has been dated (biotite) 93.7 ± 3.9 M. Y. (Tatlock, 1971); placing the intrusive in the early Cretaceous, or Lovelock period of plutonism as defined by Smith et al. (1971). The exposed intrusives in the Arabia District are in part finer-grained than the stock to the west, but they may be parts of the same intrusive mass.

Deep erosion reduced the terrain to a surface of low relief upon which varied volcanic rocks of Tertiary age were deposited, presently outcropping over approximately 50% of the Trinity Range. Erosion followed deposition of
### Generalized Stratigraphic Sequence

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<td>Middle</td>
<td>Winnemucca Formation</td>
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<tr>
<td></td>
<td></td>
<td>Lower</td>
<td>Dun Glen Formation</td>
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<td>Anisian</td>
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<td>Middle &amp; Lower</td>
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**Figure 4** Generalized stratigraphic sequence in the Humboldt and Trinity Ranges. (Silberling and Wallace, 1969, p.5, and Tatlock, 1969.)
the volcanic units, and continues to the present date. Pleistocene Lahontan Lake beds are present in the lower elevations marginal to the Trinity Range, where the lacustrine deposits are incised by the present drainage of the Humboldt River and its tributaries.
DISTRICT GEOLOGY

Mesozoic System

Stratigraphy

The Arabia District is underlain by sedimentary rocks of Triassic-Jurassic age. Tatlock (1969) included the sedimentary rocks in an undifferentiated "Jurassic-Triassic" unit which encompasses the Winnemucca sequence and younger Mesozoic rocks in Pershing County. Silberling (1971) suggests these rocks are part of the Grass Valley Formation of Upper Triassic age. Similar lithologies are found in the Humboldt Range. No Mesozoic fossils have been found to aid in dating the rocks.

Within the Arabia District, the sedimentary sequence consists of five distinct units, here described in approximate order of deposition: (1) mudstone and siltstone, (2) limestone, (3) volcanic wacke, (4) slate, and (5) quartz wacke. The mudstone and siltstone, volcanic wacke, and slate units are the major rock types, with an aggregate thickness of approximately 2,900 feet in the district. The limestone and quartz wacke form tongues and lentils respectively within the thicker units. All contacts between units are gradational.

The limestone unit (R uv) is found as a tongue within the mudstone and siltstone, locally attaining a thickness of fifteen feet. It is a detrital limestone with much intermixed
argillaceous material. Cementation is dominantly calcareous, with minor silica. The limestone is a moderate yellowish brown (10 YR 5/4) on fresh surfaces, weathering to a dark yellowish orange (10 YR 6/4).

The volcanic wacke unit ($^5$R gv$_3$) is fine-grained and very thin bedded with up to 70% lithic volcanic fragments, 15% quartz fragments, and as much as 15% argillaceous and authigenic quartz cement. It is medium dark gray (N4) on fresh surfaces, and weathers dark brownish black (5 YR 3/1).

The slate unit ($^5$R gv$_4$) is found randomly interbedded within the other rocks. It usually forms topographic lows, and is often difficult to distinguish from the volcanic wacke unit, with which it locally is intergradational. Beds of the slate are sometimes gradational downward into mudstone. The rocks consist of thinly bedded calcareous and non-calcareous beds. On a fresh surface the rock is dark gray (N3), weathering to medium dark gray (N4) except where limonite produces other colors.

The quartz wacke lentil unit ($^5$R gv$_5$) is the least extensive in the mapped area, but commonly forms bold outcrops. It consists of fine to very fine sand size quartz and lithic fragments and up to 14% argillaceous matrix. The remainder of the rock is made up of opaque grains as well as some hematite and jarosite. The sand grains are well sorted and sub-angular to rounded in shape. On a fresh surface the rock is light yellowish gray to white
(5 YR 8/2) (depending on iron content) and weathers moderate brown (5 YR 5/4).

The quartz wacke is found in beds up to 10 feet in thickness, some of which may be traced for 500 feet. The shape of the unit indicates it may have been deposited in channels or some other bottom depression which controlled local currents. It is similar to the clean sandstone unit described by Silberling (1969) in the Grass Valley Formation.

