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Summary

This paper describes the geology of Rosemont mining camp located on the eastern slope of the Santa Rita Mountains.

The oldest rock in the studied area is a pre-Cambrian porphyritic granite which forms the axis of the mountain range and is the base on which the sedimentary rocks rest. The Paleozoic rocks are represented by sediments ranging from Middle Cambrian to Permian with a total thickness of about 4,000 feet. Only a small portion of Upper Cretaceous of southeastern Arizona is found in the area. In the southern part of the area the Upper Cretaceous sediments rest unconformably on pre-Cambrian granite and Cambrian Bolsa quartzite. They are correlated with the Sonoita group of Upper Cretaceous time.

All the sedimentary rocks form a monocline along the east side of the Santa Rita Mountains with an eastward dip. Two systems of faults are developed in the area. Reverse faults of north-south direction predominate. Certain stratigraphic units are eliminated from the area by the main reverse fault, the Santa Rita fault, which probably served as a channel for ore solutions. A system of east-west high-angle faults cuts the sedimentary rocks into separated blocks. The faults were later intruded by
quartz-monzonite porphyry dikes. Mineralization followed intrusion of the dikes.

The Rosemont mining camp has produced nearly $2,250,000 worth of copper. The main deposits are of pyrometasomatic and replacement types. The location of the deposits was controlled by the structure of the area. The limestone beds of the Upper Paleozoic were the most favorable rocks for replacement.
Introduction

Acknowledgments

The author wishes to express his appreciation to Dr. B. S. Butler, Head of the Department of Geology and Mineralogy of the University of Arizona, and to Drs. A. A. Stoyanow, M. N. Short, F. W. Galbraith, and R. M. Hernon, members of the faculty, for their suggestions and assistance in carrying out this work.

The author also is indebted to Mr. J. M. Kuheim, Bisbee, Arizona, who kindly permitted him to work on his land, gave opportunity for him to become acquainted with mining reports of the area, and allowed him to camp on his property for several weeks without charge.

The writer is also thankful to Mr. Harold Steinfeld, Tucson, Arizona, for permission to read old mining reports of the Narragansett mine, and to him and to the Miller Brothers for permission to work on their land during the research.

He is also indebted to his wife, who was more successful than he in finding fossils in the area.
Scope of the present work

The field work upon which this thesis is based was carried on in July, 1939, and continued on weekends throughout the fall of 1939 and the spring of 1940.

As the basis for field mapping, the topographic plan of the Coronado National Forest, Santa Rita Division, Arizona, compiled by L. J. Neiman in 1934 on a scale of 1 in. = .5 mile, was enlarged 2,640 times by means of a pantograph.

This map on a scale of 1 in. = 1,000 ft. with 100-foot contour intervals provided a satisfactory base for the field work and needed very few later additions.

The area covered by mapping is roughly 2.5 miles paralleling the western slope of the Santa Rita Mountains and 2 miles wide in an east-west direction. It comprises approximately 5 square miles.

This report discusses the principal stratigraphic units, the igneous rocks, and the structure and ore deposits of the Rosemont mining camp. There is much that needs to be investigated more fully, and the future geological study should be based on a topographic map of at least a 500-foot scale.
Previous geologic work done in the region

The most valuable and complete report made upon the Santa Rita Mountains region and its ore deposits is "Mineral Deposits of the Santa Rita and Patagonia Mountains," Geological Survey Bulletin 582, 1915, prepared by Frank C. Schrader with contributions by James M. Hill. This work is of a reconnaissance nature, and contains a general description of the geology and ore deposits of Helvetia district and a brief discussion of the Rosemont camp. The geology of the report is based on a topographic map on a scale of 1 in. = 2 miles.


Dr. J. E. Spurr examined the Helvetia mining district in the beginning of this century, and some of his observations and conclusions are published in "The Ore Magmas," Parts I and II, McGraw-Hill Book Co., 1925. Unfortunately, his plane-table survey of some parts of the Helvetia district, and the geologic map on which is based his study of metamorphism and its relation to igneous intrusions, were not published and are most probably lost.
More recent work has been done in the Helvetia district by candidates for advanced degrees at the University of Arizona. The Master's thesis of Walter L. Thomas, "Geology and Ore Deposits of the Rosemont Area, Pima County, Arizona," described an area of .75 square mile around the Narragansett mine on a basis of a map with a scale of 1 in. = 200 ft., and a contour interval of 20 feet. The results of his work are incorporated in this report and the accompanying map, as his area lies in the northern part of the Rosemont camp.

Other completed works by candidates for advanced degrees based on geologic studies in the Helvetia and nearby districts are:


   The Cuprite deposit is about 7 miles north-northeast of Rosemont camp. The geology of about 4 square miles of this area is mapped on a scale 1 in. = 400 feet, and a contour interval of 50 feet.


   The Blue Jay mine is 4 miles northwest from Rosemont camp. The geology of the area, about 1 square mile, was mapped on a scale 1 in. = 400 feet.
In addition to the above theses, several others have been written on the geology of the Empire District, adjacent to the Helvetia District on the northeast, and only 6 to 8 miles from Rosemont camp. All these theses are listed in the bibliography.
Geographic Relations

Location

The Rosemont mining camp is situated in the southern part of the Helvetia mining district within the borders of Pima County, Arizona. It lies on the eastern slope of the Santa Rita Mountains. The Helvetia mining camp, on the other side of the ridge, is about 2 miles northwest of the Rosemont mining camp.

The location of the now deserted village of Rosemont, from which the mining area has received its name, can be found on the Patagonia sheet of U. S. G. S. on the east side of Barrel Canyon, with approximate geographic coordinates: Latitude 31° 50' N., Longitude 110° 44'.

The area mapped occupies the central part of Rosemont camp. It extends from Narragansett Canyon, a branch of McCleary Canyon to the north, to Deering Canyon, less than 1 mile north of Box Canyon, on the south. The area is limited by the range crest on the west, and by Barrel Canyon on the east.

The higher part of the area is largely covered by patented and unpatented mining claims.
Means of communication and settlements

Rosemont camp can be reached from Tucson, the principal city of Pima County and the center of supply for the Helvetia district, by traveling southwest on U. S. Highway 80 for 24 miles and then turning south on Sonoita Road or Arizona Route 83 and going 13 miles. An old country road about 5 miles long leads from the highway to Rosemont village.

Two rural roads, each about 1.5 miles long, run from Rosemont to the northern extension of the Santa Rita Mountains along McCleary and Wasp canyons, the first to the Narragansett mine in the northern part of the area, and the second to the Chicago and Saratoga mines in the middle of the area.

There are few houses in the area and most of them are now deserted. There is a small mining camp in Wasp Canyon, and some ranches in McCleary and Barrel canyons. Greaterville, the nearest town with stores and post-office, is 5 miles south from Rosemont with which it is connected by means of an old country road.

Climate and Vegetation

The climate of the district is typically semi-arid with hot summers and mild winters. The amount of pre-
Precipitation is small, being about 12 inches on the lower part and probably about 20 inches in the mountainous part of the district.

The rainy seasons come usually in July or August and between January and March. In winter the precipitation falls as snow in the mountains and remains unmelted sometimes until March or April. On the desert plains the snow does not remain longer than a few days.

Changes of temperature between day and night are great during the rainy seasons and in winter.

The vegetation is principally of the subtropical or Mexican types. It is relatively sparse on the desert plains and consists of various cacti, catclaw, greasewood, and small bushy trees such as palo-verde and mesquite.

At an elevation of 5,000 to 5,500 feet conifers appear as piñon pine, juniper, pine, and spruce, and other trees as Mexican live oak, black oak, and walnut.

The forested part of the region is in the deep canyons of the slope of the Santa Rita Mountains and is only a poor remnant of a former timber belt. The area is included in the Coronado National Forest.
Physiography

Relief

The Santa Rita Mountains, the principal topographic feature of the Helvetia mining district, lie within the Mexican Highland division of the Basin and Range Physiographic Province of Fenneman. The mountains rise abruptly from the desert plains and trend in a north-south direction for nearly 45 miles. The range reaches its maximum height of 9,432 feet at Mt. Wrightson, or Old Baldy Peak, about 4 miles south from the area. Within the area the ridge has an elevation of between 6,000 and 6,250 feet. The highest points are known under the names: Harts Butte, Old Pat Peak, and Anderson Hill.

Near the axial portion of the range, the topography is rough, with cliffs, scarps of hard quartzite, and steep slopes.

To the west, approximately from the 5,300-foot contour, the area consists of rolling foothills with a more gently sloping surface, and has a general elevation of about 5,000 feet and a relief of some 500 feet.

Drainage

The Rosemont mining camp belongs to the Gila drainage
basin of the Colorado River. Numerous subsidiary streams branch from Barrel Canyon, the main drainage of the district. The waters are carried in an east and north-east direction into the lower areas through Davidson Canyon to Pantano Wash which, in turn, flows into the Rillito Wash east and north of Tucson, and then into the Santa Cruz River, the main southern tributary of the Gila River.

All the streams of the district are intermittent, flowing only after storms. The streams follow the direction of less resistant beds, faults, or other lines of weakness.

In the mountainous part of the area the streams are in narrow limestone canyons, and away from steep slopes they deposit debris often cemented by calcareous material.
History and Production

History of Mining in the Helvetia District

The Santa Rita Mountains, of which the Helvetia mining district is only a small part, and their southern extension, the Patagonia Mountains, form the oldest mining region in Arizona. Mining operations were carried on in the Santa Rita Mountains by the Papago Indians before the Spanish conquest of Mexico in the sixteenth century. The Spanish Jesuits were the first white men to come into this region. At the close of the seventeenth century they came into southern Arizona and established missions. They gave some attention to mining and conducted operations with the help of friendly Indians. Padre Eusebio Francisco Kino mentions the mining of rich silver ores in 1705 which were probably in the Santa Rita Mountains. The "Old Salero Mine" of Tyndall district is the oldest mine in the region. Piles of slags may still be seen near the mission ruins as evidences of activity during this period.

In the beginning of the eighteenth century the Spaniards and Mexicans continued to work the mines, but the missions were destroyed and early settlements were often harassed by Indians. However, new discoveries were made and some

* See Bibliography, References 4, 18.
attention was given to the mining of rich copper ore. The Santa Rita del Cobre mine was worked in the eighteen thirties, and it is reported that it produced ore yielding 75 percent copper. A small slag pile in the Wasp Canyon of the Rosemont camp probably dates back to this time.

In 1853 when the Gadsden Purchase secured from Mexico that part of Arizona and New Mexico south of the Gila River, the Santa Rita Mountains were opened to American prospectors. Veins of silver ore were discovered by exploring parties from the Sonora Exploring and Mining Company and by other independent prospectors. Several small mining companies were organized for development and exploitation, among them the Santa Rita Mining Company which was organized in 1858. Large amounts of silver ore were taken out, and mining operations continued to increase until interrupted by the Civil War.

After mining in this region was revived in the seventies following the close of the Civil War and the subjugation of the unfriendly Apache Indians, the new districts of Wrightson and Greaterville yielding gold and lead were found in the Santa Rita Mountains. Mining claims were located on both sides of the ridge in the Helvetia district. The oldest works in the district were "Old Frijole" and "Old Dick" on the west side of the ridge, and "Chicago", owned by L. J. Rose, and "Narragansett", owned by J. J. Brown on
the east side. These mines produced rich copper ore which was smelted in the Columbia furnace, about one-mile north of Helvetia.

The mining activity increased considerably when the Territory of Arizona was connected with the East by the Southern Pacific transcontinental railroad in 1879, and by the Atlantic and Pacific (Sante Fe) railroad in 1883. New mining companies were organized, and copper deposits were developed and worked, the ores generally being treated in smelters within the borders of the district.

The developments on the east slope began when the Rosemont Mining and Smelting Company was organized in 1884. The company started with prospecting and exploration of a group of claims, and later erected the Mohawk Smelter on the west side of the ridge. The ore was transported from the mines across the ridge on the backs of burros.

In 1896 the copper mines passed from L. J. Rose and the Rosemont Mining and Smelting Company into the hands of Lewisohn Brothers, copper brokers of New York City. A new one-stack 60-ton smelter was built in Rosemont, and development and exploration was carried forward on the chief claims, notably the Chicago, the Oregon Copper, and the Narragansett. The last was acquired in 1897 by Lewisohn Brothers who put down a 115-foot shaft and produced ore yielding about 20 percent copper.
On the west side of the ridge few companies conducted mining operations. The largest, the Helvetia Copper Company of New Jersey, produced principally copper ore to the value of $400,000 during ten years. The Helvetia Mining Company of Minneapolis, Minn. continued work. It built a new 150-ton copper-matte smelter in 1905. The mining was carried on chiefly in the Tip-Top and the Isle Royal mines. The latter's shaft was sunk to 1,000 feet, the deepest working of the district. Production continued in the district until 1908 when the industrial depression of 1907-1908 forced the mines and smelters throughout the region to close.

A partial revival began in 1909, but owing to the low price of copper and to the fact that the high grade ore near the surface was worked out, there was small production, but some development work was done in addition to the usual annual assessment work. The Helvetia Copper Company did a large amount of prospecting on its claims by diamond drilling. However, the mines of this company were closed in 1911 and practically all mining operations ceased in other parts of the district.

The rise in price of copper during the first World War brought unusual mining activity in the Helvetia district. Old mines were re-opened, and during the years 1916 to 1918 Rosemont camp was a producer of more than 1,000 tons of copper yearly with a value of $600,000 (see chapter on
"Production"). With the close of the war and the decrease in the price of copper, production was generally reduced in the district, and on most properties only assessment work and developing were carried on. Production did not then exceed $20,000 a year.

