THE GEOLOGY OF THE ESPERANZA MINE AND VICINITY
PIMA COUNTY, ARIZONA

by
Dean W. Lynch

A Thesis Submitted to the Faculty of the
DEPARTMENT OF GEOLOGY
In Partial Fulfillment of the Requirements
For the Degree of
MASTER OF SCIENCE
In the Graduate College
THE UNIVERSITY OF ARIZONA

1967
STATEMENT BY AUTHOR

This thesis has been submitted in partial fulfillment of requirements for an advanced degree at the University of Arizona and is deposited in the University Library to be made available to borrowers under rules of the Library.

Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the Graduate College when in his judgment the proposed use of the material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

SIGNED: Dean W. Lynch

APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

Willard C. Lacy
Head, Department of Mining and Geological Engineering

Date
ACKNOWLEDGEMENTS

The author is indebted to the following people for previous geologic work on the Esperanza area which greatly facilitated the writing of this paper: Dr. Harrison A. Schmitt, Consulting Geologist; Donn M. Clippinger, Senior Geologist, Duval Corporation; Ezra H. Lewis, former Resident Geologist, Duval Corporation and Dr. John R. Cooper, Geologist, U. S. Geological Survey. For the many helpful suggestions, and editing, and supplying mining data, appreciation is expressed to the following Duval personnel: Royce A. Hardy, Director of Development, Tom Jancic, Chief Mine Engineer, and Bruce L. Wilhelm, Geologic Draftsman. The excellent rock type closeups were taken by John Balla, Geologist, Bear Creek Mining Company.

Special thanks go to John E. Frost, Chief Geologist, Duval Corporation for his guidance, constructive criticism and encouragement in the preparation of this paper.

Charles H. Curtis, Resident Manager, Duval Corporation, generously contributed suggestions and material from his paper on "The Esperanza Concentrator".

The author wishes to express his gratitude to Messrs. W. P. Morris and G. E. Atwood, President and Vice
President, respectively, of Duval Corporation for permission to prepare and publish this paper.

The author is also grateful for the motivation and direction of Drs. J. A. Anthony, W. C. Lacy and W. C. Peters of the University of Arizona during the term of his course work.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF ILLUSTRATIONS</td>
<td>vii</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>ix</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Previous Work</td>
<td>1</td>
</tr>
<tr>
<td>Field Work and Scope of Paper</td>
<td>1</td>
</tr>
<tr>
<td>Location and General Setting</td>
<td>3</td>
</tr>
<tr>
<td>Physical Features</td>
<td>3</td>
</tr>
<tr>
<td>History and Development</td>
<td>5</td>
</tr>
<tr>
<td>ROCK TYPES</td>
<td>12</td>
</tr>
<tr>
<td>Sedimentary Rocks</td>
<td>12</td>
</tr>
<tr>
<td>Extrusive Rocks</td>
<td>15</td>
</tr>
<tr>
<td>Rhyolitic Welded Tuff</td>
<td>15</td>
</tr>
<tr>
<td>&quot;Silverbell&quot; Welded Tuffs</td>
<td>18</td>
</tr>
<tr>
<td>Intrusive Rocks</td>
<td>22</td>
</tr>
<tr>
<td>Quartz Latite Porphyry</td>
<td>22</td>
</tr>
<tr>
<td>Biotite Granodiorite</td>
<td>25</td>
</tr>
<tr>
<td>Quartz Monzonite Porphyry</td>
<td>28</td>
</tr>
<tr>
<td>Quartz Diorite</td>
<td>32</td>
</tr>
<tr>
<td>Dacite Porphyry</td>
<td>37</td>
</tr>
<tr>
<td>Andesite Porphyry</td>
<td>38</td>
</tr>
<tr>
<td>Zebra Quartz</td>
<td>40</td>
</tr>
<tr>
<td>METALLIZATION</td>
<td>43</td>
</tr>
<tr>
<td>Hypogene</td>
<td>43</td>
</tr>
<tr>
<td>Chalcopyrite</td>
<td>43</td>
</tr>
<tr>
<td>Molybdenite</td>
<td>44</td>
</tr>
<tr>
<td>Galena and Sphalerite</td>
<td>44</td>
</tr>
<tr>
<td>Pyrite</td>
<td>46</td>
</tr>
<tr>
<td>Supergene</td>
<td>46</td>
</tr>
<tr>
<td>Chalcocite</td>
<td>46</td>
</tr>
<tr>
<td>Covellite</td>
<td>47</td>
</tr>
<tr>
<td>Oxide Zone</td>
<td>47</td>
</tr>
<tr>
<td>Native Copper</td>
<td>47</td>
</tr>
<tr>
<td>Ferrimolybdite</td>
<td>47</td>
</tr>
<tr>
<td>Oxidation Products</td>
<td>48</td>
</tr>
<tr>
<td>Metallization Summary</td>
<td>49</td>
</tr>
</tbody>
</table>
### TABLE OF CONTENTS—Continued

<table>
<thead>
<tr>
<th>STRUCTURE</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geologic Setting</td>
<td>50</td>
</tr>
<tr>
<td>Ore Controls</td>
<td>51</td>
</tr>
<tr>
<td>Faults</td>
<td>52</td>
</tr>
<tr>
<td>Joint Systems</td>
<td>54</td>
</tr>
<tr>
<td>Folding</td>
<td>55</td>
</tr>
</tbody>
</table>

| ALTERATION                          | 56   |
| K-Felspar                           | 56   |
| Silicification                      | 56   |
| Argillization                       | 60   |
| Sericitization                      | 60   |
| Biotization                         | 61   |

| ECONOMIC GEOLOGY                    | 65   |

| SELECTED BIBLIOGRAPHY               | 69   |
# LIST OF ILLUSTRATIONS

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Location map</td>
<td>4</td>
</tr>
<tr>
<td>2.</td>
<td>Aerial photograph of the Esperanza Mine area before stripping operations. Taken January 1958 looking southwest</td>
<td>8</td>
</tr>
<tr>
<td>3.</td>
<td>Aerial photograph of the Esperanza Mine as of June, 1963, looking southwest</td>
<td>9</td>
</tr>
<tr>
<td>4.</td>
<td>Surface geology, Esperanza area</td>
<td>In pocket</td>
</tr>
<tr>
<td>5.</td>
<td>Fine grained quartzite. Specimen obtained from the 3900 Bench</td>
<td>13</td>
</tr>
<tr>
<td>6.</td>
<td>Rhyolitic welded tuff showing chalcocite dissemination and exhibiting sub-conchoidal fracturing</td>
<td>16</td>
</tr>
<tr>
<td>7.</td>
<td>Surface and pit geology, Esperanza Mine</td>
<td>In pocket</td>
</tr>
<tr>
<td>8.</td>
<td>Geology map of the 4040 Bench</td>
<td>In pocket</td>
</tr>
<tr>
<td>9.</td>
<td>Quartz latite porphyry showing both veining and dissemination of chalcocite</td>
<td>23</td>
</tr>
<tr>
<td>10.</td>
<td>Fresh surface of biotite granodiorite</td>
<td>26</td>
</tr>
<tr>
<td>11.</td>
<td>Quartz monzonite porphyry displaying alternating bands of quartz and feldspar with both vein and disseminated chalcopyrite and pyrite. Light colored fragments are feldspar</td>
<td>29</td>
</tr>
<tr>
<td>12.</td>
<td>Quartz monzonite porphyry displaying twinned orthoclase feldspar and chalcopyrite and pyrite cluster</td>
<td>31</td>
</tr>
<tr>
<td>13.</td>
<td>Quartz diorite porphyry showing both vein and disseminated chalcopyrite and pyrite</td>
<td>33</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
<td>------</td>
</tr>
<tr>
<td>14.</td>
<td>Andesite porphyry showing both vein and disseminated chalcopyrite and pyrite. Quartz veinlet through the center</td>
<td>35</td>
</tr>
<tr>
<td>15.</td>
<td>Diamond sawed slab of zebra quartz. Light colored fragments are quartz latite (?)</td>
<td>41</td>
</tr>
<tr>
<td>16.</td>
<td>Chalcopyrite, pyrite, quartz vein partially replaced by chalcocite. Molybdenite coating on outer edges and as a vein in the center</td>
<td>45</td>
</tr>
<tr>
<td>17.</td>
<td>Vertical sections, Esperanza Mine and vicinity, showing ore body outline</td>
<td>In pocket</td>
</tr>
<tr>
<td>18.</td>
<td>Fresh surface of quartz monzonite porphyry with large, secondary potash feldspar phenocryst</td>
<td>57</td>
</tr>
<tr>
<td>19.</td>
<td>Dacite porphyry, fresh surface, displaying K-feldspar phenocryst and veinlet</td>
<td>58</td>
</tr>
<tr>
<td>20.</td>
<td>Secondary potash feldspar with chloritized rim. Rock type is quartz diorite</td>
<td>59</td>
</tr>
<tr>
<td>21.</td>
<td>Andesite porphyry completely altered to sericite. White spots are coarse-grained sericite centers. Ground mass is fine-grained sericite</td>
<td>62</td>
</tr>
<tr>
<td>22.</td>
<td>Rhyolitic welded tuff almost totally altered to quartz and sericite. Black metatization is chalcocite replacing pyrite and chalcopyrite. Fine-grained molybdenite is also present</td>
<td>63</td>
</tr>
<tr>
<td>23.</td>
<td>Hydrothermal biotite clusters and clay in andesite porphyry</td>
<td>64</td>
</tr>
<tr>
<td>24.</td>
<td>Vertical sections, Esperanza Mine, showing ore body outline</td>
<td>In pocket</td>
</tr>
</tbody>
</table>
ABSTRACT