**Intrusive Rocks**

Two kinds of Mesozoic intrusive rock are exposed in the Arabia District. These are quartz diorite and granodiorite. Tatlock (1969) included all the intrusive rocks of the Arabia District in a Cretaceous age grouping. As mentioned previously, a Cretaceous date has been obtained from a granodiorite stock to the west. It is possible that the intrusives exposed in the area mapped are late differentiates from the larger granodiorite mass to the west. If this is the case, then a Cretaceous age is indicated.

The two types of intrusives exposed are never found in contact, but detailed study indicates the quartz diorite mass was emplaced first. This is supported by fractures present in many grains of the quartz diorite as well as minor aplite dikes cutting the mass. The fractures are thought to be due to stresses imposed by the later intrusives.

The quartz diorite comprises the easternmost intrusive, and is a hypidiomorphic granular rock with phenocrysts of
hornblende up to one and one-half centimeter in length. The dominant plagioclase (28%) is andesine of An$_{30-37}$, with K-feldspar comprising 3%, and quartz, 26%; with hornblende and biotite making up 21% of the mode.

Granodiorite, which in places is porphyritic, comprises all the remaining intrusive masses. Sericitization is pervasive throughout this unit, as well as some secondary biotite. The alteration will be covered in more detail in a later section. The granodiorite is composed of 23 to 33% quartz, and 47 to 56% feldspar, of which an estimated 10 to 20% is orthoclase. The feldspars are extremely altered, and difficult to identify. Some phenocrysts of plagioclase up to 3 millimeters in diameter are present in a hypidiomorphic granular ground mass. The granodiorite may locally be quartz monzonite or quartz diorite, but extensive microscope work would be required to delineate the variations.

Both intrusive rock types present in the district were probably emplaced in a deep epizonal environment, since characteristics of both the epizone and mesozone (Badgley, 1965, p. 335) are evident. The granodiorite bodies in the main mining area (Plate 2) display sharp intrusive contacts with contact metamorphic effects up to two feet from the contact. In this area, the volcanic wacke unit has been recrystallized to a cordierite-biotite hornfels.

Also present in the intrusive bodies shown on Plate 2 are xenoliths of the volcanic wacke. These are rather
prominent along the Electric, Jersey, and Montezuma veins. The xenoliths show contact metamorphic effects, but retain nearly the same bedding attitudes as the sediments surrounding the intrusive bodies, indicating little rotation during their engulfment.

The xenoliths as well as other criteria outlined by Badgley (1965, p. 358) tend to support a permissive emplacement, magmatic stoping mechanism for the intrusive bodies. The individual intrusives tend to be elliptical in plan; the long axis striking nearly east-west, and discordant to the country rock. The contacts with country rocks are sharp, and in one underground exposure, dikes of the granodiorite are observed cutting the sedimentary rocks. These observations lend support to the magmatic stoping mechanism of emplacement.

**Tertiary System**

**Stratigraphy**

One Tertiary sedimentary unit is exposed, which is tentatively assigned a Miocene age. The unit is a detrital limestone with fossils locally making up 50% of the rock. Chalcedony cement has solidified the unit, and makes removal of the fossils nearly impossible. Silberling (1971) assigned a Tertiary date, but does not define it more closely.

**Igneous Rocks**

Extrusive igneous rocks underlie approximately one-half
of the mapped area in the Arabia District. These include andesite, rhyolite, latite, and vitric tuff, and an intercalated mud flow.

The andesite flow found in the eastern portion of the mapped area is of similar composition and texture as the andesite intrusive body (Tai) located in south central portion. The flow unit may locally be 50 feet thick, but is obscured by overlying volcanic units.

Overlying the andesite flow is a more extensive rhyolite unit which forms the basal flow over the largest outcrop area and may attain a thickness of 200 feet. The rhyolite locally has obsidian at the base, up to 10 feet thick. The unit locally grades into a rhyolite breccia with fragments up to 3 cm in diameter. The brecciated portion is usually cemented by volcanic glass, but locally opal is found.