Within the last two years interest in the district has revived. Several mines have been examined, and some prospecting work has been carried on. William Braden of California is doing some deep-diamond drilling on the claims of the Lewisohn Brothers on the east slope north of Narragansett mine.

There are no statistics on the early production of metals in the Helvetia district. However, since the beginning of the present century, data of mine production have been collected by various government and state offices. The yearly records of production of gold, silver, copper, and lead in the Helvetia and Empire districts, published by the United States Geological Survey for 1903-1912, are summarized in Table I.

Production of the Helvetia district in comparison with other districts of the Santa Rita and Patagonia Mountains

*See Bibliography, References 8 and 18.
Tables III and IV are arranged in a different order of comparison from that used by the Arizona Bureau of Mines.

According to Table II, the total production for the Helvetia district during the last 25 years (1908-1933) was 75,895 tons of ore valued at $2,337,386. The total production from 1880 is $3,320,000. Nearly two-thirds of the ore (52,000 tons) and three-quarters of the value ($1,895,000) were produced during the short period of the first World War. Practically 40 percent of all the ore produced came from the Narragansett mine in the northern part of Rosemont camp. Among the mining districts of the Santa Rita and the Patagonia Mountains, the Helvetia ranks second in value of production, giving first place to the Patagonia district.

From Table III it is seen that the Helvetia mining district is predominantly a copper district. Silver forms less than 4 percent of the value of production, and lead and zinc about 2 percent. Mining of copper, beginning in 1911, was more important on the east side than on the west side of the ridge.

Some production of molybdenum in the Helvetia district
has been mentioned during the present century. An attempt at the development of manganese ore was made during the first World War on claims of Mr. J. M. Muheim.
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<td>-</td>
<td>836</td>
<td>444</td>
<td>13,043</td>
<td>1,630</td>
<td>5,378</td>
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<td>1912</td>
<td>586</td>
<td>2.37</td>
<td>49</td>
<td>16,873</td>
<td>10,377</td>
<td>39,792</td>
<td>6,565</td>
<td>3,759</td>
<td>169</td>
<td>17,160</td>
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<tr>
<td>Totals</td>
<td>32,271</td>
<td>91.85</td>
<td>$1,899</td>
<td>53,817</td>
<td>$31,286</td>
<td>2,585,923</td>
<td>$421,554</td>
<td>199,250</td>
<td>$8,611</td>
<td>$463,150</td>
</tr>
</tbody>
</table>

(From statistics in U. S. Geol. Survey Bull. 582, Mineral Deposits of the Santa Rita and Patagonia Mountains, Arizona, by Frank C. Schrader.)
<table>
<thead>
<tr>
<th>Year</th>
<th>Lode Producers</th>
<th>Tons</th>
<th>Gold, Value</th>
<th>Silver, Ounces</th>
<th>Copper, Pounds</th>
<th>Lead, Pounds</th>
<th>Zinc, Pounds</th>
<th>Total Value</th>
</tr>
</thead>
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<td>1908</td>
<td>3</td>
<td>892</td>
<td>61</td>
<td>949</td>
<td>91,146</td>
<td>374</td>
<td>-</td>
<td>12,611</td>
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<tr>
<td>1909</td>
<td>2</td>
<td>11,257</td>
<td>597</td>
<td>11,688</td>
<td>1,156,504</td>
<td>-</td>
<td>-</td>
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<td>-</td>
<td>-</td>
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<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1911</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1912</td>
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<td>-</td>
<td>-</td>
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<td>-</td>
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<td>-</td>
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<td>6</td>
<td>739</td>
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<td>62,605</td>
<td>10,592</td>
<td>236,117</td>
<td>24,185</td>
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<tr>
<td>1914</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
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<td>1915</td>
<td>6</td>
<td>2,506</td>
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<td>14,609</td>
<td>289</td>
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<td>499,820</td>
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<td>1917</td>
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<td>289</td>
<td>24,325</td>
<td>2,615,613</td>
<td>19,171</td>
<td>-</td>
<td>736,495</td>
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<td>2,156,486</td>
<td>12,406</td>
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<td>3,357</td>
<td>300</td>
<td>5,479</td>
<td>414,370</td>
<td>58,432</td>
<td>-</td>
<td>85,607</td>
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<td>1920</td>
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<td>2,516</td>
<td>8</td>
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<td>5,618</td>
<td>-</td>
<td>60,988</td>
</tr>
<tr>
<td>1921-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1922</td>
<td>6</td>
<td>683</td>
<td>163</td>
<td>5,024</td>
<td>69,633</td>
<td>40,590</td>
<td>-</td>
<td>17,580</td>
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<td>1923</td>
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<td>202</td>
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<td>1,459</td>
<td>35,585</td>
<td>9,018</td>
<td>-</td>
<td>6,130</td>
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<tr>
<td>1924</td>
<td>8</td>
<td>319</td>
<td>80</td>
<td>2,500</td>
<td>41,972</td>
<td>6,000</td>
<td>-</td>
<td>8,500</td>
</tr>
<tr>
<td>1925</td>
<td>5</td>
<td>73</td>
<td>100</td>
<td>150</td>
<td>9,272</td>
<td>3,000</td>
<td>-</td>
<td>1,765</td>
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<tr>
<td>1926</td>
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<td>116</td>
<td>136</td>
<td>73</td>
<td>15,332</td>
<td>2,761</td>
<td>-</td>
<td>2,159</td>
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<tr>
<td>1927</td>
<td>4</td>
<td>150</td>
<td>140</td>
<td>70</td>
<td>18,750</td>
<td>2,700</td>
<td>-</td>
<td>3,042</td>
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<td>6</td>
<td>756</td>
<td>34</td>
<td>852</td>
<td>84,823</td>
<td>2,774</td>
<td>-</td>
<td>15,952</td>
</tr>
<tr>
<td>1929</td>
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<td>2,256</td>
<td>185</td>
<td>1,282</td>
<td>145,822</td>
<td>80</td>
<td>-</td>
<td>19,648</td>
</tr>
<tr>
<td>1930</td>
<td>1</td>
<td>40</td>
<td>-</td>
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<td>1</td>
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<td>-</td>
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<td>-</td>
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<td>1932-</td>
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<td>-</td>
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<td>-</td>
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<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1933</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>75,895</td>
<td>2,761</td>
<td>101,954</td>
<td>9,628,287</td>
<td>243,219</td>
<td>725,280</td>
<td>12,337,386</td>
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</tr>
</tbody>
</table>

Table II
Production of Helvetia District, Pima County
Arizona Bureau of Mines Bulletin 140, 1936; 1908 - 1933
### Table III

**Approximate Production of Helvetia District by Mines**

<table>
<thead>
<tr>
<th>Mines</th>
<th>Copper Pounds</th>
<th>Gold Value</th>
<th>Silver Value</th>
<th>Total Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Narragansett</td>
<td>6,000,000</td>
<td>-</td>
<td>$40,000</td>
<td>$1,525,000</td>
</tr>
<tr>
<td>2. Rosemont and Mohawk 1886-1929</td>
<td>2,900,000</td>
<td>-</td>
<td>20,000</td>
<td>710,000*</td>
</tr>
<tr>
<td>3. Helvetia (Copper World) 1899-1911</td>
<td>4,250,000</td>
<td>$1,000</td>
<td>20,000</td>
<td>705,000</td>
</tr>
<tr>
<td>4. Tip-Top (Little Helvetia) 1904-1926</td>
<td>1,000,000</td>
<td>-</td>
<td>4,000</td>
<td>160,000</td>
</tr>
<tr>
<td>5. Columbia - 1882</td>
<td>500,000</td>
<td>-</td>
<td>-</td>
<td>95,000</td>
</tr>
<tr>
<td>6. Omega - 1883</td>
<td>500,000</td>
<td>-</td>
<td>-</td>
<td>85,000</td>
</tr>
<tr>
<td>7. Silver Spurr - 1880-1889</td>
<td></td>
<td></td>
<td></td>
<td>40,000</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>15,150,000</strong></td>
<td><strong>$1,000</strong></td>
<td><strong>$124,000</strong></td>
<td><strong>$3,520,000</strong></td>
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</tbody>
</table>

* includes about 60,000,000 lbs. of zinc.
Table IV
Summary of Production of Major Metals by Mining Districts
Arizona Bureau of Mines Bulletin 140, 1936

<table>
<thead>
<tr>
<th>Districts</th>
<th>Patagonia</th>
<th>Helvetia</th>
<th>Harshaw</th>
<th>Empire</th>
<th>Tyndall</th>
<th>Greaterville</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>1908-33</td>
<td>1908-33</td>
<td>1908-33</td>
<td>1915-33</td>
<td>1908-33</td>
<td>1908-33</td>
</tr>
<tr>
<td>Tons*</td>
<td>152,159</td>
<td>75,895</td>
<td>42,039</td>
<td>13,929</td>
<td>10,027</td>
<td>1,162</td>
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<tr>
<td>Gold Value</td>
<td>$27,541</td>
<td>2,761</td>
<td>9,454</td>
<td>10,215</td>
<td>15,452</td>
<td>65,031</td>
</tr>
<tr>
<td>Silver Ounces</td>
<td>513,804</td>
<td>101,954</td>
<td>685,942</td>
<td>98,961</td>
<td>90,320</td>
<td>8,667</td>
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<tr>
<td>Copper Pounds</td>
<td>10,846,542</td>
<td>9,626,287</td>
<td>290,374</td>
<td>114,550</td>
<td>329,859</td>
<td>17,910</td>
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<tr>
<td>Lead Pounds</td>
<td>5,461,465</td>
<td>243,219</td>
<td>3,899,624</td>
<td>6,223,700</td>
<td>2,939,925</td>
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<tr>
<td>Zinc Pounds</td>
<td>3,686,519</td>
<td>725,280</td>
<td>-</td>
<td>74,614</td>
<td>148,192</td>
<td>-</td>
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<tr>
<td>Total Value</td>
<td>$3,414,579</td>
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<td>$826,424</td>
<td>$595,166</td>
<td>$357,331</td>
<td>$393,586</td>
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</table>

*Tonnage is incomplete for several districts.
Geological History of Southeastern Arizona

Various stages of the geologic history of southeastern Arizona have been described by F. L. Ransome, F. C. Schrader, N. H. Darton, and A. A. Stoyanow,* and a few historical summaries have been published giving a description of the different ore deposits of this province.**

The contents of this chapter will, therefore, be a brief review of conclusions based on well-known facts of stratigraphy, structure, and igneous activity in this part of Arizona.

Little is known about the pre-Cambrian history of southeastern Arizona. The oldest known rocks are the Pinal schist of sedimentary origin which is correlated with the Vischnu schist of the Grand Canyon, and they are of early pre-Cambrian or Archeozoic age.

A large land or barrier, extending from California (Ensenada Land of Schuchert) to Central Arizona (Mazatzal Land of Stoyanow) was present owing to an uplift. A long period of land conditions ensued and continued until the

* See Bibliography, References 6, 17, 18, 24.
** See Bibliography, Reference 4.
Middle Cambrian age. There is no evidence of folding and faulting during pre-Cambrian time, but such structures probably existed and later had influence on the history of the province. On the whole the pre-Cambrian period was of no importance regarding the mineralization in the area.

The earliest Paleozoic rock is the Bolsa quartzite which comprises metamorphosed conglomerates, grits, and sandstones, and rests unconformably on the Pinal schist or on pre-Cambrian granite. The Bolsa quartzite indicates the beginning of the large marine transgression of Cambrian age from the southeast. The following Upper Cambrian sediments show changing of lithological composition of the sediments in the northeastern direction. The Cochise formation is represented in Bisbee by limestone, at Whetstone Mountains by more arenaceous facies, and in the Santa Catalina Mountains by the Santa Catalina formation which is composed of thin-bedded sandstone, quartzite, and shale. The Abrigo formation of Upper Cambrian age shows thinning out and a more arenaceous nature in the northwestern direction. The Copper Queen limestone of Bisbee, the Rincon limestone of the Whetstone Mountains, and the Peppersauce Canyon sandstone of the Santa Catalina Mountains, although different in faunal composition and lithological character, are very close to each other in time of deposition, and are all of Upper Cambrian age.
According to Dr. Stoyanow, the lesser thickness of Cambrian strata in southeastern Arizona as compared with thicker sediments of the House Range, Utah, suggests an oscillating water body.

No Ordovician, Silurian, or Lower or Middle Devonian strata are known between Tucson and Bisbee. In the Clifton-Morenci district the shallow-water-laid Longfellow limestone is of Ordovician age.

There is a strong probability that there were land conditions between the Upper Cambrian and Upper Devonian times. It is possible also that in unexplored places some missing units will be found.

A new transgression began in Upper Devonian time. The Devonian sediments show the same gradation from the limestone facies into more and more arenaceous facies toward Mazatzal Land of Central Arizona, as in the previous period. In the Bisbee district and as far northwestward as the Santa Rita Mountains, the Upper Devonian sediments are represented by the Martin limestone. Farther northwest they are represented by the Picacho de Calero formation, a more arenaceous Martin limestone, and by the Lower Ouray formation.

The Carboniferous period began with deposition of the Escabrosa limestone of Lower Mississippian age which gradually thins out toward Mazatzal Land, and of the Paradise
formation of Upper Mississippian age found only in the Chiricahua Mountains. The latter consists of arenaceous limestone and shales deposited in shallow waters. Land conditions probably existed between Mississippian and Pennsylvanian time.

The Pennsylvanian sediments in southeastern Arizona are represented by the Naco limestone, a formation of great thickness, which was followed by deposition of the Snyder Hill formation of Permian age. The separation of these two formations in a highly disturbed area is difficult when fossil evidence is lacking.