The Esperanza Copper deposit is in the Pima mining district, Pima County, Arizona, about 30 air miles south of Tucson. This is the southernmost porphyry-type copper deposit in the district.

The old New Year's Eve mine made the first actual penetration into the area that is now the Esperanza mine. Duval Corporation acquired the property in February 1955, on the advice of Dr. Harrison A. Schmitt, consulting geologist, Silver City, New Mexico.

Capping criteria that impressed Dr. Schmitt are as follows: moderate to intense clay alteration, megascopic sericite, quartz veins, copper staining, moderate to strong brecciation, prominent goethite, and minor jarosite and hematite.

Rock types are Cretaceous (?) in age including various porphyries, and fragmental and welded tuffs. The igneous rocks were intruded and extruded in a number of individual pulses. All rock types contain sulfides in varying amounts. Strong hydrothermal alteration persists throughout the area. Potash metasomatism is a particularly distinctive feature. Commercial metallization consists of chalcocite, chalcopyrite, and molybdenite.
Prominent structural features of the area are faults and fault fissures. Major trends are northeast to east-northeast, dipping northwest and southeast, north-northwest to northwest, dipping northeast and southwest, and north-south, dipping east and west.
INTRODUCTION

Previous Work

The earliest paper concerning the Esperanza Mine area is a report by Charles A. Abderson and D. H. Kupfer for the U.S.G.S.. Their examination of the property was conducted during the years 1943-44. After Duval's acquisition of the property in 1957, detailed mapping of the area was undertaken by D. M. Clippinger, W. J. Roper, H. B. Toombs and E. H. Lewis, under the direction of Dr. Harrison A. Schmitt. John R. Cooper of the U.S.G.S. mapped the entire Pima Mining District and his report was published in 1960. Other references to the Esperanza property are by Richard & Courtright 1959, R. Lutton 1959, Lacy 1959 and Lacy and Titley 1962.

Field Work and Scope of Paper

During the period from 1961 to 1963, surface geology over the mine area and the adjacent hills was mapped on photogrammetrically prepared topographic sheets at a scale of 1'' = 200'. Additional mapping of a broader area was plotted on aerial photographs (1'' = 200') and the detail later transferred to the topo sheets and then pantographed to a 1'' = 500' regional map. All underground
workings such as drifts and raises on drill holes to confirm drill hole assays were mapped on a scale of 1" = 100'.

Colored ore zone overlays on acetate film are compiled from the exploration drill hole assays and from daily blast hole assays. Overlays are made for both copper and molybdenum. These overlays accompany each geologic bench map.

The benches are mapped daily or when a face is cleaned and the data plotted on individual bench maps, on a scale of 1" = 100'. The following procedure is observed in daily geologic mapping of benches at the Esperanza Mine: consecutively numbered stakes are placed along the bench face at points of geologic interest. These points are shot in by the survey crew by theodolite and stadia from conveniently located control points on each bench. All geology is projected to bench level. At each stake and between stakes, rock type, structure, mineralization and alteration are noted on standard pit mapping forms. Each bench level has its own geologic and copper assay contour map so that the relationships between ore grade and geology be studied more closely. Periodically, a mine geologic composite map is prepared to show the geology in its true perspective in relation to daily mining and the position of the benches.
Location and General Setting

The Esperanza Mine is situated in the Pima Mining District, Pima County, Arizona, in the southeastern foothills of the Sierrita Mountains approximately 30 miles SSW of Tucson (Fig. 1). It is easily reached by U. S. Highway 89. About 4½ miles south of Sahuarita turn west onto the paved Duval Mine Road, and follow it for 7.2 miles to the mill and mine offices.

Physical Features

The Esperanza deposit is situated within the "Sonoran Desert" section of the Basin and Range physiographic province and varies in elevation from 3800' to 4500'. Steep, sharp, spined ridges divided by narrow gullies and washes constitute the primary topographical features and these are surrounded by a pedimental to the north and east. To the south of the mine are the volcanic Tinaja Hills. Esperanza Wash to the west is the primary drainage for the area which in turn flows eastward to the Santa Cruz River. All streams, including the Santa Cruz, are intermittent and seldom flow for more than a few hours after each rainfall.

The climate is cooler than the surrounding desert flatlands due to higher elevation. Maximum temperature over a 3 year period was 106° and the minimum was 12° above zero. The mean annual temperature is 66° and the
mean annual rainfall approximately 12.7" per year. Light snow is not uncommon in the months of November and December but is rapidly melted.

Cacti of many varieties are present throughout the region. A few of the more common ones are the giant saguaro, cholla, barrel, yucca and prickly pear. Mesquite, Palo Verde, greasewood, creosote bush, ocatilla and catclaw grow profusely on the valley floors and along the washes. Oaks and cottonwoods 70' - 80' high are common along the edges of Esperanza Wash. Whitetail deer, fox, coyote, badger, coatimundi, jack and cottontail rabbits, round tailed Harris ground squirrels, rock squirrels, bobcat and javelina are the usual varieties of animal life that abound throughout the area. Desert turtles, lizards and skinks of all varieties, centipedes, scorpions, tarantulas and solpugids are a few of the more common reptiles and insects. Bird life includes hawks and owls of several varieties, Mexican white wing buzzards, turkey buzzards, Gambel and Mearns quail, ravens and dove.

History and Development

In 1691, Father Francisco Eusebio Kino, a Jesuit priest in the service of the Spanish Crown, first visited Tumacacori which is situated about 15 miles south of the Esperanza Mine on the highway to Nogales. Father Kino
roamed the surrounding area and his diaries of 1705 are full of reference to the mineral richness of the country.

After the Gadsden Purchase in 1853, miners withstood the ravages of Apaches as they worked small, high-grade gold and silver deposits of this region. The first copper development in the vicinity took place at the nearby Mineral Hill deposit between 1882 and 1884. Small mines and mills have operated spasmodically, alternately flourishing and shutting down as metal prices fluctuated.

The New Year's Eve Mine made the first actual penetration into the area that is now the Esperanza Mine. According to Anderson & Kupfer, these claims were first located and recorded by P. H. Chambers in 1895 and later became known as the Snyder claims. In 1907-08, the Calumet and Arizona Mining Company conducted considerable exploration in the area, working largely in the New Year's Eve Mine, known then as the Red Carbonate Mine. A 200 foot shaft was sunk and crosscuts, winzes and drifts were driven at this time, but the tenor of the copper mineralization and indicated tonnage did not justify a commercial venture. Consequently the property was abandoned. From available records, about 2,000 tons of carbonate ore averaging 4% copper were shipped between 1912 and 1916. In 1912, 30 tons of sulfide ore averaging 10% copper were also shipped.
No further work was done until 1936, when the Arizona Molybdenum Corporation de-watered the mine and examined it for molybdenum possibilities. However, the grade was not sufficiently high to be of interest.