Randomly within the rhyolite, flows of latite (Trachyandesite) are found. In the northwestern corner of the mapped area, this unit is up to 150 feet thick; however most occurrences are only about 20 feet in thickness. The rock contains approximately 10% mafic constituents, consisting of amphibole and pyroxene phenocrysts, and up to 10% opaque grains. The dominant feldspar is andesine of An$_{41}$ making up 11% of the rock, while orthoclase totals 9%. The ground mass is made up of 41% microlites of An$_{26}$ composition and 19% glass.

The youngest volcanic unit is a vitric tuff containing pumice fragments and minor amounts of biotite, sanidine or
orthoclase, and opaques, in a rhyolite glass. All shards in the glass have been replaced by tridymite. Leucosxene and magnetite are present locally. The unit is thin and mostly removed by erosion, however locally as much as an estimated 20 feet are present.

The volcanics present in the Arabia District are probably part of the 14 to 23 M. Y. old province as outlined by Schilling (1965). Two Tertiary Volcanic dates in the Trinity Range (Tatlock, 1971), in similar rocks within 15 miles of the district show respective ages of 14 and 23 M. Y.

Quaternary System

Quaternary sediments underlie the east, south and west sides of the district. They have been derived locally from erosion of the pre-existing rocks. The earliest Quaternary unit is a landslide block of rhyolite, underlain by slate and volcanic wacke.

Quaternary erosion has involved at least two base levels; the high stand level of Pleistocene Lake Lahontan, and the present base level of the Humboldt River and Carson Sink. During the existence of Lake Lahontan, well washed beach gravels were deposited in wave built terraces along the south and east edges of the mapped area. These gravels consist of sand and pebble-size volcanic and sedimentary fragments, in which the pebbles are normally well rounded and flat in one dimension.

Contemporaneous with the lake beds, an older alluvium
developed on the lower slopes. This has been subsequently removed in areas of more active erosion. This unit consists of sand and pebble-size particles derived from the underlying rocks.

Since the waning of Lake Lahontan, alluvial channels have been carved in the older alluvium and the lake beds. This is best expressed in the creek bed along the west side of the mapped area. Locally playa lakes have been formed where wave-built terraces or bars do not allow drainage.

Structure

The Grass Valley Formation in the area mapped is a homoclinal unit with a strike ranging from N10° to 40°W and dipping 10° to 40°SW. Local disturbances due to doming give rise to variations within the district. This homoclinal is quite possibly the limb of an anticline or syncline located outside the mapped area. Much intraformational faulting is present, of negligible offset. This is apparently related to readjustment during intrusion and doming along minor bedding planes and small normal faults.

Exposures of the Grass Valley, and other Triassic units in the Trinity and Humboldt Ranges strike generally NNE, in contrast to the NNW strike in the Arabia District. Tight folds in the Antelope Springs Mining District (Wallace et al 1969) trend NNW as do the rocks in the Arabia District. Roberts (1966) infers a NNW Lovelock-Austin mineral belt passing through the Arabia and Antelope Springs Districts.
The NNW strike of rocks in these two districts may be an expression of second order folding adjacent to a major structural break of this kind. Variations in the general attitude of the Triassic rocks between the Arabia District and the Majuba Hill area lend support for right lateral movement along a structural break between the two districts.

Local variations in bedding attitudes may be attributed to doming related to intrusives. On the northeast side of the exposed intrusive bodies, the sediments dip less steeply than on the southwest side. This is interpreted to have been caused by readjustment at the time of intrusion.

Late Tertiary normal faulting is present throughout the mapped area. These faults are nearly vertical, with one set striking N50° to 80°E, and another N40°W. A third possible set is expressed by faults striking N20° to 25°E. The normal faults are best seen in exposures of Tertiary volcanic rocks south of the West Workings. One normal fault has offset the older alluvium in the northeastern corner of the map area. Several of the veins are offset by various normal faults. Maximum displacement observed along these normal faults is on the order of a few tens of feet.

The Tertiary normal faulting started in Mid to Late Miocene time, and continued into the Pleistocene. The early volcanics are offset, while the latest (vitric tuff) shows less apparent disturbance. The latest movement is expressed in the northeast portion of the mapped area, where the alluvial unit contemporaneous with Lake Lahontan is offset.
GEOLOGIC HISTORY

The Grass Valley Formation of Upper Triassic age (upper Karnian to Middle Norian) is the lowermost unit exposed in the Arabia District. These sediments were laid down in a shallow marine or deltaic environment with west to northwestward transport. Local variations in deposition are indicated by limestone deposition as well as some quartz wacke units in possible fluvial channels.