There was less uniformity in the sedimentation during Permian time in the northwestern part of the province under consideration as seen from the presence of alternating sandstones and shales which are correlated with the Manzano group of New Mexico. This lack of uniformity may be a result of greater oscillations during Permian time. Alteration of limestones with clastic rocks made it possible to distinguish the following stratigraphic units of Permian age: the Manzano beds, the Snyder Hill formation, and the Chiricahua limestone.

During the Appalachian revolution, regional uplift took place, and the ancient mountain ranges were formed. Land conditions followed in Triassic and Jurassic times. Crustal disturbance and igneous activity occurred in the late
Jurassic or early Cretaceous period. Folding and faulting of this time are known in southeastern Arizona. The Dividend fault of Bisbee is of pre-Lower Cretaceous age. Igneous material was intruded. Ransome and Trischka regard the Sacramento stock of porphyry as pre-Cretaceous. The Juniper Flat stock in the Bisbee area is between Paleozoic and early Cretaceous age.* According to Butler and Wilson, "this activity may be provisionally correlated with the post-Jurassic revolution of the Sierra Nevada."*

In Lower Cretaceous time the land was submerged, and the thickness and lithological character of sediments indicate oscillating waters. At Bisbee the Lower Cretaceous sequence is as follows: basal member Glance conglomerate, then sandstones and shales of Morita formation, then Mural limestone, and finally, at the top, shales and sandstones of Cintura formation. All these units of the Comanche group rest unconformably upon the eroded surface of rocks of a different age and reach a thickness of 4,800 feet.

Very little study has been made of the Upper Cretaceous sediments in southeastern Arizona. The Upper Cretaceous sediments are represented by conglomerates, grits, sandstones, mudstones, thin-bedded limestone, and series of

* See Bibliography, Reference 4, p. 15.
volcanic rocks. The presence of volcanic rocks indicates the resumption of igneous activity, and the composition of sediments deposited in shallow bodies of water. A crustal disturbance and igneous activity culminated in the formation of the Rocky Mountains at the end of the Mesozoic and near the beginning of the Cenozoic era. This was the so-called Laramide revolution. At this time in southeastern Arizona the structural deformation was marked by a general uplift of the region, and by folding and faulting of Paleozoic and Mesozoic strata. Thrusting was the most characteristic type of faulting and was accompanied by series of high-angle reverse faulting. Igneous activity closely followed the structural deformation. Intrusion of batholiths, stocks, and dikes of prevalingly intermediate-to-granitic composition took place. The thrust faults of the Empire Mountains and the high-angle reverse faults of the Santa Rita Mountains belong to this time. The intrusion of rhyolite and granite porphyry and aplitic rocks in the same regions are of Laramide age.

Nearly all of the ore deposits of southeastern Arizona, including those of the Rosemont camp, are connected with igneous activity of the Laramide revolution except that of Bisbee which may be of Jurassic age.

During Tertiary time the southeastern Arizona province was exposed to erosion. Land and fresh-water lacustrine deposits predominated and there was a great accumulation
of lava interbedded with sediments. The sediments were: conglomerates, sandstones, and shales. They were deposited unconformably upon the eroded surface of Mesozoic beds principally.

In late Tertiary and Quaternary time the land and lake sediments continued to accumulate and were interrupted only by outpourings of rhyolite, quartz-latite, and andesite rocks. The Gila conglomerate is the principal formation for the above region with lava flows locally present over it.

In recent time the rocks were exposed to extensive erosion, the eroded material being deposited as detrital sediments unconformably upon the older formations. Alluvial silts and gravels are deposited along the present streams and in places are cemented by calcium carbonate. Basalt flows and dikes of Quaternary age are known in the region.
General Geology

General Statement

The rocks of Rosemont camp range from pre-Cambrian to Quaternary in age, and consist chiefly of metamorphosed sedimentary rocks and various igneous rocks. Areally the sedimentary rocks are predominant. The Paleozoic strata form a belt on the east slope of the Santa Rita Mountains of general north-south trend. The Mesozoic rocks occupy the eastern part of the area, and trend generally in a N 30° E direction with a dip of 65° - 50° to the east. The Tertiary and Quaternary deposits are known only along Barrel Canyon.

The sequence of sedimentary rocks is shown in the generalized columnar section of Plate II. The sedimentary rocks are folded, faulted, intruded, and deformed by igneous intrusions. The rocks were weathered during the present erosion period and probably during several erosion periods in the geologic past.

The igneous rocks consist of stocks, dikes, and flows of various composition and are described in the chapter on "Igneous Rocks."

The distribution of the sedimentary and igneous rocks is shown on the geologic map, Plate III. The vertical relationship between the rocks and the structure of the area
Quaternary sediments

Upper Cretaceous beds:
Sonoita group

Snyder Hill formation

Quartzite
Shale
Limestone
Manzano beds
Marl
Shale

Escabrosa limestone
Martin limestone (?)
Rincon limestone (?)
Abrigo formation
Cochise formation
Bolsa quartzite

Pre-Cambrian porphyritic granite
are shown on the east-west geologic sections spaced about one-half mile apart. (Plate IV).

Stratigraphy

The following stratigraphic units of the Paleozoic and Mesozoic Eras are present in the area:

Mesozoic: Upper Cretaceous beds: Sonoita group
break

Paleozoic: Lower Permian: Snyder Hill formation
Manzano beds
break
Lower Mississippian: Escabrosa limestone
Upper Devonian Martin limestone(?)
break
Upper Cambrian: Rincon limestone(?)
" " Abrigo formation
Middle Cambrian Cochise formation
Bolsa quartzite

Only a small area is covered by late Tertiary and Quaternary deposits which are predominantly conglomerates, fluvial alluvium, and detrital deposits.

Cambrian Sediments

Bolsa quartzite

The Bolsa quartzite is the oldest sedimentary rock in the Rosemont camp area. It consists of metamorphosed sand-
stones, grits and conglomerates, now predominantly fine
grained thick-bedded, and vitreous quartzites. The rock
is dense, hard, and pinkish or reddish in color. Bedding
and cross bedding in some beds is conspicuous. A conglom­
eratic bed from two to five feet in thickness with small
pebbles of red color can be found at the base. A coarse­
grained, buff, hard sandstone bed a few feet in thickness
is found in places at the top of the formation and is prob­
ably the Pima sandstone of Stoyanow.* The Bolsa quartzite
forms the crest of the Santa Rita Mountains in the Rosemont
area and can be traced along the east slope of the range.
On the west, usually less than one hundred feet from the
watershed, the formation, in places, is separated from the
pre-Cambrian granite on the north by a steep fault, and
on the south by a steep dipping sedimentary contact. Usually
the contact is obscured by detritus of Bolsa quartzite.

The formation trends N 5° E to N 15° W and dips easter­
ly at an angle not less than 35°. The dip increases to
the north, and near the Narragansett mine it is almost
vertical. The thickness of the formation varies from 300
to 800 feet, but on an average is about 600 feet. The form­
ation is faulted by several east-west high-angle faults.

Being resistant to weathering, the rocks form cliffs
with isolated knobs and peaks, and the western slope is

* See Bibliography, Reference 24, p. 466.
covered with rusty quartzite float.

The lithological resemblance of the quartzites to the Bolsa quartzites of the Bisbee quadrangle and other regions of southern Arizona, the great thickness of the formation, and the stratigraphic position of it under the Cochise and Abrigo formations, suggest that the old quartzite of the camp is equivalent to the Bolsa quartzite.

No fossils were found in the Bolsa quartzite. According to Stoyanow, the Bolsa quartzite is of Middle Cambrian age.

**Cochise formation**

Between the Bolsa quartzites and the Abrigo formation lies the Cochise formation. Lithologically it consists of various members with a base composed of brownish shales and thin-bedded, soft sandstones, a few beds of quartzite, and compact pink and gray-blue limestone at the top. In places the limestone is fragmental. The formation is best exposed west and northwest of the Chicago mine. The attitude of the formation is the same as that of the Bolsa quartzite. The thickness is from 100 to 200 feet.

Being weak, the lower part of the formation forms saddles between the harder rocks of Bolsa quartzite and the limestone beds of the upper part of the Cochise formation or the Abrigo formation. The formation is usually
observed by faulting parallel or close to the strike, by detritus of Bolsa quartzite, and by thick vegetation. The presence of the Cochise formation south of the Chicago mine is uncertain, although several thin beds of shales are present on top of Bolsa quartzite.

No fossils were found, nor beds of oolitic or pisolithitic blue limestone, so characteristic of the type locality in the Whetstone Mountains.

The lithological difference between the underlying Bolsa quartzites and the overlying Abrigo formation is very characteristic and is sufficient evidence for the separation of the Cochise formation. The Cochise formation is correlated by Dr. Stoyanow with the Marjum formation of the House Range section, Utah, and therefore is of Middle Cambrian age.

Abrigo formation

The Abrigo formation is distinguished from other Paleozoic sediments by its peculiar lithology. It consists of thin-bedded, cherty and dolomitic limestone which, when weathered, shows interbedding of thin, irregular sheets of hard chert that protrudes beyond the layers of soft limestone and limy shale. The individual members of the formation are from one-half to two inches thick, usually less than one inch. In the upper part of the formation the chert layers are distinctly thinner than the limestone.
layers. Occasional beds of limestone measure two feet in thickness, and near the top of the formation are in general appearance similar to the limestone member of the Cochise formation. At the top, the Abrigo formation contains a hard, fine-grained, dark-brown or black shaly bed, ten feet thick in places. The strike and the dip of the formation vary on account of folding and faulting of beds. The average strike is close to N 20° E, and the dip is close to 60° to the east. The thickness of the formation is about 400 feet.

The best outcrops of the Abrigo formation are found northwest of the Chicago mine. Here it rests conformably upon the Cochise formation, and is overlain by Mississippian limestone. Because of chert layers, the Abrigo formation is less readily eroded than the overlying and underlying beds, and therefore withstands the weathering better and is expressed physiographically by slight elevations. The peculiar lamellar appearance of this limestone is similar to that of other areas, and makes it a very valuable unit in mapping.

The Abrigo formation of southern Arizona is of Upper Cambrian age and is correlated by Stoyanow with Week's formation of the House Range section of Utah.

Rincon limestone (?)

The higher members of the Upper Cambrian strata, the
Peppersauce Canyon sandstone of the Santa Catalina Mountains, or Rincon limestone of the Whetstone Mountains, are not proved to be present in the area. West of the Chicago mine the Abrigo formation is overlain by limestone about 200 feet thick which is cherty at the base and soft, pink, and gray crystalline in the upper part. No oolitic texture or accumulation of green matter, glauconite or epidote, or fauna of the Rincon limestone of the Whetstone Mountains is found in this limestone.

On top of this member, north of the Chicago mine, rests a massive, fine crystalline, white quartzite bed. It is easily traced on the surface, and in places forms cliffs, but is probably of lenticular nature because thickness varies and rarely exceeds 50 feet.

Both members are included in the Abrigo formation.

Devonian Sediments

Martin limestone (?)

In the Rosemont camp the Ordovician, Silurian, Lower and Middle Devonian deposits are absent as they are in other places in southeastern Arizona.

According to Stoyanow*, the "Santa Rita limestone" of

*See Bibliography, Reference 24, pp. 494-495.
Middle Devonian time, described by Stauffer* from the Santa Rita Mountains about 5 miles south of Rosemont, was assumed on the basis of fossils too poorly preserved for positive identification. The unit has not been located elsewhere in southeastern Arizona, and Stoyenow considers it unwise at the present time to include the "Santa Rita limestone" in the Paleozoic stratigraphic column of Arizona.

The principal unit of Upper Devonian time known between the Bisbee district and the Empire Mountains is the Martin limestone. The outcrops of the Martin limestone north and south of Rosemont camp were described in the Santa Rita Mountains by many investigators. Martin limestone consists of gray, compact limestone, in part thin-bedded, calcareous sandstone, and rare shaly beds. The thickness of the formation is from 60 to 200 feet with the upper limit somewhat uncertain.

No Devonian fossils were found in the Rosemont camp, and the Martin "formation" cannot be separated solely on the basis of lithology from the overlying Escabrosa limestone. Its presence is suspected west and north of the Chicago mine with a thickness of about 200 feet.

* See Bibliography, Reference 23.
North of the Chicago mine the hypothetical Martin limestone overlies the parting quartzite member of the Rincon limestone (?) on the west, and is separated by a north-south fault from the Cretaceous beds on the east. In other parts of the area there is no doubt that Martin limestone was faulted out.

**Mississippian Sediments**

**Escabrosa limestone**

The Mississippian sediments are represented by the Escabrosa limestone which Girty and Stoyanow correlate with the Kinderhookian of Lower Mississippian time.

The Escabrosa limestone consists, in general, of medium to thin-bedded pure limestone, pink and gray, on weathered surfaces, and white on fresh surfaces. It is usually metamorphosed to coarse marble. The limestone contains crinoidal material, *Syringopora, Michelinia*, and single undescribed corals that distinguish the formation from others. The best outcrop of the Escabrosa limestone is west of Anderson Hill where it forms a saddle between the principal ridge of the Bolsa quartzite on the west and metamorphosed shales of the Manzano group on the east. In other parts of the area the formation, when present, forms either depressions or gentle sloping surfaces. The strike is N - S to N 20° E, and the dip varies from 50° to 60° eastward. The thickness of the Escabrosa limestone is
between 400 and 500 feet. The presence of the Pennsyl-
vanian strata in the area has not been established either
on the evidence of fossils, or on a lithological basis.
Since the actual contacts of the stratigraphic units of
the Paleozoic sediments are predominantly along the north-
south faults, the Pennsylvanian strata are either absent
or hidden by this faulting.