In 1939, an organization known as the Southern Arizona Molybdenum Corporation, H. S. Hart, President, 151 Water Street, New York City, again de-watered the mine and engaged C. J. Sarle, Tucson, Arizona, to make an examination of the property. Again, the property did not appear to contain ore of encouraging value and options were allowed to lapse with no additional work being done.

The property was picked up in 1942 by Dr. S. Isermann, President, Amargosa Molybdenum Corporation, Catalina Foothills Estates, Tucson, Arizona, and de-watered again. No production was recorded.

Subsequently, Sierrita Mining and Ranching Company acquired the claims and leased them to C. D. Wilson of Tucson. In turn the claims were brought to the attention of Duval Corporation (formerly known as Duval Sulphur & Potash Company), who retained Dr. Harrison A. Schmitt, Consulting Geologist, to conduct a geological reconnaissance. Acting on the recommendation of Dr. Schmitt, Duval Corporation acquired control of the claims in February of 1955 (Figs. 2, 3).
Fig. 2. Aerial photograph of the Esperanza Mine area before stripping operations. Taken January 1958 looking southwest. (Photo by Ray Manley)
Fig. 3. Aerial photograph of the Esperanza Mine as of June, 1963, looking southwest. (Photo by Ray Manley)
Mention must be made here of the fact that the orebody today as delineated by drilling varies only from 50 to 75 feet from the orebody as outlined by Dr. Schmitt on his original surface geology map. In May of 1955, an exploration drilling program commenced under the supervision of Dr. Schmitt. A total of 88 holes were drilled by churn and diamond drills on a 500 foot equilateral triangle grid pattern. Ore was encountered after drilling through an average overburden depth of 95 to 100 feet. Today, Duval Corporation holds 93 patented claims and 100 claims by possessory rights.

A report published in 1947, U. S. Bureau of Mines, by S. L. Tainter, indicates that the U.S.B.M. drilled 3 holes, aggregating 1,500' in Copperos Gulch (Fig. 4) to determine the molybdenum and copper mineralization. From the report, drill hole logs show very poor core recovery and low assays which undoubtedly discouraged further exploration until Duval Corporation became interested and began drilling in 1955.

There are 10 or 12 small shafts and headframes to the south and west of the Esperanza Mine concerning which very little recorded historical data are available. As far as can be determined from the condition of the head frames and timbering, these mines were worked around the turn of the century. From examination of the dumps, they
were evidently worked for lead, zinc, silver and probably copper. All are on faults or fissures. Underground examination of these mines was prevented by the presence of water in some and deterioration of timbering and caving in others.
ROCK TYPES

Sedimentary Rocks

Distribution and General Relationships. Occurring in the lower center of the mine, northeast of the mine and to the southwest, quartzite is found in isolated pods and lenses interbedded or interfingered with Cretaceous (?) rhyolitic welded tuffs. North-northeast of the New Year's Eve shaft, this highly durable rock type forms a conically shaped hill that is encompassed by quartz diorite, quartz latite porphyry, granodiorite and rhyolitic welded tuffs. On the south and east side of the 3900 and 3935 Benches, quartzite is interfingered with rhyolitic welded tuffs and in most instances, definite contacts are extremely rare and difficult to recognize due to strong alteration along the contact zone. One method utilized in delineating quartzite lenses on these lower elevations is by mapping strong concentrations of azurite which have a definite affinity for this rock type. However, this approach can be utilized only in the mine area where there is an abundance of azurite.

Quartzite (Fig. 5) is light grey to light tan in color when observed in a surface outcrop and light grey to dirty white on a fresh surface. Individual grains are
Fig. 5. Fine grained quartzite. Specimen obtained from the 3900 Bench.
readily visible without the aid of a hand lens. Very hard in character, this firm, compact rock type usually fractures sub-conchoidally and with great reluctance and displays a vitreous luster. Alteration is negligible and usually occurs only along the contact zone in the form of scattered feldspar phenocrysts. Metallic minerals observed in quartzite consist of chalcopyrite, pyrite, chalcocite, azurite and minor malachite occurring as blebs and stains and rarely as small fibrous nodules. Cuprite, chalcotrichite and molybdenite are found in vugs, seams, veinlets and along joint and fracture planes. Dissemination of metallic minerals is rare in this rock type due to its impermeable character, which was caused by recrystallization of the quartz and resulted in lack of space for the ingress of ore bearing solutions.

Quartzite is thought to be either older than the Cretaceous (?) welded tuffs or nearly the same age. The possibility exists that the lenses and pods of quartzite were rafted in by the younger rhyolitic welded tuff flows. Cooper (personal communication) states that he has seen similar occurrences of quartzite with Cretaceous (?) volcanics throughout the Esperanza area and southward.
Extrusive Rocks

Rhyolitic Welded Tuff

Distribution and General Relationships. Rhyolitic welded tuff (Fig. 6) is the most abundant rock type in the general mine area and includes (1) vitric welded tuffs, (2) fragmental welded tuffs with both rounded and angular zenocrysts of pre-existing rocks that have been incorporated in the host rock, (3) a highly siliceous aphanitic tuff with occasional euhedral phenocrysts of sanidine, and (4) a poorly consolidated tuff with little welding and devitrification. This unit has a distinct wedge-shaped areal distribution with a northeast-southwest trend. Rhyolitic welded tuffs extend through and beyond the Esperanza Mine in both these directions (Fig. 4). The open end of the wedge is to the northeast. From the 3900 Bench upward through the 4075 Bench on the southeast side of the mine, the fragmental welded tuffs underly quartz monzonite porphyry along a fault contact (the Buzzard's Roost fault--see Figs. 4, 7, 8). Elsewhere in the mine area, andesite and dacite porphyries have intruded rhyolitic welded tuffs along old faults.

In 1960, R. Lutton (AGS Digest, 1961, pp. 43, Vol. IX) published a study on the banded tuffs southwest of the Esperanza Mine. The area is bounded on the north by the Cooper Fault and on the south by the Trident Fault.
Fig. 6. Rhyolitic welded tuff showing chalcocite dissemination and exhibiting sub-conchoidal fracturing.
Classifying the rock as a lensoidal rhyolite, Lutton describes it as follows:

It is gray, tan, white, pink or purple and porcelaneous in texture. It is always hard and is little affected by weathering. Some rock lacks foliation but nevertheless contains the peculiar, wreathed inclusions that elsewhere are streaked to extreme lengths. Sub-angular feldspar and quartz crystals and lithic fragments are not uncommon. In thin section, the microcrystalline ground mass is sharply bounded from the lenses and contains one or two percent of magnetite and the rest is quartz and feldspar partly altered to clay. Locally, the welded structure is recognizable, but usually the granular, microcrystalline assemblage has obliterated it.

In the mine area the lenses vary in length from 1/2" to 1 1/2" and 1/16" to 1/32" in width.

Lutton further states:

Under the microscope the lense is seen to be a zonal arrangement of a polycrystalline quartz center surrounded by a border of euhedral orthoclase with well developed crystals at the periphery are present in the core. Relic banding that is identifiable as that of collapsed pumice is noted in some axiolites. The transformation of such fragments must have occurred at high viscosity and may even have been more properly, devitrification.

On the 3900 and 3935 Benches, fragmental welded tuffs are dark gray in color with sub-rounded to angular fragments and ghost remnants of pre-existing rock enclosed in a highly silicic matrix. Fragments reach a maximum size of 1 1/4 inches in length and 4 inches in width. These xenoliths were probably ingested by the ash flow tuff as it progressed over an old erosion surface and upon cooling
and welding, became an integral part of the rock unit. It has a vitreous to porcelaneous appearance and characteristically exhibits conchoidal fracturing. Jointing is well formed, occasionally showing a hexagonal pattern. Elsewhere in the mine, welded tuffs range in color from tan to cream and show various stages of welding.

Alteration produced in rhyolitic welded tuffs by weathering processes consists of clay in surface outcrops and sericite, biotite, and quartz of hydrothermal origin. The fragmental welded tuffs are little effected by alteration due to the highly silicious nature of the rock. This rock unit is a host for copper mineralization, which varies from poor in the fragmental varieties to average in the banded tuffs, dependent upon the density of the rock and the amount of fracturing. Chalcocite, chalcopyrite, pyrite, minor magnetite, sphalerite, galena and in the oxide areas, azurite, malachite, covellite and cuprite are found in the rhyolitic welded tuffs both within the mine limits and the general mine area.