Following deposition of the sediments, gentle folding produced a homoclinal sequence through the district. This was followed in Cretaceous time by gentle doming and permissive emplacement of quartz diorite and granodiorite bodies in the Lovelock intrusive epoch. With cooling of the granodiorite bodies, tensional fractures developed in which quartz veinlets and quartz sulfide veins formed. These veins formed in a deep epizonal environment, probably in the range of 1,000 to 3,000 feet below the surface.

Erosion followed intrusion and mineralization, continuing into the Miocene. Late in this epoch of weathering the veins were oxidized. In Early Miocene time, volcanic units were erupted, probably continuing into the Pliocene, during which several hundred feet of volcanics were accumulated. One Tertiary sedimentary unit, a lacustrine limestone, is probably Miocene or earlier, but a definite age was not determined.
Commencing in Mid to Late Miocene, normal faulting affected the district and has been active until at least Pleistocene time. Due to this faulting, many of the veins have been offset as well as portions of them being displaced along strike.

During Pleistocene time, Lake Lahontan lapped onto the lower edges of the district and formed various wave-built beach features. At this time, alluvial fans were formed with the lake as a base level. Local landsliding in the rhyolite unit occurred. With the dessication of Lake Lahontan, recent drainages have incised into the earlier features to form the present channels. Locally, playa lakes have formed where drainage is impeded by wave-built terraces.
ALTERATION

Three genetic types of alteration are found in the Arabia District. These include contact metamorphism, hydrothermal alteration related to mineralization, and supergene alteration of the veins. The hydrothermal alteration related to mineralization is further broken into three facies zonally related to the veins.

Contact Metamorphism

Contact metamorphism related to the granodiorite intrusive bodies is best exposed in the lowest open workings of the Electric Mine. At this location, the volcanic wacke unit has been metamorphosed to a cordierite-biotite hornfels. The metamorphic zone is restricted to within a few feet of the intrusive contact. In this facies, cordierite porphyroblasts with biotite, quartz, chlorite, goethite, plagioclase, and opaque grains occur.

This suite of metamorphic minerals is similar to that determined by Compton (1960) for one type of contact metamorphism observed in the Santa Rosa Range. Compton concluded this is characteristic of alteration associated with a relatively dry intrusive. At one point, granodiorite is in contact with the mudstone unit, and only minor recrystallization is evident in hand specimens.

Silicification has occurred at a number of places along the intrusive contacts, as for example west of the West Workings, where the slate unit has been silicified, locally
pyritized, and bleached. Weak vein structures are present here, but have not been responsible for the silicification.

**Hydrothermal Alteration**

As will be discussed later, the mineralization is found in distinct veins cutting both intrusive and sedimentary rocks. However, most productive ore bodies have been found where the veins are located in granodiorite.

A distinct hydrothermal alteration pattern is present surrounding the veins in granodiorite. This zonation is transitional from sericitic nearest the veins, through intermediate argillic and finally into propylitic alteration (Meyer and Hemley, 1967). The propylitic alteration is pervasive throughout all intrusive bodies in the district.

The sericitic zone, up to one foot wide near the veins, is characterized by quartz grains embayed and corroded by sericite. Primary biotite is totally altered to leucoxene and pyrite, with chlorite apparently altered to sericite. Plagioclase feldspars have been totally replaced by sericite and quartz, as well as montmorillonite clays. Silicification has introduced fine-grained quartz throughout the altered rock. Small crystals of apatite and sphene make up less than 1% of the rock. Limonite is found scattered through the zone, probably representing former ferromagnesian minerals. Prominent silicification borders some veins in this area.

Outward from the sericitic zone, an intermediate argillic zone varies in width from 1 to 2 feet on either side of the
veins. This facies is characterized by approximately 50% of the plagioclase being converted to sericite and montmorillonite. Minor epidote is found replacing feldspar, intermixed with sericite. The biotite is entirely converted to chlorite, epidote, pyrite, and leucoxene. Silicification has introduced minor quartz, and some quartz crystals are embayed by sericite. Apatite and sphene are present, but less abundant than in the sericitic zone.