It must be mentioned that sediments of Devonian,
Mississippian, and Pennsylvanian age are not observed in
the Narragansett mine area although they were described by
Thomas* as Martin limestone, Escabrosa limestone, and Naco
limestone. According to the writer's observations, all
the limestone of the northern part of the camp belongs to
the Snyder Hill formation.

**Permian Sediments**

The study of the Permian sediments of southeastern
Arizona and their separation from Pennsylvanian deposits
began only within the last twenty years. Three strati-
graphic units are distinguished by Stoyanow:**
1. A formation of clastic rocks and limestone, equivalent
   of the Manzano group of New Mexico.
2. The Snyder Hill formation, predominantly limestone beds.

* See Bibliography, Reference 26.
** See Bibliography, Reference 24, p. 530.
3. The Chiracahua limestone, equivalent of member B of the Kaibab formation of Grand Canyon, Arizona.

The Snyder Hill formation and Chiricahua limestone were described by Stoyanow, and as stratigraphic units are well established. The oldest Permian unit, equivalent to the Manzano beds of Texas, has been known only a few years. It was first described by Stoyanow* as beds with Manzano fauna from the Whetstone Mountains, and is represented by clastic rocks, sandstones, and shales, nearly 750 feet in thickness, and thin-bedded bluish-gray limestone, 250 feet thick. Because of insufficient lithological and paleontological material he did not separate the sediments as a unit, and did not give a name to the formation. During the last four years, the students of the Empire Mountains have established the presence of gypsum and marl beds, and have shown the necessity of separation of the Manzano beds as a separate unit. In places the beds are more than 1,000 feet thick. The unit was called by Alberding** the Cienega beds, and by other students of the Empire Mountains, the Manzano beds or Manzano group. Similar sediments of the Rosemont camp are described under the name of Manzano beds.

* See Bibliography, Reference 24.
** See Bibliography, Reference 1.
Manzano beds

In general, the separation of the Manzano beds in the Rosemont camp is based on their lithological similarity to the Manzano beds in the Empire Mountains. The sediments consist of metamorphosed shales and limestone. On the surface the shales are either banded with alternating, thin, irregular layers of grayish-green and white colors, or mottled, with the same colors. They may be defined as hornfels. The rock weathers buff and brown, and in some places presents a peculiar aspect of either irregular pits or thin bedding. Even the limestone beds in shales show the same bedding appearance on the surface because of their more sandy content. No gypsum beds are found. An impure, soft limestone bed or marl forms a depression in the formation. Thick quartzite beds which are so characteristic of the Manzano group at the Empire Mountains are absent in the southern part of the area, but there are lenses of quartzites less than three feet in thickness.

Fossils, found in some limestone beds, are scarce, and those that are present are either so poorly preserved that positive identification is difficult, or they characterize a rather long range of sediments. Productidae of Dictyoclostus (Productus semireticulatus) type, coiled gastropods and numerous spines of the sea urchin of Archaeocidaris are the only fossils found.
On account of the comparative hardness and toughness of metamorphosed shales, the Manzano group forms the west slope and crest of Anderson Hill, the best outcrops of this formation in the area. The elongated outcrop of Manzano beds is cut at both the north and south ends by east-west faulting, and on the west rests unconformably on Escabrosa limestone. On the east it is separated from Cretaceous sediments by a north-south fault.

In the northern part of the area no shaly or limestone members of Manzano beds are known. A quartzite bed nearly 200 feet in thickness which rests on the older Paleozoic sediments and is overlain with structural unconformity by the Snyder Hill formation belongs to the Manzano group in the opinion of the writer. The bed can be traced from the Old Pap fault north to the Narragansett mine where it is faulted together with the Snyder Hill formation and the older Paleozoic strata.

Snyder Hill limestone

As a stratigraphic unit the Snyder Hill formation was described by Stoyanow from the type locality at Snyder Hill, on the Ajo road, about 10 miles southwest of Tucson. At the type locality the base of the formation is not exposed, and the exact thickness of the unit cannot be measured, but it is estimated to be between 200 and 500 feet. At Bisbee,
the Snyder Hill formation overlies the Naco limestone of Pennsylvanian age. Both formations are represented by limestone, and separation is possible only on the basis of paleontology. In the Empire Mountains Dr. Galbraith placed the boundary between the Manzano beds and the Snyder Hill formation at the top of the second quartzite bed which shows distinct bedding and is from 50 to 200 feet in thickness.* In the Helvetia camp on the western slope of the Santa Rita Mountains just northwest of the area, the Snyder Hill formation rests on the second quartzite member of the Manzano beds which is only about 50 feet thick here.

The formation lithologically is rather thick-bedded, gray and black, on weathered surfaces, and is usually compact and metamorphosed limestone. Marmorisation and dolomitization of the limestone and formation of metasilicates are due to the metamorphism. No quartzite beds are present. Chert is abundant as small irregular nodules and lenticular bodies. Silicification of fossils is common, but is more conspicuous at the base of the formation, thus explaining the poor preservation and scarcity of fossils.

Fossils are restricted to a few horizons, and are abundant only in a few species. Near the base, reef-

* Oral communication.
building bryozoa and corals of Stromatopora are found, also Dictyoclastus (Productus) of bassi-ivesi type, and sea urchins close to Archaeocidaris sp. described by Girty.* At the middle of the formation there are a few horizons with the following brachiopods: Composita mexicana (Hall), Dyctyoclastus occidentalis (Newberry), and Squamularia quadalupensis (Shumard), all of which are guide fossils for the Snyder Hill formation. Near the top are numerous gastropods, different single corals, and a few brachiopods. Lamellibranchs are represented by *Nyalina*. Small orthoceratids and bellerophontids, Straparollus and Murchisonia give the formation an unusual appearance. This assemblage of brachiopods and gastropods is characteristic of the Snyder Hill formation.

The best outcrop of the formation with a varying thickness rarely more than 800 feet is north of the Old Pap fault zone. It is separated from Cretaceous sediments by a fault. Near the Narragansett mine, only remnants of less than 200 feet in thickness are known. According to Thomas,** west of the Narragansett mine, erosion cut through the Cretaceous rocks and uncovered limestone of probably Pennsyl-

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* See Bibliography, Reference 12.
** See Bibliography, Reference 26.
vanian age.

It is very difficult to correlate the Snyder Hill formation of southwestern Arizona with other Permian sediments of adjoining states. R. E. King* correlates the Manzano beds with the lower member of the Gym formation of New Mexico, and the Snyder Hill formation with the middle and upper members of the same formation.

The upper member of the Manzano beds, the San Andres limestone, is proved to be present in the Whetstone Mountains. It is suspected that it lies between the quartzite beds in the top of the Manzano beds in the Empire Mountains. The peculiar assemblage of fauna of the Snyder Hill formation sharply differs from that described in the San Andres limestone, New Mexico, although there are some common forms in both formations.

Upper Cretaceous beds

The Cretaceous sediments of the Santa Rita and Patagonia Mountains, made up of arkose sandstone, mudstone, and shale, with subordinate tuff and limestone, were first described by Schrader.** On the basis of lithological resemblance and poorly preserved fauna, he correlated the Cretaceous beds with the Comanche series (Bisbee group) of the Bisbee quadrangle.

* See Bibliography, Reference 13.

** See Bibliography, Reference 18.
The study in recent years by faculty members and graduate students of the University of Arizona has provided additional data and changed the interpretation of these beds. The Cretaceous sediments occupy a larger area than that which was partially mapped by Schrader as gravels and sands of Quaternary age, and conglomerate, shale, and sandstone of Eocene age. The sediments are of enormous thickness, probably not less than 20,000 feet, and form a monocline with regional strike close to N 20° W and general dip 45° - 70° to the east. Locally, owing to the effect of intrusives and faulting, the strike and dip change considerably.

Stoyanow* separates the Upper Cretaceous beds of southeastern Arizona into two principal formations, underlain by a series of volcanic rocks: rhyolite and andesite flows and breccias. The volcanic rocks and sediment occupying a large area between Patagonia and the Casa Blanca Canyon are named by Stoyanow the Casa Blanca formation.** The basal member of higher sedimentary beds, the Fort Buchanan formation, consists of sandstones, conglomerates, and arkoses of great thickness with fossiliferous thin-bedded shaly limestone beds. The upper member, the Fort Crittenden formation, consists of soft, gray, yellow, red, and black mudstones and sandstones with fresh water fossils and remains

* See Bibliography, Reference 25.
** Oral communication.
of dinosaurs, overlain with conglomerates of considerable thickness.

Both units compose the Sonoita group of Stoyanow, and on the basis of fossiliferous zones, are correlated in a general way with the Laramie.

Although the Cretaceous sediments occupy a large area east of the Santa Rita Mountains, only a small part of the entire sequence is represented in the Rosemont camp. In the south the sediments rest unconformably upon the porphyritic granite, and are represented by conglomerates, grits, and sandstones. Farther north the Cretaceous beds are separated from Paleozoic limestone by north-south faults. Here the Cretaceous strata are thin-bedded arkoses, sandstones, grits, mudstones, and shales, buff and gray-green in color. In places the sediments are metamorphosed and mineralized, and their color is changed to red and brown of various tints which makes it easy to distinguish them from the more monotonous normal gray-green beds. According to Thomas* the Cretaceous beds in the Narragansett mine area overlie the Paleozoic limestone of Carboniferous age.

The Cretaceous beds are faulted considerably, but faults are usually not conspicuous on account of the uniform character of the strata and rarely can be traced even for a few hundred feet. Nevertheless, their presence is often estab-

* See Bibliography, Reference 26.
lished by indirect evidence such as dragging and local faulting of limestone beds, changes in the direction of washes, the presence of water springs in the fault zone, and the degree of metamorphism.

In general, silicification, epidotization, and mineralization occur more intensively close to the mountain range, and are connected with the structural breaks that can be traced to the Paleozoic rocks but which are not conspicuous in the Cretaceous. Metamorphism gradually decreases away from the mountain range.

On the whole, the Cretaceous sediments are relatively soft, and therefore form a comparatively smooth land surface with somewhat higher portions here and there caused by the presence of harder sediments such as conglomerates or beds of volcanic rocks.

Lithologically, the Cretaceous sediments of the Rosemont camp can be separated into two divisions. The lower division consists of conglomerates, grits, and sandstones, without beds of limestone and andesite tuff. Limestone conglomerate and maroon shales are also characteristic members of this division. The best outcrop of this part of the Cretaceous section is in the south where sediments rest on porphyritic granite and gradually pass east to more shaly Cretaceous rocks. The limestone conglomerate is the
predominant surface rock in this part of the area. It is composed of poorly rounded pebbles of marbleized limestone of light colors and silicified brown-red sandstone cemented by lime. The pebbles show some elongation along the bedding planes. The limestone conglomerate is very resistant to erosion. Near the base, boulders up to 1.5 feet in diameter are found. Within the mapped area the relation between the conglomerate and other members of the lower division is not quite clear. South of the area the conglomerate lies on metamorphosed red shales. The strike of the beds is N 25° W, and the dip is close to 70° to the southwest(?).

No fossils were found in the lower division of the Cretaceous beds. On the basis of lithology it may be correlated with Fort Buchanan formation.

In other parts of the area near the east base of the mountain range, the Cretaceous sediments are less gritty, but are predominantly arkosic sandstones and shales usually altered, crushed, and faulted, and of a red-brown color. The limestone beds and andesite tuffs are absent and therefore probably belong in the lower part of the Cretaceous section of Rosemont camp.

The only exception known of the presence of limestone bed and andesite tuff near the mountain range is that near the mining camp in Wasp Canyon. A thin-bedded, paper-like
calcareous shale of gray-blue color up to 15 feet in thickness crops out of about 600 feet along the strike N 30° W, and dips steeply (75°) to the south. The bed is folded and faulted and is cut out by almost inconspicuous faults.

About one hundred feet south of the limestone there are outcrops of tuff with white siliceous matrix and irregular "pebbles" of granite porphyry, and fine-grained, bedded, brownish silicified sandstone. The irregular fragments are usually from 0.5 to 10 cm. in diameter. Small particles show some sorting and elongation with indistinct bedding planes. The rock weathers easily on the surface leaving a detritus of sandstone and granite porphyry fragments, the former being removed faster than the latter. An outcrop of such rock can be easily mistaken for granite-porphyry. The thickness of the tuff cannot be measured. The strike is close to the strike of the limestone bed and the dip is to the south at an angle of 40°.

The upper part of the Cretaceous sediments consists predominantly of arkosic sandstones, mudstones, shales, gray and green in color, and is less altered and faulted. Limestone beds are present at the base, and numerous beds of andesite tuff are known higher in the section. Fossils were found in a limestone bed about 50 feet in thickness,
and in mudstone and arkosic sandstone in a thickness of about 600 feet. These are abundant in places, although usually represented by only one species of *Viviparus*, and rare fragments of *Unio*.

The limestone beds are found in groups rarely more than 10 feet in thickness and are thin-bedded, gray, and blue in color. They can be traced along the strike for less than a few hundred feet, and show dragg ing and faulting. As a rule they are not fossiliferous. One thin limestone bed higher in the section above the first andesitic tuff is composed wholly of fragments of shells, but owing to attrition before burial and following cementation and silification, the fossils are not well preserved. Gastropods predominate, and some species are of *Turritella* type.

The presence of *Viviparus* and the lithological composition suggest the Fort Crittenden formation of Upper Cretaceous age.