This rock type and its attendant variations have been tentatively assigned to the Cretaceous period.

"Silverbell" Welded Tuffs

**Distribution and General Relationships.** South and east of the plantsite is a sequence of welded tuffs that have been locally designated by Richard and Courtright as
"Silverbell" welded tuffs (1960 Arizona Geological Society Digest), the name being derived from the type locality which is near American Smelting and Refining Company's Silverbell Mine.

This sequence of welded tuffs consists of breccias, andesitic welded tuffs of several varieties and rhyolitic welded tuffs. Along the eastward flowing Cascabel Wash, the base of the low range of hills is composed of brecciated and fragmental andesitic welded tuff with fragments of pre-existing rock up to 2½ feet in diameter. Ranging from angular to rounded, these inclusions were either ingested by the ash flow tuff as it flowed over an erosion surface or are lithic fragments torn from the vent. Oval shaped fragments of andesitic welded tuff contained in a matrix of the same rock type suggests autobrecciation of the flow while in a viscous or semi-viscous state. Above this fragmental layer lies a sequence of andesitic welded tuff that is virtually free of xenoliths. The attitude is fairly flat and good contacts can be found on the north side of the ridge facing Cascabel Wash. Above this rock type and also having a very gently dipping attitude, are the rhyolitic welded tuffs. They are readily distinguishable by the light tan color of the rock. Good jointing is preserved by the migration of silica to the joint faces, forming a hard shell about 1/4" thick. Where this silica
shell has been breached, the exposed rhyolitic welded tuff disintegrates rapidly. Thickness of this volcanic sequence in this area is at least 700 feet, and Richard and Courtright place it as +12,000 feet near the Silverbell Mine. Quartz latite porphyry and quartz monzonite porphyry intrude the Silverbell series south of the Esperanza Mine.

"Silverbell" andesitic welded tuff varies in color from light gray-green to dark gray-green to black and purple. It is moderately hard with a fair amount of silicification. Nodules of epidote, tourmaline mats on joint faces and the fragmental nature of this rock are distinguishing characteristics. Fragments of pre-existing rocks range from angular to rounded and exhibit sharp boundaries. These fragments vary in composition from granitic through volcanic and sedimentary rock types. Immediately above this basal member, is a layer of unbrecciated andesitic welded tuff, having a gradational lower contact, and is probably part of the same ash flow. It is dark gray to black in color and moderately hard. Phenocrysts of hornblende and plagioclase are visible without the aid of a hand lens but the texture is characterized by fine grained phenocrysts in an aphanitic ground mass. Overlying this member of the volcanic sequence is a very light tan, rhyolitic welded tuff. Along the north face of the ridge
southeast of the primary crusher, a sharp contact dipping 25° to 30° south is exposed. South and west of this exposure is another variety of andesitic welded tuff that has been tentatively designated as "Silverbell" andesite porphyry. This member is gray to light gray in color and contains larger plagioclase phenocrysts than the other varieties of andesitic welded tuffs. Also, auto-breciation is best exhibited by this variety of welded tuff just southwest of section corner $\frac{16}{21}$ $\frac{15}{22}$. It is also much softer than the other varieties of "Silverbell" andesitic welded tuff and forms gently rounded hills. Strong clay alteration and minor secondary epidote, derived from weathering processes are readily visible. The thickness of this rock type is not known at this writing.

Richard and Courtright have tentatively assigned this series of welded tuffs to early Tertiary and agree that the previously discussed rock types are identical to the series near the Silverbell Mine (personal communication).

The "Silverbell" series is a very poor host rock for copper mineralization in the Esperanza area and the usual visible metallics consist primarily of pyrite, magnetite and rarely, chalcocite and chalcopyrite.
Quartz Latite Porphyry

**Distribution and General Relationships.** Within the mine limits, quartz latite porphyry (Fig. 9) is restricted in areal extent to the southwest side of the mine. Quartz latite porphyry is younger than rhyolitic welded tuff and older than quartz monzonite porphyry. The contact between quartz latite porphyry and quartz monzonite porphyry strikes northwest and dips approximately $55^\circ$ northeast on the southwest side of the mine. In the West Esperanza ore body area, this rock type forms two northwest trending ridges and a conical shaped hill. The author does, however, recognize the possibility that there are two different ages of quartz latite porphyry; the older being post-rhyolitic welded tuff and pre-quartz monzonite porphyry in age and the younger being post-quartz monzonite porphyry in age. The latest quartz latite porphyry intrusive forms small, northeast trending dikes in biotite granodiorite and small pods and lenses in the "Silverbell" volcanic series.

Between the Chula and Black Bottom faults south of the mine, quartz latite porphyry forms a breccia pipe that is roughly circular in plan and has a maximum diameter of 1,000 feet. Brecciation extends westward across Esperanza Wash for approximately 225 feet. Angular fragments rarely
Fig. 9. Quartz latite porphyry showing both veining and dissemination of chalcocite.
exceed 2 inches in any dimension and are tightly cemented together with rock flour and quartz. Sericite, quartz, jarosite, goethite and hematite are prominent around the margins of the breccia pipe. On the very peak of the pipe, copper oxides such as azurite and malachite are present as seams and as stains. Holes drilled on the flanks of the breccia pipe were not conclusive in proving or disproving the presence of ore grade copper.

Quartz latite porphyry is light tan to brownish red in color in weathered outcrops and cream white to light gray on a fresh surface. The ground mass is aphanitic with conspicuous euhedral to subhedral phenocrysts of orthoclase and plagioclase. Predominant alteration products are sericite and clay. Occasionally this rock type will present a banded appearance because of oriented 1/4" quartz stringers.

As a host rock for copper mineralization, quartz latite porphyry is quite favorable. Metallization in the form of chalcocite, chalcopyrite, pyrite and molybdenite is present both as disseminated grains and as seams and stringers in fractures and along joint planes. On the upper benches, covellite coating pyrite and chalcopyrite is common along with secondary chalcocite. On the lower benches, chalcopyrite predominates.
Due to its associations in the mine area, quartz latite porphyry has been assigned an age between that of the rhyolitic welded tuffs and quartz monzonite porphyry.

Biotite Granodiorite

**Distribution and General Relationships.** North and east of the Esperanza Mine is a large biotite granodiorite batholith that contains three or four textural variations (not mapped separately) and a quartz monzonite porphyry facies. Biotite granodiorite (Fig. 10) does not outcrop within the mine limits. Excellent fault contacts between Cretaceous (?) rhyolitic welded tuffs and biotite granodiorite can be seen in the road cut leading to the primary crusher and in the road behind the fine ore storage bin. This rock type has been intruded by the younger variety of quartz latite porphyry and by quartz diorite (Fig. 4). No igneous contacts have been located between quartz monzonite porphyry and biotite granodiorite, instead, there is a gradational zone about 100 feet wide in which this rock gradually changes characteristics and finally emerges as a quartz monzonite porphyry. Biotite micas gradually diminish in volume and orthoclase feldspars increase. In the wash and throughout the northeast trending hill immediately north of the mine offices, ellipsoidal, dioritic inclusions weather rather easily, leaving egg shaped depressions in the surface. Fine grained dikes of quartz latite porphyry
Fig. 10. Fresh surface of biotite granodiorite.
have intruded this rock along a NNE trend and after intrusion, have been faulted. These dikes and faults follow the predominating joint plane trend and usually have a high angle of dip (Fig. 4).

Cooper (1960, pp. 72) classified this rock as a granodiorite and his excellent description of its distinguishing characteristics is as follows:

The unaltered granodiorite is generally light gray, which in places has a pinkish, yellowish or brownish cast. Quartz, feldspar and books of biotite are evident in hand specimens of all facies of the rock. With a hand lens it is commonly possible to distinguish gray, twinned plagioclase from slightly pinkish gray, untwinned potassium feldspar and to discern small, brilliant honey colored crystals of sphene. In the eastern, equigranular facies of the large body, hornblende is also common.

Continuing with Cooper's description:

As seen in thin section, the equigranular granodiorite and the ground mass of the porphyritic granodiorite have a hypidiomorphic-granular texture. Anhedral potassium feldspar and quartz are interstitial to euhedral or subhedral crystals of plagioclase, biotite and hornblende (if present). The plagioclase in all the facies has an average composition of oligoclase and is commonly zoned from a 25-40 in the centers of the grains to a 8-15 at the rims. The potassium feldspar is generally microcline, but some lacks visible quadrille twinning and may be orthoclase.