The propylitic zone is found peripheral to the intermediate argillic zone, and affects all the remaining granodiorite in the mapped area. This facies is characterized by 10 to 50% of the plagioclase being altered to sericite and epidote. Cloudy feldspars result from alteration to montmorillonite clays. Twenty percent of the biotite is altered to chlorite, pyrite, and minor rutile. Calcite veinlets are present.

As mentioned previously, propylitic alteration is found throughout the exposed granodiorite. The quartz diorite intrusive is weakly altered to a propylitic facies, with minor (less than 10%) calcite and chlorite. Textural studies show this is due to deuteric alteration of the intrusive, rather than related to hydrothermal solutions. No silicification or pyritization are evident in this intrusive.

Figure 5 (p. 26) is a generalized AKF-ACF diagram from Meyer and Hemley (1967) showing the approximate composition of the alteration facies outlined. The numbers in the figure represent the approximate mineral composition of their
respective alteration facies.

**Supergene Alteration**

Following deposition of the ores, erosion took place which led to supergene alteration of the vein minerals. This alteration had profound influence upon the hypogene mineralization. More will be said of this alteration in a later section.

At the Montezuma Mine, jasperoid is developed in the vein structurally below the ore. This jasperoid is shown to be supergene by fragments of enriched ore encased within it, and developed at the time of supergene enrichment of the overlying ore.
The four types of alteration found in the district are represented in this diagram. The following numbers define the alteration stages represented by numbers in the diagram.

1. Sericitic
2. Intermediate Argillic
3. Propylitic
4. Propylitic (weakly expressed in quartz diorite)
ORE DEPOSITS

At least five separate mines, prospects, or groups of prospects are named and described in the Arabia District. The names as assigned by Lawrence (1963) will be followed, with the exception of the Jersey Mine whose location is corrected, and other prospects which are named according to the claim names. Other prospects and mines, besides the Jersey, include the Montezuma Mine, Electric Mine, Jaxrace Jewel Prospect, and the West Group of Workings. All have produced lead-antimony-silver ores. Lawrence (1963) states that at least 500 tons of antimony metal has been produced from the district. This production figure is substantiated by the estimates and recorded production shown on Figure 3. Reactivated names of prospects and mines include the Victor Mine (Jersey Mine of Lawrence), Aztex, and the Last Chance. Two views of the main mining area are shown in Figures 6 and 7 (p. 28).

Structural Control

The productive veins are dominantly located in granodiorite wall rocks and display structural as well as lithologic control. The major veins in the district strike N10°E to N20°W and dip 20° to 60° east, except in the Montezuma Mine area where the main vein strikes east and dips about 45° north.

The Electric Vein displays the best exposed evidence of
Figure 6  Main Mining Area - View East

Figure 7  Main Mining Area - View South

AKABIA  PERSHING COUNTY
structural control in the district. On three levels in the incline, the largest showing of ore (up to 3 feet wide) is in the portion of the vein which strikes approximately N20°W. In both directions along the vein, the strike changes to approximately N5° to 10°E, and the mineralization diminishes to a 1 to 2 inch stringer. Approximately 460 feet north of the incline on the Electric Vein, the strike changes to the west, attaining a width of 36 inches in a zone striking N03°W, dip 44° to the east. Footwall branches of the main vein are exposed on all three levels of the Electric incline. These branches strike parallel to the main structure but dip more steeply into the footwall. The mineralization in the footwall is the same as the main vein, but the veins do not exceed 6 inches in width.

The veins are thought to have developed in fracture zones which were caused by the doming at the time of intrusion. This type fracture is known as a "flat-lying normal fault", and is described by Balk (1936). The fractures would more aptly be called "low angle tensional faults". The Electric, Jersey, and Montezuma veins cut sedimentary rocks which are apparently xenolithic within the intrusive. The Electric vein appears to be localized along the footwall of a xenolith in one portion of the mine. This contact may have offered a weak zone which broke as one of the low angle tensional faults.