**Quaternary sediments**

Alluvium deposits of recent stream-laid sands and gravels occur in a narrow belt along Barrel Canyon. They rarely exceed 50 feet in thickness. Outcrops of late Tertiary conglomerate, with a thin horizontal lava flow on top, are found in the bank of the same canyon less than one-half mile south from the area.
Igneous Rocks

General Statement

Igneous rocks of the Rosemont camp can be divided into three classes separated on the basis of time of origin:

1. Pre-Cambrian plutonic rocks of granitic composition.
3. Late Tertiary or Quaternary basic rocks.

To the first division belongs the pre-Cambrian porphyritic granite, the base on which sedimentary rocks of the district rest. Mesozoic igneous rocks are represented by quartz-monzonite porphyry dikes and small irregular bodies, and by andesite tuff in the Upper Cretaceous sediments. To the same period belong the granodiorite and alaskite described by Lee and Borland from the Cuprite mine, alaskite described by Thomas from the Narragansett mine area, and numerous stocks in the Empire Mountains. All the Mesozoic and early Tertiary rocks are differentiated from the same general magma and belong to the same igneous cycle.

To the third division belongs basalt. According to Schrader the basalt is not older than late Miocene time, and the outpourings and intrusions in the form of dikes occurred several times during late Tertiary and Quaternary time.
Pre-Cambrian Porphyritic Granite

Schrader states that in the Helvetia district the granite intrusive forms a belt 2.5 miles wide and about 10 miles long which is composed of two granites similar in composition and appearance, one of pre-Cambrian age, the other of Mesozoic age.

Within the Rosemont camp the porphyritic granite underlies the Bolsa quartzite. The outcrops of granite, usually poor, decomposed, and covered by talus, are best exposed near the Old Pat Peak. The porphyritic granite here is silicified and has been prevented from weathering by overlying Bolsa quartzite.

In the southern part of the area the stream of Deering Canyon cut its bed deep into the granite and uncovered the contact with the Bolsa quartzite. Only a few hundred feet farther east it uncovered the sedimentary contact with the Upper Cretaceous conglomerates and grits.

On the surface the granite is easily decomposed to a buff, gray-brown, crumbly material having different sized grains. On account of the long period of weathering, the disintegration of the rock is deep, making it difficult to obtain a fresh specimen for petrographic study.
The granite is porphyritic in texture, and some feldspar crystals, predominantly orthoclase, reach 20 by 40 millimeters in size. The rock is coarsely crystalline and consists of plagioclase, orthoclase, and quartz from 2 to 5 millimeters in diameter. The ferro-magnesian minerals form elongated and irregular black grains and are not abundant, but in places give the rock a dark appearance instead of pinkish-gray. In some parts the granite is sheared and shattered, while in others it is silicified. Near the contact with Bolsa quartzite, quartz veins in the granite are abundant and vary in thickness from a fraction of an inch to 6 inches.

Under the microscope the granite (without phenocrysts) from the southern part of the area consists chiefly of the following minerals: plagioclase-oligoclase \( (Ab_{58}An_{42}) \), 40 percent; alkali feldspar (orthoclase, microcline, and microperthite), 35 percent; quartz, 20 percent; and ferro-magnesian mineral, 5 percent. With phenocrysts the content of orthoclase in the granite predominates over plagioclase.

The feldspar minerals, especially plagioclase, show strong alteration to sericite and kaolinite with a subordinate quantity of calcite. The more brittle and hard mineral, quartz, in grains up to 2 millimeters in diameter, is recrystallized into grains of 0.1 to 0.02 millimeter in diameter, forming a mosaic texture. The ferro-magnesian mineral, probably biotite, is completely altered to magne-
tite and epidote. Accessory minerals are primary magnetite, apatite, and sphene, the last altered to magnetite.

Another specimen from the outcrop near Old Pat Peak shows silicification of the granite. The ferro-magnesian mineral (biotite (?)) in grains from 0.5 to 0.15 millimeter is recrystallized into small grains of biotite of an average size of 0.03 by 0.005 millimeter. The quartz grains indicate the same recrystallization as that in the first thin section. Feldspar is strongly altered by sericitization and kaolinization.

The characteristic features of the porphyritic granite are recrystallization of the quartz and ferro-magnesian mineral, and strong alteration of the feldspar. The recrystallization and bending of minerals are probably due to intense stress during the period of mountain folding when the rock at great depths must adjust itself by rock flowage.

**Age of Porphyritic Granite**

There are strong evidences that the porphyritic granite is older than the Upper Cretaceous beds, and also older than the Bolsa quartzite of Middle Cambrian age.

In Deering Canyon the Upper Cretaceous conglomerates and grits rest with sedimentary contact on the granite. A short distance away the basal bed of the Cretaceous rests on the Bolsa quartzite.
The lithological composition of the Upper Cretaceous conglomerates suggests that the sediments were derived from erosion of the granite and the Paleozoic rocks. The basal member of the sediments overlying granite contains numerous, irregular, slightly rounded fragments of quartz cemented by coarse-grained material of granitic composition. Some parts of the conglomerate are macroscopically closely similar to the granite, but weather differently, and are probably derived from the granite. The thickness of the basal member is decidedly variable. Grits which form the higher members contain small pebbles of quartzite and a smaller amount of granite and coarse-grained material in which pink orthoclase crystals nearly one-half inch in diameter are found.

The sediments at the base of the Cretaceous beds are so similar to the granite that they suggest gradual transition from sediments to intrusives at a distance of several hundred feet. The separation, therefore, is difficult, and is based on the presence of bedding and irregular fragments of quartzite.

The contact between the Bolsa quartzite and granite is only slightly exposed and is partially obscured by later north-south faults. In the southern part of the area the
basal member, conglomeratic quartzite, rests on granite. The beds of Bolsa quartzite dip about 50° in this area. The sedimentary contact is also exposed near Old Pat Peak. Here the contact between the Bolsa quartzite and granite is steep (70°) and shows some movement. The conglomeratic bed is present at the base of Bolsa quartzite.

The general appearance of granite on the surface and the alterations which were visible under the microscope are additional evidences of the pre-Cambrian age of granite.

The pre-Cambrian age of the porphyritic granite seems clear, but it is evident that the determination of pre-Cambrian granite and its separation from younger granite, reported by many investigators, deserve special study.

Quartz-Monzonite Porphyry

The quartz monzonite porphyry of the Rosemont camp belongs to the group of satellitic (hypabassal) rocks which differs from the plutonic rocks only in texture. The rock is porphyritic with microcrystalline groundmass. It is found in this area in the form of dikes, from 50 to 300 feet wide, and in small irregular bodies.

On the outcrop the rock forms low ridges and is not always conspicuous. The more siliceous type with comparatively small quantities of phenocrysts is difficult to separate from quartzite beds. Some of the small bodies are
more readily decomposed, probably because of the presence of ferro-magnesian minerals, and form only slight elevations among the soft Cretaceous beds. In this case mapping is difficult, and boundaries of the bodies are only approximate.

The quartz-monzonite porphyry is restricted chiefly to the structural breaks of east-west direction. These rocks are important because mineralization in the Rosemont camp is associated with them.

In hand specimens, the quartz-monzonite porphyry is a white-gray or pink rock, with phenocrysts of quartz and feldspar, and aphanitic groundmass. On weathered surfaces the fragments of quartz are conspicuous, and the feldspars form either white spots or leave a pitted surface by removal. On fresh surface, the phenocrysts of quartz are irregularly rounded, clear, and glassy, and those of feldspar show as pink well-defined crystals of orthoclase. The phenocrysts are rarely more than 5 millimeters in diameter. Some specimens contain a small quantity of ferro-magnesian minerals usually in grains less than 2 millimeters in diameter.

Under the microscope the rocks show several types. The specimen from the Gray Copper claim consists of 30 percent phenocrysts: quartz, orthoclase, and plagioclase, and 70 percent of groundmass, a microcrystalline aggregate of quartz and feldspar grains less than 0.01 millimeter in
The anhedral grains of quartz form about 12 percent of the thin section. The grains are rounded and partly resorbed in the magma with typical embayments of groundmass. The feldspar phenocrysts which are composed of orthoclase and equal quantities of plagioclase range in size from 1.8 by 0.4 millimeter to 1 millimeter in diameter. Each composes about 10 percent of the slide. The plagioclase grains are strongly altered by sericitization and kaolinization. Determination of plagioclase indicates that it is oligoclase (Ab$_{74}$An$_{26}$). Some grains show concentric structure, or zoning, indicating a more calcic core. The ferro-magnesian mineral is represented by elongated, sometimes curved, grains of biotite from 1.0 by 0.4 to 0.2 by 0.05 millimeter in size. Biotite is altered to chlorite, magnetite, and ilmenite, with some calcite and zoisite. Biotite forms only 5 percent of the slide. Accessory minerals are primary magnetite in grains up to 0.05 millimeter in diameter, apatite in grains less than 0.1 millimeter in diameter, and a small quantity of sphenite, garnet, and pyrite. Tiny veinlets of quartz intersected the slide, the quartz grains varying from 0.1 to 0.03 millimeter in diameter.

Another thin section of a specimen from the Saratoga claim shows that feldspar phenocrysts predominate over the quartz, and that orthoclase slightly exceeds oligoclase-andesine. The feldspar grains are altered. The ferro-magnesian minerals form nearly 10 percent of the thin
but are so altered that identification is impossible.

It is probable that the rocks have a wide range in composition and belong to the same group of rocks described by Schrader as granite-porphyry, alaskite porphyry, and aplitic rocks, derived from the same general magma. The alaskite of Thomas is close to quartz-monzonite porphyry.

The dikes of quartz-monzonite porphyry cut the Paleozoic and Mesozoic rocks, and are restricted to fault zones.

A small outcrop of a tuffaceous bed in the Upper Cretaceous sediments contains irregular fragments of sandstone and quartz-monzonite porphyry. West of the Saratoga Hill a small body of quartz-monzonite porphyry was intruded into the Upper Cretaceous beds.

W. L. Thomas regards the aplite of the Narragansett mine area as being of post-Cretaceous age. M. S. Dunham considers the quartz-monzonite intrusion near the Blue Jay mine area to be Tertiary. Lee and Borland regard the cuprite granodiorite stock as of late Cretaceous and early Tertiary time, or of Laramide revolution. Most of the students who have studied the quartz-monzonite rocks of the Empire Mountains regard them as being similar to those of other mining districts of southern Arizona, and as being early Tertiary.

It is evident that the igneous activity and accompanying structural movements began during the Mesozoic era and
reached their climax in the Laramide revolution. The characteristic feature of all the igneous rocks of this period is that they are of intermediate composition.

**Amygdaloidal Basalt**

Amygdaloidal basalt is found only as small dikes in the southern part of the area, intruding Cretaceous conglomerates. In hand specimen the rock is fine grained, ranging in color from gray-green to iron-gray or black, and containing amygdules of zeolite, calcite, and quartz. The amygdules are from 2 to 15 millimeters in diameter and form only a small percentage of the rock. Under the microscope the black rock is of holocrystalline basaltic texture. The amygdules in this section are either filled with calcite, or composed of isotropic zeolite, analcime, calcite, and pumpellyite (?). The altered feldspar laths which crystallized before the mafic mineral vary in size from 0.3 by 0.05 to 0.15 by 0.03 millimeter, and comprise more than 50 percent of the thin section. Filling the interspaces between plagioclase crystals is a ferro-magnesian mineral, probably augite, highly altered to magnetite, calcite, and epidote.

Another thin section of a gray-green specimen shows altered rock and the original texture is nowhere apparent. Epidote is the predominant mineral and is associated with the original ferro-magnesian minerals. Feldspar laths are
completely altered to kaolinite, sericite, and other minerals. Bleached biotite (?) partly altered to magnetite is found in the groundmass. A serpentine-like mineral suggests the presence of some olivine. Amygdules in this section are composed of quartz which, with analcrite, is also found in the fissures of the groundmass.

Gray-green basalt predominates in the outcrops, and a black rock with ophitic texture represents the middle part of the dike. The presence of amygdules indicates that the gases, separated from the dike, were caught by the rapid cooling of the rock, and formed vesicular or cellular textures. Later the cavities were filled with zeolites, calcite, and quartz, forming typical amygdaloidal texture.

The basalt dikes in the southern part of the area cut the Upper Cretaceous sediments. In composition the basalt is close to that described by Schrader from the Redrock district which cuts andesite of late Miocene age. Therefore, the age of the basalt may be late Tertiary or even quaternary.
Structural Geology

General Statement

The complex structural history of the Rosemont camp can be separated into four principal periods. The sequence of structural events is as follows:

1. The folding or faulting with accompanying intrusion of porphyritic granite in pre-Cambrian time.
2. The regional folding and accompanying faulting of late Paleozoic or early Mesozoic time. The period was followed by extensive erosion and sedimentation during Upper Cretaceous time.
3. Formation of principal north-south and east-west structural (high-angle faults) with accompanying intrusion of quartz-monzonite porphyry and mineralization of Laramide age.
4. Post-mineral normal faulting of late Tertiary and quaternary time.

Pre-Cambrian Structures

The early structural history of Rosemont camp has been complicated and obscured by crustal movement of the Laramide revolution.

The first intense period of crustal disturbance in southeastern Arizona is attributed to the Mazatzal Revolution (Archeozoic period) which is characterized by folding
and faulting of great magnitude and by intrusion of porphyritic rocks: diorite-porphyry, porphyritic pyroxene, granite, granite-porphyry.* No folding or faulting of this revolution is preserved in the Santa Rita Mountains, but the intrusion of porphyritic granite in the western part of the area is of pre-Cambrian age and may be connected with this period. The intrusion followed lines of weakness in the crust, indicated by zones of faulting or folding in a north-south direction. The predominant trend of ancient folds in southeastern Arizona is north to northeast.