Biotite granodiorite is a very poor host rock for copper mineralization, although azurite and malachite can occasionally be found in a few of the fault fissures. Magnetite is prevalent throughout this rock type and after rainstorms, washes that traverse biotite granodiorite will
be streaked with this metallic mineral. Cooper places this rock type in the late Cretaceous or the early Tertiary period.

Quartz Monzonite Porphyry

**Distribution and General Relationships.** Quartz monzonite porphyry (Fig. 11) is a lithologic facies of the granodiorite batholith. Apophyses of this rock intrude the mine area to the southeast, south and southwest (Fig. 4) with an overall northwest trend to the outcrop pattern. Quartz latite porphyry, rhyolitic welded tuffs and Silver-bell andesite porphyry are all intruded by this rock type, and in turn, quartz monzonite porphyry is intruded by dacite porphyry.

In the mine area, quartz monzonite porphyry is in fault contact with quartz latite porphyry on the south and west sides of the mine and in fault contact with rhyolitic welded tuffs on the southeast side (Figs. 7, 8). At the eastern side of the pit, quartz monzonite porphyry is blocky, hard, well jointed and exhibits pervasive silicification. At the south and west portions of the pit, it is extremely fractured and brecciated, has erratically oriented jointing, and characteristically has a banded appearance due to oriented silicification in the form of veinlets.
Fig. 11. Quartz monzonite porphyry displaying alternating bands of quartz and feldspar with both vein and disseminated chalcopyrite and pyrite. Light colored fragments are feldspar.
Hand specimens from surface outcrops are orange-brown to saddle brown in color and display minute grains of sericite along with quartz stringers and sulfide casts. Minor veinlets of turquoise, azurite and malachite, usually as stains or blebs, are scattered throughout outcrops over the ore body. Along Amargosa Wash, melaconite and tenorite can also be found. The distinctive color of weathered quartz monzonite porphyry easily delineates this rock type from the reddish hues of the more pyritic clastic volcanics. Orthoclase and plagioclase phenocrysts have been almost completely obliterated by kaolinization and sericitization. Casts of these feldspars give the rock a distinctive "honeycomb" texture. Remnant biotite books are sometimes the only remaining clue to the nature of the original rock along with doubly terminated quartz crystals. Limonite, jarosite, goethite and hematite are ubiquitous in the capping over the ore body. Surface and near surface exposures of quartz monzonite porphyry have a more dense, aphanitic ground mass and smaller phenocrysts than are found deeper in the mine.

Unaltered quartz monzonite porphyry specimens are a light to pinkish gray with distinctive pink phenocrysts of potash feldspar (Fig. 12), light gray to white plagioclase, glassy quartz "eyes" and biotite imbedded in a fine-grained ground mass of feldspar and quartz. Secondary
Fig. 12. Quartz monzonite porphyry displaying twinned orthoclase feldspar and chalcopryite and pyrite cluster.
orthoclase, occurring as stringers, veinlets and as coatings on joint and fracture planes, is more prevalent along the contact between quartz monzonite porphyry and Cretaceous (?) rhyolitic welded tuffs. On the north and east side of the mine on the lower benches, orthoclase crystals 3 cm x 5 cm in size are common, and usually exhibit an albitized (?) rim. The average orthoclase crystal size is about 5 mm x 10 mm. Sericite is common, and where it occurs in heavy concentrations, high grade copper and molybdenite are in intimate association.

Quartz monzonite porphyry is unquestionably the most favored host rock for both hypogene and supergene metallization. On the east side of the pit, vertical seams of massive chalcocite and chalcopyrite 3" to 4" thick, increased the grade considerably over that indicated by the exploration drill holes. Copper metallization occurs both as disseminated grains and veinlets, while molybdenite is usually found as seams and coatings on fractures and in quartz veinlets.

Quartz monzonite porphyry has been tentatively assigned to the time span between late Cretaceous - early Tertiary.

Quartz Diorite

_Distribution and General Relationships._ Quartz diorite (Fig. 13) occurs in widely scattered locations.
Fig. 13. Quartz diorite porphyry showing both vein and disseminated chalcopyrite and pyrite.
NNE of the mine, this rock type forms a rather small, elongate depression enclosed by quartz monzonite porphyry, biotite granodiorite, quartz latite porphyry and quartzite. It outcrops in the mine area adjacent to the New Year's Eve shaft (Fig. 4) and in the gulch on the west side of the mine (Fig. 7). In both the Esperanza and West Esperanza orebodies, quartz diorite is intermixed with andesite porphyry, a rock type which it resembles so closely that it was not mapped as a separate rock type in the early stages of pit and field mapping. Northwest of the West Esperanza ore body in a "V" formed by Esperanza Wash and one of its tributaries, a larger body of quartz diorite outcrops, as shown in Fig. 4. Delineation of the quartz diorite body to the north of the mine was best accomplished by the use of colored aerial photo transparencies. Although most of the quartz diorite is covered by alluvium, the dark, black to gray color is visible through the alluvium cover. In the mine area, this rock type has intruded rhyolitic welded tuffs, quartz latite porphyry and the "Silverbell" volcanics. Younger quartz latite dikes intrude quartz diorite in a few locations northeast of the mine.

Quartz diorite is a fine grained igneous intrusive rock that varies in color from black to gray-green. Sometimes mistaken for andesite porphyry (Fig. 14), quartz
Fig. 14. Andesite porphyry showing both vein and disseminated chalcopyrite and pyrite. Quartz veinlet through the center.
diorite has a ground mass of visible grains where andesite porphyry does not. This rock type was mapped as a biotite-quartz granulite by Anderson and Kupfer (1945, pp. 5). Further megascopic examination shows an equigranular texture with plagioclase, biotite and minute quartz grains. Surface exposures are soft with a large percentage of the rock altering to clay and chlorite under normal weathering conditions. As a result, they form topographic lows and saddles, as does andesite porphyry.

Cooper (1960, pp. 71) in his microscopic examination of quartz diorite describes it as having an intergranular texture. He further states:

Laths of plagioclase (calcic andesine) make up about 60 percent of the rock and have subparallel orientation. Biotite and actinolitic (?) hornblende, in nearly equal amounts, make up much of the rest and have random orientation. Potassium feldspar and quartz rim and embay the other minerals, and are largely or wholly of replacement origin. Accessory minerals include magnetite, sphene, apatite, and epidote. The dark clots, so characteristic in most hand specimens, consist of aggregates of biotite, hornblende, and commonly magnetite dust.

Metallic mineralization occurring in quartz diorite consists of chalcopyrite, chalcocite, pyrite, molybdenite, covellite, cuprite and magnetite. This rock type is considered to be a good host rock for both hypogene and supergene copper mineralization.

Relationships between quartz diorite and andesite porphyry have not definitely been established, but it is
believed that they are genetically related intrusives. Field relationships indicate that quartz diorite is younger than biotite granodiorite and older than quartz monzonite porphyry.

Dacite Porphyry

**Distribution and General Relationships.** Dacite porphyry is limited in its occurrence at the Esperanza Mine to vague, poorly defined dikes and stringers, and is usually associated with andesite porphyry (Fig. 8). Immediately north of the mine beyond the ore limits, dacite porphyry outcrops as a small, semi-circular body at the base of a quartz latite plug (Fig. 4). A few small outcrops are visible both north and south of the main intrusive body. Cretaceous (?) rhyolitic welded tuffs and quartz monzonite porphyry are intruded by this rock within the pit area. Possibly a genetic relationship exists between dacite porphyry and andesite porphyry. However, no evidence has been collected to substantiate this hypothesis.

A typical specimen of dacite porphyry is dark gray to dark gray-green in color, and exhibits a very hard, aphanitic ground mass. Dacite porphyry weathers in the same manner as quartz monzonite porphyry and presents the same "honeycomb" appearance due to feldspar deterioration. However, the gray-green ground mass color is distinctive.
Potash feldspar metasomatism has affected this rock type and it is not unusual to find disseminated orthoclase crystals 3 cm x 5 cm in size as well as stringers of orthoclase. Where feldspar crystals are observed in a weathered hand specimen, they display a creamy color with a faint undertone of green. Quartz "eyes" are quite common in dacite porphyry and usually have a glassy luster. Hornblende and biotite clusters are also diagnostic of this rock type. Weathering effects on dacite porphyry are negligible.