At least five periods of deformation have affected the
veins. The first was the development of the vein structures by tensional stresses induced during cooling of the intrusive body. This was followed by introduction of early quartz and sulfide vein mineralization. The veins were then brecciated and late productive mineralization occurred. Subsequent to late productive mineralization, faulting in the plane of the veins induced permeability and greatly aided the supergene processes which followed. After the major epoch of oxidation, the veins were again faulted in the plane of the structures. This deformation has locally displaced the mineralization into discontinuous pods. Such pinching out and widening of ore pods is seen well in the Last Chance workings. Post-mineral faulting did not affect the footwall veins present in the Electric Mine.

The fifth period of deformation was nearly vertical faults related to normal faulting in the district. These faults have offset most of the veins at one place or another from a few inches to several feet in a vertical direction, and one important faulted extension of ore is suggested in the Montezuma Vein.

**Lithologic Control**

As mentioned previously, the main mineralization is in veins contained within granodiorite host rock. Along the strike of exposed veins, sedimentary rocks are encountered. This change in lithology at several places was accompanied by a change in strike of the vein. Within sedimentary host
rock, the veins narrow in width, and commonly appear as shear planes with iron oxide stains after pyrite. The lack of development of veins in sedimentary rocks is thought to be due to the incompetent nature of the rocks.

Immediately north of the West Workings, vein structures may be traced for as much as 500 feet in the slate. Along these structures, sulphide mineralization is essentially absent. The same is true in the northern extension of the Electric Vein. This vein may be traced for about 500 feet in the volcanic wacke unit, but mineralization is restricted to quartz and calcite in about equal proportions, with minor oxide minerals after sparse ore minerals.

**Hypogene Mineralization**

The majority of the following paragenetic information was collected in the Electric and Jersey Mine areas, because these workings can be entered, and exposures are good.

Early barren quartz veins (See Figure 8) were emplaced locally in the vicinity of the Electric Vein before sulphides were introduced. The veins are less than two inches in width, and lack the alteration zones found around the main stage veins. The early quartz is compact and crystalline, a type not recognized in the main stages of mineralization.

Figure 8 (p. 32) portrays the two stages of productive hypogene mineralization. The first developed after the early barren quartz. The first stage developed pyrite, with subordinate jamesonite, pyrrhotite, arsenopyrite, and quartz.
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<th>MINERALS PRESENT</th>
<th>EARLY EARREN</th>
<th>EARLY PRODUCTIVE</th>
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Figure 8  Paragenetic development of minerals.

Broken vertical lines indicate periods of deformation of the veins. Horizontal lines indicate the presence of each mineral in the paragenetic stages.
The jamesonite, pyrrhotite, and arsenopyrite occur as small, corroded and rounded inclusions within the pyrite. This stage of mineralization was brecciated prior to introduction of the second stage. The pyrite of the first stage shows caries textures, with crystalline quartz of the second stage attacking it.

The second stage of mineralization is dominantly clear crystalline quartz, with pyrite, pyrrhotite, arsenopyrite, jamesonite, chalcopyrite, gold, tourmaline, and calcite.

Quartz and calcite (in variable proportions) comprise up to 80% of the vein material with the sulfides representing up to 25%, while tourmaline makes up less than 1%. As the veins pass into sedimentary rocks, and away from granodiorite, calcite increases, being generally more abundant than quartz. The quartz of this stage is clear and crystalline, and is seen veining and replacing the pyrite of the first stage. Chalcopyrite was found 200 feet southeast of the Montezuma Mine. Native gold was observed in goethite after pyrite of this stage.

Tourmaline is recognized in the Montezuma Mine, and high boron analyses (200 to 700 ppm) for other veins by spectrographic analysis indicate the mineral is probably present there also. Quartz is found throughout the vein system, while calcite is found only outside the ore zones. Calcite originally occurred in the ore zones, but has been removed during supergene alteration. Jamesonite was
apparently abundant in the Montezuma Mine, as indicated by Knopf (1917), but has been selectively mined so efficiently that none was observed in place during the course of field work.