Appalachian Structures (?)

From Proterozoic to late Paleozoic time there was a period of erosion and sedimentation. During the Appalachian Revolution, mountain building forces were active and were manifested by regional folding of Paleozoic rocks into monoclinal structure of the Santa Rita Mountains with sediments dipping east. Faults, if present, were not important, and igneous activity was absent. There are no Lower Mesozoic sediments in the Rosemont camp and, therefore, the direct evidence of the age of folding indicates a possible range from the end of the Paleozoic Era to the beginning of Upper Cretaceous time.

* See Bibliography, Reference 4, p. 11.
Laramide Structures

The Laramide revolution followed a period of comparative quiescence and of extensive erosion and sedimentation during the Mesozoic era. North-south reverse faults and east-west high-angle faults with accompanying intrusion of quartz-monzonite porphyry and mineralization belong to this period. The trend of the structures was probably influenced by older pre-Cambrian structures.

North-south reverse faults

A series of north-south reverse faults form the most important structural feature of the Santa Rita Mountains. They are not well exposed on the surface, are displaced by a series of east-west fault zones, and are covered by talus. They can be traced in prospects and by a few outcrops where they show gouge, iron-stained quartzite, and mineralization. The faults are identified by the absence of certain stratigraphic units. The great apparent thickness of some units, as the Abrigo formation, may be explained by duplication owing to this faulting. The faults approach the strike-fault type, being roughly parallel to the strike of the Paleozoic beds, or forming a sharp acute angle with them. The faults are important because of mineralization, and were probably the channels for ore-bearing solutions. It is likely that some horizontal
displacement occurred along the strike of the faults.

The principal fault of this group is the Santa Rita fault near the top of the Bolsa quartzite. It can be traced with great difficulty on the surface along the east side of the ridge, and is broken into several pieces by east-west faults. Its presence is recognized by the absence of the Abrigo formation and Martin limestone west of Anderson Hill, by probable duplication of the Abrigo formation northwest of the Chicago mine, and by the absence of a thick group of sediments between the Cochise formation and the upper part of the Manzano beds in the northeastern part of the area. It is impossible to determine the strike and the dip of this fault on the surface, although the measurements in an old incline show that the strike of the fault is N 20° E and the dip 45° eastward in the southern part of the area.

Another fault of this series is between the Cretaceous sediments and the Paleozoic strata. Southeast of Saratoga Hill where the contact between the limestone and Cretaceous beds is exposed, the strike of the fault is N 20° W, and the dip from 75° to 85° eastward. The fault zone is about 25 feet wide, and the limestone at the footwall is shattered. On the surface this fault can be traced to the south as a belt of crushed, powdered, white limestone, and near Minna Haley Hill, by breccia of limestone. In the northern
part of the area the fault between the Cretaceous beds and
the Snyder Hill formation strikes N 35° E, and dips from
55° to 75° to the east. Thomas* has described the con-
tinuation of this fault in the Narragansett mine area as
the Rosemont thrust fault with gentle western dip.

A nearly north-south fault between the Bolsa quartzite
and pre-Cambrian granite may be referred to this series
of reverse faults. The importance of this fault was ex-
aggerated by Schrader.** According to his description,
the "Greaterville" fault between the granite and Paleozoic
rocks can be traced from the Greaterville district to
Helvetia for about 7 miles, and is a thrust fault with a
gentle dip to the southwest in the Helvetia district, and
is a nearly vertical fault in the Greaterville district.

Traces of another large fault in the Cretaceous beds
are found about 2,000 feet east of Saratoga Hill, and it
is very probable that similar faults are present in other
parts of the area.

High angle reverse faults are characteristic structure
of the Rosemont camp.

* See Bibliography, Reference 26.
** See Bibliography, Reference 18.
Principal east-west structures

The formation of east-west faults followed north-south faulting. The east-west faults cut the Paleozoic sediments into several separate blocks and slightly displaced them by rotation. The faults are expressed on the surface by depressions; the presence of fault breccia; crushed, shattered, and sheared rocks; and slickensides and gouge. Except for the Altamont fault, the east-west faults are wide zones of movement. They were later intruded by quartz-monzonite porphyry which was followed by mineralization. The faults are not conspicuous in the Cretaceous sediments, but indirect evidences and some mineralization suggest continuation and gradual dying out of the faults. The principal east-west faults from south to north are:
1. Altamont fault.
2. Coconino-Chicago fault zone.
3. Old Pap fault zone.
5. Helvetia fault zone.

The Altamont fault

The Altamont fault in the southern part of Rosemont camp trends northwest-southeast and separates the Upper Cretaceous sediments, limestone, conglomerate, and grits, from the Manzano beds. The fault is seen in the
Altamont Canyon with a wash running along the fault which at this point is nearly vertical with a steep dip to the south. The fault zone rarely exceeds 50 feet in width. At the western part of the area the fault is obscured by talus, soil, and vegetation.

The Coconino-Chicago fault zone

The Coconino fault

The Coconino fault is the most important structural break in the central part of Rosemont camp. It can be traced on the surface in an east-west direction by the saddle on the ridge, by a slight depression on the east slope of the mountains, and by the presence of a wash farther to the east. A dike of quartz-monzonite porphyry on the top of the ridge continues in a N 80° W direction in the fault that shows small displacement by north-south faulting. On the east side of the ridge, numerous outcrops of the same rock are found in the fault. The most important old mines of the district, Coconino, Saratoga, (Sweet Bye and Bye of Schrader), and others, and many new prospects are situated in this fault.

According to Schrader, the upper tunnel of Saratoga claim "extends south 118 feet in altered, crushed, and silicified limestone and crosses numerous east-west slip planes and two zones of more marked faulting along which copper carbonates are deposited. A fault at the
mouth of the tunnel dips 40° N."

The lower tunnel cuts a fault of east-west strike, dipping 42° 30' N.*

The mine openings in the Coconino claim "show a 12-foot zone of crushed, silicified, and mineralized limestone which dips to the north under a hanging wall of granite porphyry" (Schrader.)

**The Chicago faults**

Near the Chicago mine a series of divergent faults (N 30° W - S 60° E) together with north-south faults cut the Paleozoic sediments into several small blocks and cause intricate folding of laminated beds in the Abrigo formation.

The northern fault of this group strikes N 30° W, and is indicated on the surface by a depression and washes. Near the ridge it is marked by old prospect workings with iron-stained quartzite, impregnated copper oxides, and carbonates, and by the presence of altered rock, probably a dike of quartz-monzonite porphyry. East of the Chicago mine, limestone breccia, and gouge mark the fault. Farther east the fault cannot be traced in the Cretaceous sediments, although some mineralization is found in fissures striking N 75° W and dipping to the north.

* From a map of the Saratoga mine, "Workings on Muheim Group, Helvetia District," scale 1 in. = 20 ft., 1929. Mr. Muheim, owner.
The quartz-monzonite porphyry dike, with which is associated the mineralization of the Chicago mine, is not present farther north as it is cut out by a fault.

A more southern fault in this area strikes N 75° W and is clearly identified by a wide zone of shearing in the thick beds of Bolsa quartzite. The fault continues westward from the mountain range, and beyond the area it is marked by a deep depression, but on the east side of the ridge it is less conspicuous. It should be noted that between the northern and southern faults is the best outcrop of the Cochise formation in the Rosemont camp.

A fault of S 60° W direction of the Chicago group is a branch of the southern fault and separates the Abrigo formation from higher beds of limestone.

The whole area between the Coconino fault on the south and Chicago faults on the north may be regarded as a wide fault zone of east-west direction parallel to those of the Old Pap and the Helvetia fault zones described on the following pages. The evidences of the Coconino-Chicago fault zones are: the presence of quartz-monzonite dikes of east-west and north-south strike in the fault zone; mineralization; numerous faults in the area; and wide shearing zones in the Bolsa quartzite. The quartz-monzonite dikes are restricted to the fault zone which dips to the north as do both the Coconino and northern Chicago faults.
The Old Pap fault zone

The Old Pap fault can be traced on the surface for about one-half mile in an east-west direction. It is conspicuous in the western part of the area south of Old Pat Peak, or Weigle Butte of Schrader. It forms a saddle in the ridge and uncovers the base of Bolsa quartzite in contact with the pre-Cambrian porphyritic granite on the east side of the ridge. It separates the Bolsa quartzite on the north from the higher Paleozoic units on the south, and farther east, the Snyder Hill limestone on the north from Upper Cretaceous beds on the south.

The fault zone reaches a width of 500 feet in places and dips to the south with an angle of not less than 55°. It is concealed by stream gravel, or talus, but in its west portion a few outcrops of brecciated limestone can be found in the north-south washes. Several prospect openings in the western part of the fault show that the fault zone contains crushed and sheared quartzite that was later cemented by silicification and mineralization. Outcrops of quartz-monzonite porphyry are found in the fault zone.

Schrader reports that the Old Pap tunnel was driven along the fault in a N 17° W direction. After going through 118 feet of silicified, crushed quartzite with copper carbonate ore on joint and shear planes, the tunnel cut the main fault zone of east-west direction dipping to the south.
"This fault zone is marked by much silicification of crushed granite and quartzite, which carries copper carbonates, cuprite, and chrysocolla in a somewhat banded structure due to movement." (Schrader) The tunnel cut the porphyritic granite about 574 feet from the entrance.

The fault zone itself shows the presence of associated fractures at an oblique angle to the main fault movement. These "open gash fractures" strike close to N 20° W. The Old Pap tunnel was trending along a fault striking N 17° W. East of the tunnel a dike of quartz-monzonite porphyry occupies a fracture of N 20° W strike in the main fault zone.

Quartzite and other rocks involved in the structure contain several copper prospects usually found in places of intersection with north-south faults along shear planes and other fractures.

One of the most interesting mineralization areas in the central part of Rosemont camp is in the continuation of this fault zone to the east where the Cretaceous sediments are shattered, crushed, and silicified. Abundant copper carbonates can be found along numerous tiny fissures.

The Cuba fault

Less important from the standpoint of mineralization is the Cuba fault about 1,000 feet north from the
Old Pap fault zone. On the surface it is marked by a slight displacement of a quartzite member of the Manzano beds and Snyder Hill limestone, and by a slight depression and wash. A few copper prospects are situated at the intersection of the Cuba fault with a north-south fault between Paleozoic rocks and Cretaceous beds.

The Helvetia fault zone

The chapter on structural geology would not be complete without describing the Helvetia fault zone in the northern part of Rosemont camp, although more work must be done before it can be described in detail.

In the outline of structure in the Narragansett mine area, H. Thomas says:

"The faults are reverse with dips to the south at angles approximating 60°. The granite porphyry stock to the north is faulted and displaced by the third system of faulting which forms a large fault zone. Within this fault zone are fragments of Cretaceous shales, aplite, and altered Paleozoic limestones indicating the strata that were severed by the shear."

Thomas described the aplitic intrusion in this area as follows:

"It is elliptical in shape and averages about 1,200 feet long and 500 feet wide trending east and west. This aplite has partially replaced a quartzite series and parallels the stratification of the original beds. Large unreplace masses of quartzite still remain as isolated bodies within the aplite."
In the opinion of the author, the fault zone of nearly east-west direction was formed before the aplitic intrusion, as were faults in other parts of Rosemont camp. The intrusion itself was controlled by this wide zone of weakness. Additional movement in the fault zone after the intrusion may have taken place with the formation of fragments of aplitic. If the replacement of original sedimentary rocks took place in any great degree, it was possible only when these rocks were brecciated and shattered by faulting before the intrusion. The truth of the statement that aplitic parallels the stratification of the original beds is doubtful because the prevailing strike of Paleozoic rocks in Rosemont camp and in the area north of it is north-south, not east-west, and in the fault zone and close to it, the strike and dip of beds are abnormal.

One of the outstanding characteristics of the country rocks of many mines of the Helvetia district, as described by Schrader, is that: "The rocks, except most of the alaskite aplitic, are crushed, faulted, shattered, and altered, with seams or veinlets of sulphides."

According to the same author, within the Narragansett-Helvetia area:

"is the Helvetia copper belt, about 1 mile wide and 3 miles long, extending from the Rosemont properties on the east slope of the range northwestward through the Helvetia basin to the Tip-Top mine, and comprising nearly all the producing or known workable properties in this district."
Briefly, the following conclusions may be stated:

1. The presence of the wide fault zone is demonstrated by various investigators, although the term fault-zone was not used.

2. The fault zone is earlier than the aplite intrusion and is of reverse character with a width of about 1 mile.

3. The zone differs from other east-west faults by the amount of displacement and by the more intense mineralization.

4. The sedimentary rocks south of and close to the fault zone show abnormal strike and dip (west instead of east), and are shattered, which suggests some drag folding along the fault zone.

The age of east-west faults

It is evident that the east-west faults preceded the intrusion of quartz-monzonite porphyry. Some fragments of porphyry are found in the tuffaceous bed of Upper Cretaceous sediments. The east-west faults cannot be older than Upper Cretaceous time, and therefore must be regarded as of Laramide age, or younger.

Post-mineral normal faulting

Post-mineral normal faults are later than Laramide structures. Two systems of normal faulting may be distinguished in Rosemont camp, one of east-west direction
and the other of north-south direction. These faults are in some places difficult to separate from the older ones. They took place along the pre-existing zones of weakness, and are due to adjustment of the crust after extensive folding and faulting. The faults are characterized by the absence of mineralization, by slight displacement, and small extent. By renewed movement on some of the older faults they may displace ore bodies or intrusive rocks, such as aplite of the Narragansett mine area.