This rock type, which is really very limited in the pit area, exhibits metallic mineralization very similar to that of quartz monzonite porphyry.

Dacite porphyry is believed to be younger than quartz monzonite porphyry but older than the quartz latite porphyry plug.

Andesite Porphyry

**Distribution and General Relationships.** Andesite porphyry (Fig. 14) is confined in areal distribution to the Esperanza Mine, West Esperanza Mine, and a few, small, scattered outcrops along fault zones in the "Silverbell" volcanics. Faults and zones of structural weakness are the primary control for the distribution of andesite porphyry. In the mine area, this rock type, which characteristically occurs as tabular bodies, may be discordant on
one bench and concordant on others (Fig. 7). Readily susceptible to weathering, andesite porphyry forms saddles and topographic lows where exposed on the surface. Jointing is not well pronounced in most exposures and is not structurally significant.

Two petrologic varieties of andesite porphyry are recognized but not mapped as separate units. Both are a dark slate gray to black in color, one variety having easily visible hornblende laths in an aphanitic ground mass and the other variety conspicuous plagioclase phenocrysts. The weathered rock is usually soft and contains a high percentage of clay and chlorite. Under the microscope, the ground mass is definitely holocrystalline with a mosaic texture. Phenocrysts of plagioclase (andesine) and hornblende are conspicuous. Biotite, chlorite, clay, and accessory apatite are imbedded in a fine grained ground mass of quartz, feldspar and green tinted biotite. Plagioclase feldspars usually exhibit Carlsbad twinning. In an average specimen of andesite porphyry, phenocrysts make up 30% of the total volume.

Andesite porphyry is an important host for hypogene ore and is also the most favorable host for supergene ore. Examination of a specimen from the secondarily enriched zone by eye or with a hand lens does not reveal the pervasiveness of chalcocite mineralization which has assayed
as high as 4% Cu. As mining progresses deeper, chalcopyrite, pyrite and minor molybdenite predominate. Cuprite, native copper, azurite and malachite are the usual oxide zone minerals.

Andesite porphyry intrudes rhyolitic welded tuffs and biotite granodiorite.

Zebra Quartz

**Distribution and General Relationships.** Zebra quartz (Fig. 15), perhaps more logically considered to be a structural-textural feature than a separate rock type, is included under rock types because it is a mappable lithologic unit. Taking its name from the banded arrangement of breccia fragments, this tabular shaped unit, which averages 70 feet in thickness, is almost in the exact center of the Esperanza pit and extends downward from the 4040 Bench to, at least, the 3900 Bench (Fig. 7). The bottom of the zebra quartz has not been determined. The east and west flanks are bounded by fault zones which have also been used as a means of ingress by andesite porphyry. Apophyses of massive quartz, three feet wide, extend into the adjacent rhyolitic welded tuffs. Zebra quartz did not outcrop on the original surface, but was encountered only after about 120 feet of rock had been removed.

A hand specimen of zebra quartz shows creamy tan, elongate fragments of quartz latite (?) imbedded in a
Fig. 15. Diamond sawed slab of zebra quartz. Light colored fragments are quartz latite (?).
ground mass of vitreous quartz. Dimensions of the frag­ments, which are distinctly angular and show no evidence of rounding, range from 1 cm to 14 cm in length and 1 cm to 4 cm in width with an increase in fragment size with increasing depth. Microscopic examinations of zebra quartz indicate that the fragments are composed of very fine grained quartz with minor sericite in a ground mass of larger grained quartz. This rock, before brecciation and cementation, may have been a quartz latite.

Zebra quartz is a poor host for copper mineralization, either supergene or hypogene. However, excellent molybdenum values occur in the brecciated fault zones on the east and west contacts along with minor chalcocite, chalcopyrite and pyrite.

The age of this distinctive unit is not known, but it is probably a product of the stresses that produced much of the major faulting prior to and during the period of metallization.
The Esperanza Mine can be included under the loose classification of mineral deposits known as "Porphyry Coppers" and contains the type of metallization generally associated with a mine of this type, at least, as is known in the southwest. The ore of the Esperanza Mine is a mixture of hypogene and supergene metallization occurring in veins and as disseminated grains. Roughly surrounding the copper-molybdenum ore zone is an aureole of vein type deposits that were worked for lead, zinc and silver around the turn of the century. Metallization was associated syngenetically with more than one intrusive pulse and was followed by a post-intrusive metallization period associated with hydrothermal alteration and potash metasomatism.

**Hypogene**

**Chalcopyrite**

Chalcopyrite \((\text{CuFeS}_2)\) becomes increasingly important as mining progresses deeper. This sulfide of copper is intimately associated with pyrite, and is of hypogene origin. Veins of chalcopyrite with a coating of either chalcocite or covellite are prominent in quartz monzonite porphyry on the east side of the mine. A thin lamenaie of
molybdenite is usually present on the outer edges of these veins (Fig. 16). Throughout the mine, chalcopyrite occurs as disseminated grains and as veinlets and coatings in fractures and joint planes. Metallurgical studies indicate that the usual ratio of chalcopyrite to pyrite is 1:1.

Molybdenite

Molybdenite ($\text{MoS}_2$) is widespread throughout the mine and occurs as a coating on joint and fracture surfaces (Fig. 16) and as a significant constituent in quartz veinlets. Dissemination of this sulfide is rare. The highest concentrations of molybdenite are found in secondarily silicified quartz monzonite porphyry on the west side of the pit and on the lower benches (3935, 3900). Important concentrations also occur in a few, small, scattered, brecciated quartz pipes in the south center of the pit in association with chalcopyrite, pyrite, sphalerite and galena. The New Year's Eve Mine, mentioned in previous chapters, contains enough molybdenite to warrant including it in the mine limits. Specimens of molybdenite veins from this location usually show a thin salvage of potash feldspar.

Galena and Sphalerite

Galena ($\text{PbS}$) and sphalerite ($\text{ZnS}$) always occur together. Neither sulfide occurs in sufficient quantities
Fig. 16. Chalcopyrite, pyrite, quartz vein partially replaced by chalcocite. Molybdenite coating on outer edges and as a vein in the center.
to be economically important. Two veins, 2 to 3 inches wide, can be traced through three benches and for all practical purposes, this is the extent of galena and sphalerite mineralization in the mining area.

Pyrite

Pyrite (FeS$_2$), as is usual in secondarily enriched copper deposits, played an important role in supergene enrichment. The majority of chalcocite ore in the enriched zone shows remnant pyrite centers. Excellent chalcocite psuedomerphs after pyrite occur in quartz monzonite porphyry on the east side of the mine. On the lower benches in the primary sulfide zone, pyrite is intermixed with chalcopyrite, and appears as veinlets and coatings in fracture and joint surfaces and as disseminations in all rock types. Pyrite metallization extends well beyond the ore zone. Marcasite has occasionnally been found, but it is not common in the Esperanza ore body.

**Supergene**

Chalcocite

Chalcocite (Cu$_2$S) along with chalcopyrite is the most important ore mineral at the Esperanza Mine (Fig. 16). At this writing, chalcocite of hypogene origin has not been indentified. Polished and thin section studies show that chalcocite is entirely of supergene origin and replaces
pyrite and chalcopyrite either wholly or in part. From the 4005 Bench to the 3970 Bench, chalcocite and chalcopyrite are approximately equal in volume. Below the 3970 Bench, chalcopyrite predominates.

Covellite

Covellite (CuS) is common in the ore zone as a coating on pyrite, chalcopyrite, and chalcocite. It occurs throughout the oxide and supergene zones.

Oxide Zone

Native Copper

Native copper (Cu) is uncommon in the Esperanza ore body. It so far has been found only in the secondarily enriched and oxide zones, and is probably entirely of supergene origin.