The ore and gangue minerals are found in veins which range up to 4 feet wide in structurally favorable locations. Spectrographic analysis indicates the presence of arsenic, lead, and antimony, all greater than 1%, and silver, 150 to 300 ppm. Chemical analyses indicate mercury values up to 3 ppm, and selenium ranging from 8 to 50 ppm. The latter two elements are not recognized in mineral form. The lack of specific mercury and selenium minerals agrees with data of Davidson (1960) concerning selenium in epithermal deposits. The selenium is probably present as substitution for sulfur, while the mercury may be proctoring for lead. Maximum values by spectrographic analysis for bismuth (20 ppm), cobalt (10 ppm), nickel (5 ppm), zinc (less than 200 ppm), and tungsten (less than 50 ppm), makes the existence of mineral phases for these elements most unlikely.

**Supergene Mineralization**

Following the hypogene mineralization the veins were exposed at the surface by erosion, and supergene alteration occurred. Prior to oxidation of the veins brecciation related to faulting facilitated access of surface solutions into the vein structures. This pre-oxidation brecciation of the veins is seen best in strongly oxidized zones in the veins,
as angular oxidized fragments which have been later rebrecciated.

A large variation of supergene minerals are present, and include bindheimite (two varieties), stetefeldite, proustite, scorodite, hematite, limonite, goethite, covellite, gypsum, manganese wad, quartz, argentite, and possibly native silver. The bindheimite, as noted by Knopf (1917), occurs in a pitchy brown as well as an earthy yellow variety. The earthy yellow variety was shown to be silver bearing by laser microprobe analysis, and chemical analysis of the same gave 1460 ppm silver. Therefore, silver values in the oxidized zone are at least in part carried in bindheimite.

Stetefeldite is found in intimate association with both types of bindheimite. The minerals were identified by x-ray diffraction techniques, and compare in characteristics to the data of Mason and Vitaliano (1953). The three minerals are found in the oxidized portions of the Electric, Jersey, and Last Chance veins, as well as in the West Workings. Apparent lack of the minerals in the Montezuma Mine is attributed to efficient removal during mining.

One of the most abundant oxide minerals present is goethite. It is found replacing pyrite, pyrrhotite, and arsenopyrite with well developed caries, sea island, and atoll textures. It shows excellent pseudomorphic textures with well developed zonation, indicating that replacement was initiated along fractures. The pitchy brown bindheimite
similarly replaces pyrite. The earthy yellow bindheimite and stetefeldite are confined to fractures between grains of pyrite-goethite-pitchy bindheimite. Goethite is often associated with hematite and limonite.

Deeper in the mine workings covellite, argentite, proustite, and native silver become evident. Covellite and argentite occur as small irregular grains in the goethite. Argentite is also seen in thin veinlets cutting quartz. The proustite is found as microscopic euhedral crystals protruding into cavities. A mineral questionably identified as native silver is found as minute specks with high reflectivity within goethite.

Supergene quartz is found as narrow veinlets of fine-grained euhedral crystals. The veinlets are late in the sequence, and can be found cutting other supergene minerals. Manganese wad is found primarily in the Montezuma Mine open cut. It occurs locally in the footwall of the original orebody. Gypsum is found abundantly on the surface in the area of the West Workings.

In the highly oxidized zone, silver is enriched as well as antimony and lead, while arsenic is depleted. The development of antimony oxides and antimony-lead oxides is promoted in the highly oxidized zone because of the tendency of antimony to form insoluble oxides (Emmons, 1916, p. 407) and the immobility of lead. Arsenic, because of its position in the Schurmann Series, and mobility as an oxide, will
migrate from the oxidized zone. Silver has replaced lead or antimony in the bindheimite or antimony oxide structures, in the highly oxidized portions of veins. These processes lead to a "residual" enrichment of silver, antimony, and lead in the oxidized portions of the veins.

Calcite decomposes completely and is removed while pyrite leaves secondary iron oxides in the highly oxidized portions of the veins. This results in an enrichment of the ore metals due to removal of other vein materials. The two types of enrichment complement each other in the development of rich ore in the highly oxidized portions of veins.

Post-oxidation deformation of the veins is widespread and consists of two types. The most obvious type of deformation is movement in the plane of the veins, which develops gouge in oxidized minerals, as well as pinches and swells of the veins themselves. In the Last Chance Vein, this movement has distorted the vein into discontinuous pockets of ore along the workings. This movement inhibits further supergene enrichment because of the impermeability of the extensive gouge developed. Minor supergene minerals have developed after this as shown in Figure 8.