The east-west faults are more common. Some of the north-south faults are of bedding-plane type, and probably are more numerous in the area than previous investigation has revealed.

Normal faulting, as the result of settling of the region, was later than the mineralization and continued for a long time during late Tertiary and Quaternary time.
Metamorphism

General Character of Metamorphism

The sedimentary rocks of the Rosemont camp were not only folded and faulted, but extremely metamorphosed. It is believed that the character and intensity of metamorphism are controlled by distance from the igneous intrusion, structural conditions, composition of sedimentary rocks, and character of solutions.

The metamorphism of sediments in the Rosemont camp consists of simple recrystallization of original material and cementation and formation of new minerals, with or without addition of material from igneous sources. On the whole, the metamorphism preceded and accompanied mineralization, and was caused by changes in pressure and heat, and introduction of thermal solutions. It seems probable that these factors were controlled by the presence of an igneous body close to the existing surface and at the base of the Santa Rita Mountains. Such a body is indicated by numerous granite-porphyry bodies.

In general, the effect of metamorphism is notable in all Paleozoic sediments, but less so on Cretaceous beds.

Metamorphism of Sandstones

There are several fine-grained quartzite beds in the
Paleozoic section, and in subordinate quantity, quartzites, conglomerate, and grit. All are metamorphosed sandstones, conglomerates, and grits, so thoroughly recrystallized and cemented that nearly all evidences of sedimentary textures are obscured.

The lowest Paleozoic member, the Bolsa quartzite, has preserved the original character of basal conglomeratic and coarse-grained sandstone, and bedding and cross-bedding in some beds. It is pink, indicating the presence of some ferruginous mineral. The character of the quartzites shows that the original sediments were to a great extent pure quartz before metamorphism.

Other Paleozoic quartzite beds predominantly of Manzano age are fine grained, in many places cherty, and where weathered, show distinct bedding and ochre tint, but are quite vitreous on fresh surface. The cementation and recrystallization of original sandstones of Paleozoic age were accomplished by circulating thermal solutions rich in silica derived from underlying intrusive bodies.

The sandstones of Cretaceous age are less metamorphosed than those of the Paleozoic age. The metamorphism is expressed by induration and by the production of abundant epidote in places in the impure calcareous sand beds. The lesser degree of metamorphism is due not only to greater distance from the center of metamorphism, but to the pre-
dominantly arkosic character of the sandstones, and to the absence of, or to a different character of structure of the Cretaceous rocks.

Metamorphism of Limestones

Limestones are differently metamorphosed. The degree of metamorphism shows a distinct relation to the original composition of limestone and relation to structural breaks, as channels of thermal solutions. Marmorisation, or recrystallization, much bleaching, and little mineralogical changes, characterized the more pure limestone beds, as the Escabrosa limestone and Snyder Hill formation. Dolomitization is more pronounced in more impure limestone of the Abrigo formation and Manzano beds. Silicification affected the limestone close to the structural breaks. Formation of different meta- and ortho-silicates of calcium and iron, as wollastonite, garnet, and epidote, is usually restricted to separate beds and is associated with faults and fissures. In many places, wollastonite in disseminated crystals is found in marble and elsewhere. In the Snyder Hill formation it is seen as an important constituent in patches. Epidotization and garnetization are indications that some material was added by the solutions. Mineralization with iron oxides is associated with garnet. The selective and gradual replacement of limestone or limy beds by silicates is shown on the surface by the peculiar "breccia-like"
appearance of separate beds. Such metamorphic rocks are on the outcrops of the Manzano beds.

Fossils in metamorphosed limestone are usually destroyed, or are silicified and poorly preserved. Even the single corals lose their characteristic internal structure, and positive identification of genera is difficult.

Metamorphism of Shales

The metamorphism of shales and shaly beds of the Manzano group is very striking. The beds are usually so altered that the original sedimentary texture of the metamorphosed rocks is revealed in the field only on the weathered surface. Some of the shaly beds are changed to hornfels, a dense, fine-grained rock which shows conspicuous banding with alternating grayish-green and ivory-white layers. These beds were hardened by dehydration and recrystallization and then silicified. Silicification may be so complete that the cherty-looking rock may be called quartzite. Epidotization in the form of small nests, or as "cement-like" material, suggests the selective replacement of some of the beds. Such beds have a pitted appearance on weathered surface. Garnetization is also common in more calcareous horizons and close to structural breaks.

The shaly members of the Abrigo formation have been indurated and silicified. Some of the shaly beds of the Cochise formation acquire a secondary laminated structure
and are close to schists.

The shales of Cretaceous age are altered by dehydration, induration, and recrystallization. Silicification is less expressed, as is the addition of any other material. Some epidotization is known close to the base of the Santa Rita Mountains.

**Age of Metamorphism**

It is possible that metamorphism of Paleozoic strata took place before Upper Cretaceous time. Quartzite pebbles and irregular fragments are found in the Cretaceous conglomerate overlying the Bolsa quartzite. Some conglomerate beds contain numerous fragments of metamorphosed limestone. Although the conglomerates are consolidated, they show a sharp difference from the Paleozoic rocks.

In general, metamorphism of Paleozoic and Mesozoic rocks preceded and accompanied the mineralization which took place in Laramide time.

The first stage of metamorphism followed the intrusion of igneous rocks and was largely due to heat and pressure. These factors influenced a rather large area and brought about bleaching and marmorisation of the limestone. There was probably a very slight introduction of new elements and even formation of new minerals.
The second stage of metamorphism followed and was caused by thermal solutions escaping along faults and fissures from the cooling intrusive body. The solutions introduced new elements and compounds: Mg, SiO₂, and Fe. Dolomitization probably preceded silicification. During this period formation of meta- and ortho-silicates took place close to the solution channels by selective replacement of more susceptible beds.
Geomorphology

Development of the Topography of the Santa Rita Mountains

The preceding chapters describing the geologic history, the sedimentary and igneous rocks, and the structure of Rosemont camp are necessary for the interpretation of the present topographic forms of the area. The physiographic development of the surface extended over a long period of time and was influenced chiefly by weathering of the rocks. Structure, lithology of the rocks, and climatic conditions were the factors which controlled the weathering.

The ancient Santa Rita Mountains were subjected to extensive erosion during Upper Cretaceous time. The period of weathering was of long duration and the degree of erosion was great. Evidences of denudation of older rocks are found in the area. In the southern part of the camp the continuous and intense erosion destroyed a great thickness of Paleozoic rocks, revealing the pre-Cambrian granite. After that, the granite was under the influence of agents of weathering, which explains the considerable alteration in the non-resistant feldspars and ferro-magnesian minerals, and general disintegration of the rock close to the surface. The erosion of the Paleozoic rocks along the Santa Rita Mountains was not uniform, probably because of different altitudes of the same formation. Only Bolsa quartzite was preserved in the southern part of the area. Farther to
the north, Escabrosa limestone was left on the surface. In the middle part of the area the Manzano beds are in fair preservation, and in the extreme north even the Snyder Hill formation remains.

The material from weathering of rocks of the ancient Santa Rita Mountains was carried to the Cretaceous sea, and deposited in the form of conglomerates, grits, sandstones, and shales of enormous thickness. This period of deposition was interrupted several times by volcanic activity, forming lava beds interbedded with typical sedimentary deposits.

During the Laramide revolution, a period of igneous activity and structural disturbance, the Santa Rita Mountains were once more uplifted, broken by faults into separate blocks, and intruded by igneous rocks. A new, continuous, and vigorous erosion followed during the Tertiary and Quaternary time.

Different rocks offered dissimilar resistance to weathering. The climatic conditions favored weathering of some of the rocks, and hampered that of others. Some structural breaks were zones of weakness, others were resistant to weathering.

The semi-arid climate of the region, with dry and wet seasons, the small amount of precipitation, the torrential character of the rains, meager vegetation, and rapid changes
in temperature, were favorable for preservation of massive homogeneous rocks such as fine-grained quartzite and hornfels, or compact, thick-bedded limestone.

On the other hand, heterogeneous rocks composed of different coarse crystalline minerals like porphyritic granite were more susceptible to weathering because of difference in hardness, and coefficient of expansion and contraction of its constituents. Such rocks were rapidly broken down to fine material and carried away.

The influence of structural breaks on the topographic forms is very striking. A series of east-west faults crossed the strike of the Paleozoic rocks, which forms the west slope of the Santa Rita Mountains and produced zones less resistant to erosion. Even the most resistant rock of the area, the Bolsa quartzite, shows depressions along the crest of the ridge at the places of intersection with east-west faults. Most passes of the Santa Rita Mountains are attributed to this cause. Topographically the east-west faults are expressed by the presence of washes and canyons, some of which are steep and narrow in more resistant rocks.

The washes carried a large quantity of material from the mountainous part of the area and deposited it as alluvial fans close to the mountain range. Thus is explained the presence of debris of rock fragments, sand,
and fine material in a heterogeneous mass in the banks of the washes close to the mountain range.

The north-south faults rarely have surface expression except on the gentle sloping surface of Cretaceous beds. Being close to the strike of Paleozoic formations, the weak fault zones were protected either by overlying and underlying hard and resistant rocks, as Bolsa quartzite, or by subsequent metamorphism and mineralization, forming a more resistant material. However, the beginning of the washes in the mountainous part of the area usually starts at the intersection of weak beds, as the Cochise formation, with north-south faulting. In the gentle sloping area of Cretaceous beds, the drainage took place in washes coinciding with some north-south faulting, and even some east-west washes from mountains changed their direction on account of north-south faulting.

The summit of the Santa Rita Mountains is composed of Bolsa quartzite, and the ridge itself is elongated in the direction of the strike of the formation. The resistant character of the quartzite to erosion is evident. However, because of the work of disintegrating agents, detritus of irregular and large fragments covered the surface down the steep slope of the ridge and even protected the weaker formations from erosion.

The elevation of Anderson Hill, as well as that of a group of hills east and southeast of it, is due to the
resistant nature of the metamorphosed rocks of the Manzano beds. Where the upper, more resistant beds of the formation were eroded, the lower beds of impure limestone or marl were removed rapidly, forming depressions and uncovering the base of the Manzano group. If the resistant upper beds were found on the surface, they protected a large thickness of softer rocks and gave such topographic features as Saratoga or Minna Haley hills.

The conglomerates of Cretaceous time are the next most resistant rock in the area. On the surface they are distinctly associated with a broad elevated area in the southern part of the camp.

The limestone beds of Paleozoic age usually form either saddles between the more resistant quartzite rocks, or form the slope of the mountains, the steepness of which depends on the resistance to erosion of different formations. In general, the Snyder Hill limestone forms steeper surfaces than the Escabrosa limestone.

The Cretaceous beds, except conglomerates, gave little resistance to weathering. They form more or less gently sloping surfaces from the mountain range to the west, with separate hills and small ridges capped by more resistant beds, and with washes running either along the strike of weak beds, or along inconspicuous faults.
The last stage of metamorphism overlapped the second and was characterized by more intense replacement of limestone and deposition of iron oxides and sulphides. Silicification accompanied the mineralization.

Mineral Deposits

General Features of Ore Deposits

The writer does not intend to give a full and detailed description of the numerous mine openings of the area. Nearly every one of the 100 claims was prospected by a shaft or tunnel, but only a few of them had workings of more than 100 feet. Most of these mining workings are difficult to examine because they were abandoned from 20 to 30 years ago and are now dangerous to explore. Some of these old mines were described by Schrader during their time of production.* The description of the Narragansett mine was given by Thomas.**

Copper is the principal metal produced by Rosemont camp, silver and gold are found in small quantities, and zinc and lead are reported produced northeast of the area nearer the Cuprite mine and the Empire Mountains.

* See Bibliography, Reference 18, pp. 128-132
** See Bibliography, Reference 25.
The hypogene ores of the camp belong principally to the pyrometasomatic group of ore deposits formed at high temperature near the contact of sedimentary rocks with igneous intrusions. The deposits are characterized by intense metamorphism of sedimentary rocks, and replacement of calcareous rocks, chiefly limestone, by magmatic emanations. The ore bodies are very irregular in shape, consisting of the ore minerals: magnetite, hematite, pyrite, and chalcopyrite; and the gangue minerals: quartz, garnet, epidote, and carbonates. They are controlled by the structure of the area and are confined to the beds more susceptible to replacement.

The oxidized part of the ore deposits forms economically important ore bodies, and consists of the following ore minerals: azurite, malachite, tenorite, cuprite, and chrysocolla, together with the gangue minerals: sericite and kaolin. The oxidation is usually of shallow depth, although along the structural breaks it may be more than 100 feet. After deposition the ore deposits suffered considerable and rapid erosion which explained the shallow depth of oxidation.

The deposits were probably formed at great depth. There is no indication of more than one period of mineralization.
Distribution of Ore Deposits

The ore deposits of Rosemont camp show distinct association with the principal structural breaks of the area. They are confined either to the intersection of north-south faults with east-west fault zones, or to these two systems of faults.

The mineralization of pyrometasomatic type with iron oxides is restricted either to the Santa Rita fault or to the portions of east-west faults close to it. Mineralization in the north-south fault between the Paleozoic rocks and Cretaceous sediments is less important and includes copper carbonates and wulfenite. Some mineralization is found near the contact of Bolsa quartzite and pre-Cambrian granite.

Poor mineralization is connected with the Altamont fault. Copper carbonates are found in fissures striking parallel to the fault (N 45° W) and dipping 80° northward in the eastern part of the fault.

Some mines were mentioned in the description of the Coconino east-west fault zone, as the Saratoga and Coconino mines. To these must be added Oregon Copper and Grey Copper prospects. The ore deposits in the Coconino fault zone show the same characteristic features. The ore minerals, principally copper carbonates, with a mixture of quartz, are found in a crushed and silicified zone of
limestone in the footwall of quartz-monzonite porphyry which dips 40° - 50° northward.