Ferrimolybdite

Ferrimolybdite (Fe₂(MoO₄)₃.8H₂O), an oxidation product of molybdenite, has occasionally been found in the oxide zone of the Esperanza Mine. A brilliant canary yellow in color, this mineral is undoubtedly intermixed with yellow jarosite and probably more exists than is recognized.
Oxidation Products

Capping over the Esperanza and West Esperanza ore bodies did not contain copper oxides or carbonates in substantial amounts. Large concentrations of azurite, moderate malachite and minor amounts of cuprite and chalcotrichite preferred andesite porphyry and quartzite as host rocks within the mine areas. North of Amargosa Wash, malacoite, tenorite, azurite and malachite are pervasive throughout quartz monzonite porphyry to a known depth of 350 feet. Jarosite, limonite, goethite and hematite, while rare in this area, are prominent in all rock types over both ore bodies. Turquoise occurs in very sparse amounts throughout the area. Rhyolitic welded tuffs and associated silicic rock types are easily delineated from quartz monzonite porphyry and other granitic intrusives by capping colors. The former rock types are red to brick red in color while the latter are orange brown to saddle brown.
<table>
<thead>
<tr>
<th>Hypogene</th>
<th>Supergene</th>
<th>Oxidation Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chalcopyrite</td>
<td>Chalcocite</td>
<td>Tenorite</td>
</tr>
<tr>
<td>Molybdenite</td>
<td>Covellite</td>
<td>Malachite</td>
</tr>
<tr>
<td>Galena</td>
<td></td>
<td>Cuprite</td>
</tr>
<tr>
<td>Sphalerite</td>
<td></td>
<td>Chalcotrichite</td>
</tr>
<tr>
<td>Pyrite</td>
<td></td>
<td>Azurite</td>
</tr>
<tr>
<td>Marcasite</td>
<td></td>
<td>Malachite</td>
</tr>
<tr>
<td>Magnetite</td>
<td></td>
<td>Turquoise</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Torbernite</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ferrimolybdite</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Limonite</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Goethite</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hematite</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jarosite</td>
</tr>
</tbody>
</table>

Bornite (Cu₅FeS₄) and enargite (Cu₃AsS₄) have not been recognized in the Esperanza ore body.
STRUCTURE

Geologic Setting

The Esperanza and West Esperanza ore bodies are associated with a broad contact zone that consists of Cretaceous (?) volcanic-sedimentary rocks and Tertiary (?) igneous intrusives. Ore mineralization has a definite NW-SE trend while the prominent structural features have a NE-SW trend. Daily mapping within the mine limits has not shown any strong lineal structures on a NW-SE bearing, but the ore zone and structural alignments are obvious (Fig. 4). Cretaceous (?) rhyolitic welded tuff and quartzite have a NE trend and Tertiary (?) igneous intrusives have a rough NW trend.

One of the outstanding geologic features which influenced the localization of copper mineralization in the Esperanza area is the complex history of intrusion and extrusion that preceded, accompanied, and probably followed the period of metallization. Rock types varying from diorites to monzonites and their fine-grained equivalents were intruded in a number of pulses as stocks, dikes, and sills. Volcanic rocks, apparently derived from the same magma chamber, and more or less contemporaneous with the period of intrusion, vary from latite to andesite in composition.
Deuteric alteration, best expressed by potash metasomatism and hydrothermal alteration have substantially modified the igneous rocks in the mine area. Ore tends to be associated with the monzonite stocks and andesite dikes and their altered equivalents.

**Ore Controls**

Assay contour overlays show that faulting within the mine area acted as the "plumbing system" for the upward movement of hypogene metallization, and was also the main channelway for downward percolating enriched solutions. Primary metallization is best developed in the quartz monzonite porphyry, while andesite porphyry is the preferred host rock for secondary enrichment.

A hypothetical sequence of geologic events is postulated as follows: remnant quartzite lenses or stream channels on an old erosion surface were incorporated in rhyolitic ash flow tuffs, and intruded by quartz latite porphyry. During and after consolidation, devitrification and welding of the tuffs, faulting trending northeast to east northeast modified the areal pattern of these units. Erosion, followed by the deposition of tuffs of the "Silverbell" series is believed to be the next step. Again, cooling, compaction, devitrification and welding of these tuffs was accompanied and followed by north-south faulting. A biotite granodiorite batholith along with its quartz
diorite and quartz monzonite porphyry facies intruded the area and in turn, was intruded by younger quartz latite dikes which used pre-existing fault patterns as a major means of ingress. The exact relationship of dacite porphyry to andesite porphyry is not known at this time, but a strong possibility exists that two units are penicontemporaneous, as is quartz diorite and andesite porphyry. Quartz latite of Tertiary (?) age intruded along faults in the "Silverbell" welded tuffs. After emplacement, the quartz latite was in turn subjected to stresses that produced faulting.

Faults

Faults exerted an important control on the location and tenor of both the hypogene and supergene ores. Faults can be divided into three major sets, based on strike trend. The most important set strikes from NE to ENE and dips both NW and SE. Second in importance are those faults with a NW trend and last is the group aligned in a NS direction. A few of the important faults in the northeast group are the Searchlight, Cooper, Trident, Chula, and Hardsell (Fig. 4). All of the aforementioned are located outside of the proposed mine limits. Two prominent faults within the mine limits are the New Year's Eve and the Bluenose faults (Fig. 7). Of the northwest striking group of faults and fault fissures, only two faults are of major
importance and they are the Copporos Gulch and Buzzard's Roost faults. North-south faults are narrow in width as compared to the other two groups and are best developed in the "Silverbell" series of volcanics (Fig. 14). All faults mapped in the area are considered to be pre-metallization in age, although some have had several post-metallization movements.

Near the west end of the mine, two northeast trending reverse faults are exposed. Three nearly horizontal faults that may be thrusts are also present in this same area. No specific evidence has been uncovered to substantiate a thrusting origin, however. The three flat faults are in quartz diorite and andesite, and are about 35 feet apart. The faults contain lenses of hypogene gypsum up to 4 feet thick, and adjacent joint facies and fractures are also coated with gypsum. The gypsum coatings and lenses do not extend above the 3970 Bench.

The Buzzard's Roost fault (Figs. 4, 8), which is typical of the pre-metallization faults in the mine area, is 28 feet wide on the 3900 Bench and narrows to 4 feet on the 4040 Bench. Massive, crushed, and brecciated quartz, along with chalcopyrite, chalcocite, pyrite, galena, molybdenite and sphalerite fill the fault from hanging wall to foot wall as disseminated grains and as veinlets. Quartz characteristically exhibits comb structure. Smeared
chalcolite and molybdenite in the gouge on the hanging wall and foot wall, along with brecciated and mineralized quartz monzonite porphyry, indicates that this fault has had post-metallization movement. From the south center of the mine to the west end, a series of NNW-trending shear zones are the predominating structural features and through normal fault movement, have destroyed the continuity of earlier structures. This shear zone could also logically account for the lack of jointing and the strong amount of brecciation and clay in this section of the mine. The dip along these shear zones averages 55° NNE.

North-south trending faults are the least significant of the three classifications. The largest in this system is the 70° east-dipping "Black Bottom Fault", which is located south southeast of the mine, and which separates quartz latite porphyry on the west from Silverbell andesite porphyry on the east. In the southern part of the mine area, north-south faults are the major control of andesite porphyry intrusives and the Zebra quartz dike (Fig. 17).

**Joint Systems**

Joint systems are well-defined on the east side of the pit, and are almost totally obliterated on the west side of the pit by the NNW-trending shear zone. Prominent joint directions are east-west dipping 45-50° N, north-south dipping 60° west, and northwest dipping 55° north-east.
These joint systems are important in ore localization for they not only served as channels for hypogene solutions, but also served as channels for downward percolating solutions that caused both oxidation and secondary enrichment. Geochemical studies indicate that the chalcocite ore is shifted to the north relative to the protore. The prominent east-west striking, north-dipping joint system has been an important factor in this shift. Joints tend to be spaced 3 feet to 4 feet apart in quartz monzonite porphyry, but are only about 4 inches apart in quartz diorite and andesite.