The second type of post-oxidation deformation is normal faulting which has offset some of the veins up to 15 feet in a vertical direction. The Montezuma Vein has been offset along a nearly East-West fault as shown in Plate 2.
Guides to Ore

Several features of the orebodies should be kept in mind while looking for ore in the district. These points are generalized as follows:

1. The main veins strike N10°E to N20°W and dip to the east.

2. Variation in the continuity of the veins due to hypogene ore shoots and post-oxidation deformation are common.

3. All production has been from veins with granodiorite wall rocks, or xenoliths within granodiorite.

4. As the veins pass into sedimentary rocks, and away from ore, gangue calcite increases, and may surpass quartz in abundance.

5. Supergene enrichment is an important factor in the concentration of metals in mineable ore deposits in the oxidized zone.
POTENTIAL OF THE DISTRICT

Several areas within the Arabia District warrant further consideration in looking for ore of the type mined in the past. It should be kept in mind however, that veins would likely be narrow and mining costs high.

In the vicinity of the West Workings, a potential deposit exists about 500 feet east of the main incline. At this locality, several veins up to 20 inches in width have been explored by shallow workings. The veins are closely spaced, and appear to continue laterally from the present workings. Supergene enrichment in these veins is evident. This could possibly be developed if the veins aggregate sufficient tonnage.

Approximately 2,000 feet north of the West Workings, calcite veinlets are found cutting the sedimentary rocks, while 1,500 feet north of the workings, small intrusive masses are exposed (See Plate 1). The calcite veinlets could be an expression of veins present in the intrusive at depth. However, supergene enrichment cannot be expected in these veins because of deep burial by rather impermeable sedimentary rocks, and lack of brecciation to induce permeability.

In the Electric and Jersey Mines, the possibility exists, as mentioned by Knopf (1917), that the veins will pass out of xenoliths, and develop strong veins with depth.
This is an intriguing possibility, and could only be proven by deep drill holes into this vicinity.

The Montezuma Mine area presents an interesting location for more exploration. Approximately 30 feet from the footwall of the Montezuma vein, another vein crops out on the surface which has been little explored. This vein has not been explored at depth where it might be present along the base of the xenolith in which the Montezuma Mine is located.

Another possibility in the Montezuma area is to explore for a blind faulted segment of the Montezuma vein itself. This segment, if it exists, should be located approximately 300 feet east of the present open cut, and on the north side of the east-west normal fault. Since the fault is down on the north side, the segment might be at least 100 to 200 feet below the surface, and probably would be enriched.

A final possibility for exploration is the Aztex claim where a strong calcite vein in granodiorite may indicate quartz-sulfide mineralization at depth.

Any exploration program for deposits should keep in mind the points outlined as guides to ore. Of particular interest is the location of orebodies positioned favorably for supergene enrichment.
DISCUSSION OF THE ORE DEPOSITS

During Late Cretaceous, quartz diorite and granodiorite intrusives were emplaced in which late deuteritic solutions produced a propylitic alteration facies. Post-magmatic hydrothermal solutions from the intrusive formed quartz sulfide veins in fractures produced by the doming intrusion. These veins were later subjected to oxidation and enrichment, which led to the present orebodies.

Mining in the Arabia District has been confined to oxidized lead-antimony-silver orebodies in granodiorite wall rocks. The veins are rather narrow, with a maximum width of four feet. The average grade of ore mined was approximately 10.6% lead, 6% antimony, 13.2 ounces per ton silver, and 0.12 ounces per ton gold. The values vary from this throughout the various workings.

Considerable supergene enrichment occurred at the surface which produced high grade lead-antimony-silver deposits. These highly oxidized deposits are characterized by lead-antimony and antimony oxides, which carry high silver contents.

Knopf (1917) states that supergene silver might be found at depth in the district. This is a definite possibility, and should be checked by exploration. Minor supergene sulfide silver was encountered in the highly oxidized veins. More supergene sulfides could be expected where the watertable was located at the time of oxidation. This type of enrichment would be most inclined to form in veins with little lead and
antimony oxides at the surface, and nonreactive rocks down dip. The West Workings could be a good area for this type enrichment because of many small veins, all located in the granodiorite.
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