Numerous prospects are known in the Old Pap fault zone, and some production was reported from the Old Pap tunnel.

A most important group of mines in the Narragansett mine area is, in the opinion of the writer, in the Helvetia fault zone.

The presence of quartz-monzonite porphyry dikes in the east-west fault zones was favorable for the formation of ore deposits. They were less permeable and the ore solutions spread along the footwall of the dikes and deposited the ore minerals. The ore bodies of the Chicago mine and Pickwick prospect are examples of ore deposits along the contact with north-south dikes, and the Coconino, Oregon Copper, and Saratoga mineralization is in the footwall of an east-west dike.

The ore solutions tend to replace more favorable sedimentary beds, forming ore deposits of replacement type. The quartzite beds of Bolsa quartzite or Manzano group are unfavorable for replacement, and poor mineralization in these sediments is found only in fissures near the faults where quartzite was sheared and crushed.

Limestone beds of Upper Paleozoic strata are the most favorable rocks for replacement. The productive horizons
of Rosemont camp are: the Snyder Hill limestone in the Narragansett group of mines; the limestone members of Manzano beds in the Coconino, Oregon Copper, and Saratoga mines; and the Escabrosa limestone in the Pickwick prospect and the Chicago mine.

There is no doubt that beds of limestone show varying degrees of susceptibility to replacement by the solutions.

Aluminous rocks, like shaly members of Manzano beds, show no trace of mineralization. In the Abrigo formation only small veins of quartz with ore minerals are known. The arkosic sandstone of Cretaceous beds was not favorable for replacement, although some small pockets of oxidized ore are found. The mineralization in these beds is in the form of quartz veins with ore minerals occupying fissures in the fault zones.

Some Ore Deposits of Rosemont Camp

The oxidized copper ore in Cretaceous beds

Between the Old Pap and the Coconino-Chicago fault zones lies a large area of Cretaceous beds which, in numer-trenches, pits, and other mining workings, show some copper mineralization. The Cretaceous sediments, predominantly arkosic sandstones and shales, are usually of various tints of red to brown from oxidation of iron, and are crushed and partly metamorphosed. Silicification and epi-
dotization are restricted to separate beds. The oxidized minerals of copper, malachite, azurite, and cuprite, are confined principally to thin films in numerous fissures running in various directions. The following analyses of samples* taken from different works show the character of mineralization.

<table>
<thead>
<tr>
<th>No. of analysis</th>
<th>Location</th>
<th>Percent Copper</th>
<th>Ozs. Silver</th>
<th>Ozs. Gold</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Miller's claims</td>
<td>2.8</td>
<td>5.0</td>
<td>0.04</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>3.0</td>
<td>3.2</td>
<td>0.03</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>1.0</td>
<td>0.5</td>
<td>trace</td>
</tr>
<tr>
<td>4</td>
<td>Bisbee claim</td>
<td>1.7</td>
<td>1.6</td>
<td>trace</td>
</tr>
<tr>
<td>5</td>
<td>Tiger tunnel</td>
<td>0.4</td>
<td>0.7</td>
<td>0.02</td>
</tr>
<tr>
<td>6</td>
<td>Hunter claim</td>
<td>4.1</td>
<td>1.0</td>
<td>trace</td>
</tr>
</tbody>
</table>

Some of the ore from these deposits was sorted and shipped to the smelter. Rich lenses and pockets of oxidized ore rarely exceeding 100 tons were found in this area. Such pockets were near the mouth of Tiger tunnel and near the Hunter shaft. The latter pocket, it is

reported, gave 360 tons of sorted copper ore averaging 6 percent copper. The mineralized area of Cretaceous beds lying close to the Paleozoic sediments was cut by north-south and east-west faulting at the same time as were the lower horizons. Owing to the character of the sediments, the faults were healed readily and are now evident as metamorphosed rocks.

**Manganese Deposits**

By following the Coconino-Chicago fault zone eastward, one reaches six claims belonging to Mr. Muheim on which some prospecting for manganese was done during the first World War. The mineralization on the surface is evidenced by purple-red and yellow-brown colored outcrops. Several pits and small shafts were dug, but gave unsatisfactory results. The best sample of ore gave 58.2 percent manganese and 0.02 ounces of gold, but the average ore is poor. The ore is confined to fissures a few inches wide.

**Age of Ore Deposits**

It is believed that mineralization accompanied and followed intrusions of igneous rocks which, in turn, were closely associated with and followed strong folding and faulting. In Rosemont camp the ore-forming period was controlled by major faulting in north-south and east-west directions and followed the intrusion of quartz-monzonite por-
phyry. According to preceding chapters, the intrusion of quartz-monzonite porphyry and faulting is of late Mesozoic time, or early Tertiary. It is evident, therefore, that mineralization took place not earlier than late Cretaceous time. The ore deposits apparently belong to the late Mesozoic or early Tertiary metallogenet  

Bibliography


Plate VI.

1.

Southern part of Rosemont Camp area, looking west from Highway No. 83.

2.

Northern part of Rosemont Camp area, looking west from Highway No. 83.
Plate VII

1.

Remnants of Rosemont Smelter, as seen from the south.

2.

Limestone conglomerate in southern part of Rosemont Camp. Altona-mont fault to the right.
Plate VIII

1. Cliff-forming Bolsa quartzite rests on pre-Cambrian granite. Looking south along crest from Old Pat Peak.

2. Saddle in crest of ridge which marks Coconino fault.
Plate IX

1.

Old Pat Peak with Old Pap fault zone behind it. Viewed from south.

2.

Limestone conglomerate
Plate X

1.

Abrigo formation. Note laminated texture of rock.

2.

Quartzite bed at top of Rincon limestone (?).
Plate XI

1.
Photomicrograph of basalt with amygdules of analcime, calcite, and pumpellyte (?).
Ordinary light. x 30.

2.
Photomicrograph of basalt with quartz amygdules.
Crossed nicols. x 20.

analyzine - a
calcite - c
pumpellyite- p
plagioclase- pl
quartz - q
Plate XII

1.

Photomicrograph of pre-Cambrian porphyritic granite showing sericitized plagioclase, orthoclase, quartz, biotite (?), and epidote.

Crossed nicols. x 30.

2.

Photomicrograph of quartz-monzonite porphyry showing contrast in size between phenocrysts of quartz, plagioclase, orthoclase and biotite, and quartz and feldspar in the groundmass.

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>biotite</td>
<td>b</td>
</tr>
<tr>
<td>epidote</td>
<td>ep</td>
</tr>
<tr>
<td>orthoclase</td>
<td>or</td>
</tr>
<tr>
<td>plagioclase</td>
<td>pl</td>
</tr>
<tr>
<td>quartz</td>
<td>q</td>
</tr>
</tbody>
</table>
Plate XIII

Photomicrograph of quartz-monzonite porphyry showing contrast in size between phenocrysts of quartz, plagioclase, orthoclase, and biotite, and quartz and feldspar in the groundmass.

quartz - q
plagioclase - pl
orthoclase - or
DEPARTMENT OF THE INTERIOR
JOHN BART03ST BAYNE, SECRETARY
U. S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

PLATE I
ARIZONA
PATACONIA QUADRANGLE

TOPOGRAPHY

U.S. GEOLOGICAL SURVEY


Surveyed in 1903-1904.

Topography by R.T. Evans, J.E. Blackburn,
Chester Irvine, and H.H. Hodgeson.

Triangulation by T.M. Bannon.

Surveyed in 1903-1904.

APPROXIMATE MEAN DECLINATION, ISO *
THE TOPOGRAPHIC MAPS OF THE UNITED STATES

The United States Geological Survey is making a standard topographic atlas of the United States. This work has been in progress since 1882, and its results consist of published maps of more than 40 per cent of the country, exclusive of outlying possessions.

This topographic atlas is published in the form of maps or atlas sheets measuring about 16½ by 20 inches. Under the general plan adopted the country is divided into quadrangles bounded by parallels of latitude and meridians of longitude. These quadrangles are mapped on different scales, the scale selected for any quadrangle depending on its nature and its probable future development, and consequently though the standard atlas sheets are of near uniform size they represent areas of different sizes. On the lower margin of each sheet are printed graphic scales showing distances in feet, meters, and miles. In addition, the scale of the map is shown by a representative fraction expressing a fixed ratio between linear measurements on the map and corresponding distances on the ground. For example, the scale 1 inch represents 62,500 similar units on the earth's surface.

The standard scales used on these maps are multiples of the fraction 1/30,000. Quadrangles in thickly settled or industrially important regions are mapped on a scale of 1/60,000, or about 1 mile to 1 inch, and cover areas measuring 1½° in latitude and longitude. Quadrangles in less thickly settled or industrially less important districts are mapped on a scale of 1/90,000, or about 2 miles to an inch, and cover areas measuring 3° in latitude and longitude. Reconnaissance maps of desert or sparsely inhabited regions have been made on a scale of 1/240,000, or about 4 miles to an inch, covering areas measuring 6° in latitude and longitude. Maps for special purposes are made on scales larger than 1/30,000.

A topographic survey of Alaska has been in progress since 1898, and nearly 35 per cent of its area has now been mapped. About 10 per cent of the Territory has been covered by reconnaissance maps on a scale of 1/60,000 or about 10 miles to an inch. Most of the remaining area surveyed in Alaska has been mapped on a scale of 1/90,000, but about 3,500 square miles have been mapped on a scale of 1/240,000.

A large part of the Hawaiian Islands has been surveyed, and the resulting maps are published on a scale of 1/30,000. The features shown on these maps may be arranged in three groups: (1) water, including seas, lakes, rivers, canals, swamps, and other bodies of water; (2) relief, including mountains, hills, valleys, and other features of the land surface; (3) culture (works of man), such as towns, cities, roads, railroads, and boundaries. The conventional signs used to represent these features are shown and explained below. Variations appear on some earlier maps, and additional features are represented on some special maps.

All the water features are represented in blue, the smaller streams and canals by single blue lines and the larger streams, the lakes, and the sea by blue water lining or blue tint. Intermittent streams—those whose beds are dry for a large part of the year—are shown by lines of blue dots and dashes. Relief is shown by contour lines in brown. A contour line represents an imaginary line on the ground (a contour) every part of which is at the same altitude above sea level. Such a line could be drawn at any altitude, but in mapping only the contours at certain regular intervals of altitude are shown. The line of the seacoast itself is a contour, the datum or zero altitude being mean sea level. The 30-foot contour, for example, would be the shoal line if the sea should rise 20 feet. Contour lines show the shapes of the hills, mountains, and valleys, as well as their altitudes. Successive contour lines that are far apart on the map indicate a gentle slope; lines that are close together indicate a steep slope; and lines that run together indicate a cliff.

The manner in which contour lines express altitude, form, and grade is shown in the figure below.

The sketch represents a river valley that lies between two hills. In the foreground is the sea, with a bay that is partly inclosed by a hooked sand bar. On each side of the valley is a terrace into which small streams have cut narrow gulleys. The hill on the right has a rounded summit and gently sloping spurs separated by ravines. The spurs are truncated at their lower ends by a sea cliff. The hill at the left terminates abruptly at the valley in a steep scarp, from which it slopes gradually away and forms an inclined table-land that is traversed by a few shallow gulleys. On the map each of these features is represented, directly beneath its position in the sketch, by contour lines.

The contour interval, or the vertical distance in feet between one contour and the next, is stated at the bottom of each map. The interval differs according to the topography of the area mapped; in a flat country it may be as small as 1 foot; in a mountainous region it may be as great as 250 feet. Certain contour lines, every fourth or fifth one, are made heavier than the others and are accompanied by figures showing altitude. The heights of many points—such as road corners, summits, surfaces of lakes, and bench marks—are also given on the map in figures, which show altitudes to the nearest foot only. More exact altitudes—those of bench marks—as well as the geodetic coordinates of triangulation stations, are published in bulletins that are issued free by the Geological Survey.

The lettering and works of man are shown in black. Boundaries, such as those of a State, county, city, land grant, township, or reservation, are shown by continuous or broken lines of different kinds and weights. Metalled roads are shown by double lines, one of which is accentuated. Other public roads are shown by fine double lines, private and poor roads by dashed double lines, trails by dashed single lines.

Each quadrangle is designated by the name of the principal city, town, or natural feature within it, and on the margins of the map are printed the names of adjoining quadrangles of which maps have been published. Over 2,800 quadrangles in the United States have been surveyed, and maps of them similar to the one on the other side of this sheet have been published.

The topographic map is the base on which the geology and mineral resources of a quadrangle are represented, and the maps showing these features are bound together with a descriptive text to form a folio of the Geologic Atlas of the United States.

Index maps of each State showing the topographic maps and geologic folios published by the United States Geological Survey may be obtained free. Copies of the topographic maps may be obtained for 10 cents each, or in lots of 50 or more, either of the same or of different quadrangles, for 6 cents each. The geologic folios are sold for 25 cents or more each, the price depending on the size of the folio. A circular describing the folios will be sent on request.

Applications for maps or folios should be accompanied by cash, draft, or money order (not postage stamps) and should be addressed to:

THE DIRECTOR,
United States Geological Survey,
Washington, D. C.
November, 1919.

CONVENTIONAL SIGNS

CULTURE

(printed in black)

WATER

(printed in blue)

WOODS

(when shown, printed in green)
BLOCK DIAGRAM
OF THE
ROSEMONT MINING CAMP
PIMA COUNTY, ARIZONA

DRAWN BY E. C. TAYLOR