**Folding**

Although the volcanic rocks, in general, dip homoclinal to the south-southwest, this structure, along with the intricate structures exhibited in the mine area, were probably not produced by folding. Apparently, the stresses developed by intrusion and regional adjustments were relieved almost exclusively by faulting rather than folding.
ALTERATION

K-Feldspar

Hydrothermal alteration at the Esperanza Mine, as is usual in the porphyry copper deposits of the southwest, consists of the development of silica, sericite, clays, biotite and potash feldspars (Figs. 18, 19, 20). Alteration diminishes in intensity away from the ore zones. Over the ore zone, the chemistry of different rock types has influenced the mineralogy and the apparent intensity of alteration. The addition of potash in the form of orthoclase feldspar along with sericite and silica, are the most prominent alteration features. Within the ore zone, the abundance of sericite associated with quartz in the form of veinlets and plugs suggests that the introduction of quartz and the formation of sericite are closely related. Quartz-sericite-potash feldspar associations are quite obvious in quartz monzonite porphyry and dacite porphyry within the ore zone; however, sericite shows a marked decrease in abundance away from the ore zone, while quartz and K-feldspar are still fairly abundant.

Silicification

Hydrothermal silica in the form of veinlets, doubly terminated crystals, quartz plugs and flooding is
Fig. 18. Fresh surface of quartz monzonite porphyry with large, secondary potash feldspar phenocryst.
Fig. 19. Dacite porphyry, fresh surface, displaying K-feldspar phenocryst and veinlet.
Fig. 20. Secondary potash feldspar with chloritized rim. Rock type is quartz diorite.
prevalent throughout the Esperanza area. Quartz monzonite porphyry on the east side of the mine contains very fine-grained intergranular flooding of silica, while quartz in the form of veinlets is more common on the west side quartz monzonite porphyry. Rhyolitic welded tuffs are silicified in varying degrees and the alteration is probably a combination of inherent and introduced silica. Except for re-crystallization, quartzite is not affected by any type of alteration.

**Argillization**

Argillization varies according to rock type. Andesite porphyry and quartz diorite show the most intense alteration of this type. Both the kaolin and montmorillonite groups of clays are present. Quartz monzonite porphyry in the west side of the mine exhibits moderate to strong argillization that is best developed in areas of intense faulting and brecciation.

**Sericitization**

Within the ore zone, sericite is usually associated with quartz as veinlets or quartz plugs. Outside of the ore zone, sericite is negligible while quartz may still be persistent. Sericitization is practically limited to igneous intrusive rock types in the Esperanza area. Quartz latite porphyry and quartz monzonite porphyry are the rock
types that exhibit intense sericitization. Weak to moderate sericitization can be found in rhyolitic welded tuffs throughout the mine area. In the center of the mine on the 3935 Bench immediately adjacent to the east edge of the zebra quartz dike, a small pod of welded tuff and one of andesite porphyry have been completely replaced by quartz and sericite (Figs. 21, 22). This area of intense hydrothermal alteration represents the eastern edge of the zone of strongest hydrothermal alteration. Westward from this point, for approximately 600 feet, the rock types have been pegmatized and consist principally of quartz, sericite, biotite and K-feldspar.

**Biotization**

Hydrothermal biotite development is prominent in a few of the andesite porphyry dikes and sills (Fig. 23). In the south center of the 4040 Bench, 60% of the rock is composed of biotite. One other occurrence of this form of alteration is mentioned in the preceding paragraph.
Fig. 21. Andesite porphyry completely altered to sericite. White spots are coarse-grained sericite centers. Ground mass is fine-grained sericite.
Fig. 22. Rhyolitic welded tuff almost totally altered to quartz and sericite. Black metallization is chalcocite replacing pyrite and chalcopyrite. Fine-grained molybdenite is also present.
Fig. 23. Hydrothermal biotite clusters and clay in andesite porphyry.
The Esperanza ore body as outlined by exploration and development drilling, is roughly an ovate shape with an approximate length and width of 4,200 feet by 2,300 feet. The maximum known thickness of ore grade mineralization is 420 feet, measured at the deepest point. The thickness at the extremities of the ore zone narrows to a mineable 35 feet.

The West Esperanza ore body has an irregular boundary (Fig. 4) with average dimensions of ore grade mineralization of approximately 2,000 feet long by 1,800 feet wide. The maximum thickness of the ore grade mineralization has not as yet been precisely determined due to the inability of the rotary air-swept exploration drill to penetrate and remove cuttings from a water bearing zone which was encountered above the bottom limit of the ore grade mineralization. The ore body thickness as outlined in section (Fig. 17) of necessity is estimated because a number of drill holes must be deepened to determine maximum depths of ore mineralization.

Mine production and estimated reserves as of May 1, 1963, total 69,667,376 tons of ore containing .55%
copper and 0.026% molybdenum along with 43,424,000 tons of leach material averaging 0.25% copper.

Ore cut-off limit at the Esperanza Mine is subject to a number of variables. To date, this cut-off limit has been established at 0.4% copper equivalent based on the combined copper-molybdenum assay values. Mineralized material with copper equivalent value of less than 0.4%, but more than 0.15% total copper, is mined as leach material. Copper assay contour map overlays (Fig. 24) based on total copper content only, accompany each geologic bench map, these data being compiled from engineering ore control blast hole maps. Blast holes are drilled approximately 22 feet apart and have a vertical assay weight of 35 feet. Actual blast hole depth is 42 feet for toe breakage to aid in keeping bench levels to uniform elevation.

An average of 12,000 tons per day of ore grade material is mined and milled. At the present time, the waste-ore stripping ratio is 1 to 1. Projected overall stripping ratio for total reserves is estimated to be 1.3 to 1. Production as of January 1, 1963, includes 177,834,097 pounds of copper by flotation, 1,406,189 pounds of cement copper from the leach plant and 4,709,705 pounds of molybdenum. Copper concentrate averages from 25-30% Cu and 3 ounces of silver. Molybdenum sulfide
concentrates average 52% Mo, which is later calcined to a final product of technical grade molybdic trioxide. Cement copper averages 75% to 80% Cu.

Mining practices at the Esperanza Mine are typical of the porphyry copper mining operations in the southwest. Modern rock moving equipment which includes crawler mounted, electric powered shovels of 6 and 8 yard capacity and diesel powered trucks with capacities up to 65 tons are utilized in the mining operation. All mining operations have been, and are at the present time, conducted under a contractual arrangement with Isbell Construction Company with Duval engineers supervising mining design and ore control.

The following paragraphs on beneficiation are abstracted from a paper by C. H. Curtis, Resident Manager, Duval Corporation, entitled "The Esperanza Concentrator" (Min. Eng., 1961, pp. 1234):

Crushing is accomplished by conventional three-stage crushing by a 48 inch primary gyratory, followed by one 84 inch secondary crusher and two 84 inch tertiary crushers operating in open circuit with vibrating screens.

Wet grinding and flotation operations are conducted in two mill sections that are essentially metallurgically independent, each with separate reclaimed water systems and each producing its own final concentrate and tailing. Each grinding section consists of one rod mill in open circuit with discharge split to two ball mills, operating in closed circuits with cyclone classifiers. The two flotation sections are equipped with 48 inch mechanical cells having double froth overflows.
and froth paddles. Flotation reagents to date have consisted of potassium ethyl and amyl zanthate as collectors, together with stove oil as molybdenite promoter. Methyl amyl alcohol has been the frother. All rougher floatation concentrates are advanced for upgrading. The final copper-molybdenum concentrates are flowed to a 50 foot diameter thickener in each section. Thickener underflows are serviced by diaphragm pumps and combined underflows advanced to the molybdenum recovery plant.

Molybdenum sulfide is calcined to a final product of molybdenum trioxide. Total molybdenum recovery averages 72% and total copper recovery is approximately 85%. For details on beneficiation, the reader is referred to the previously mentioned paper.
SELECTED BIBLIOGRAPHY


Courtright, H. J., 1963, Personal communication.


SECTION A

Looking N 30° E

N 60° W

4500' 4250' 4000' 3750' 3500'

SECTION B

Looking West

4500' 4250' 4000' 3750' 3500'

EXPLANATION

SEDIMENTARY & VOLCANIC ROCKS

Quaternary alluvium
Silverbell rhyolitic welded tuff
Silverbell andesite porphyry

IGNEOUS INTRUSIVE ROCKS

Andesite porphyry
Quartz diorite
Dacite porphyry
Quartz monzonite porphyry
Quartz latite porphyry

SYMBOLS

Fault or shear
Inferred fault or shear
Contact
Drill hole
Pit outline
Ore body

SCALE 1" = 500'

DATE JUNE 1, 1963

drawn by D.W. Lynch

DUVAL CORPORATION

VERTICAL SECTIONS

THROUGH THE

ESPERANZA MINE VICINITY

FIGURE 17