ORE CONTROLS OF THE
SAN XAVIER MINE,
PIMA COUNTY, ARIZONA

by
Clyde A. Wilson

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DEPARTMENT OF GEOLOGY
In Partial Fulfillment of the Requirements
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1960
STATEMENT BY AUTHOR

I wish to express my appreciation to the Banner Mine of the San Xavier Mine, for permission to publish this work. Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgement of source is made. Requests of permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the Graduate College when in their judgment the proposed use of the material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

SIGNED: Clyde A. Wilson

Harrison Schmitt, William Loping, W. R. Loring, W. B. Karon and others. I also wish to thank Mr. F. R. MacKenzie, chief geologist of Banner Mining Company for his co-operation and advice.

Thanks is also given to the Arizona Bureau of Mines for the file from which most of the history of the San Xavier Mine was taken.

APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

S. R. Titley
Professor of Geology

Date
November 28, 1960

[Text continues with acknowledgments and thanks, including mention of Carol]
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INTRODUCTION

General Statement

The San Xavier Mine, owned by the Banner Mining Company, Tucson, Arizona, is an example of a pyrometasomatic mineral deposit that does not seem to be related to any known igneous rock contact. Lindgren (1933) defined pyrometasomatic deposits as deposits formed by the replacement of rocks, usually limestones, which are located at or near intrusive igneous contacts. He suggested that these deposits formed at a temperature of 400° to 600° C and were due to mineral-carrying emanations issuing from the intrusive igneous mass. During this replacement activity, the volume appears to have remained constant. Bateman (1950) refers to this type of deposit as contact metasomatic, while others call it contact metamorphic.

Five shafts and approximately 7 miles of underground workings which extend as deep as 900 feet are present in the mine. Zinc and lead were the main metals sought; subordinate values of silver and copper were also mined.
Location

The San Xavier Mine is located approximately 22½ miles south of Tucson, Pima County, Arizona, in an area often referred to as the Pima Mining District or the East Sierrita Mountain Mining Area. (See Figure 1.) It lies in Section 2, T16S, R12E, of the Twin Buttes quadrangle.

Geographic Setting

The Pima Mining District lies upon the pediment of the north-east flank of the Sierrita Mountains.

The pediment slopes gently eastward from an elevation of about 4,500 feet at the base of the Sierrita Mountains to the Santa Cruz River Valley which is at an elevation of about 2,700 feet.

Some of the mines of the Pima District, as the San Xavier, Mineral Hill and Daisy, are located within outcropping Paleozoic and Mesozoic sediments; other mines, such as the Esperanza, mainly occur in igneous rock masses. The recently discovered Pima and Mission ore bodies are located in sedimentary rocks that are covered by the alluvium which extends upward from the Santa Cruz Valley and overlaps the pediment.

Drainage on the pediment surface forms a radial pattern with the Sierrita Mountains as the central high point. This drainage pattern is apparently controlled.
FIGURE I.
SKETCH LOCATION MAP OF THE
SAN XAVIER MINE
by both the gentle slope of the pediment and the direction of fracturing in the underlying bedrock. The drainage pattern in the San Xavier Mine area trends toward the Santa Cruz River Valley, with the runoff disappearing into the valley alluvium.

The mean annual temperature is approximately 70°F. Average rainfall is about 10 to 12 inches per year. Most of this precipitation occurs in the late summer months as torrential-type rains, which often flood the streams for short periods of time and cause rapid erosion of the outcrops. Weathering is mainly by mechanical processes, which result in large amounts of alluvium in the stream beds.

**Purpose of Study**

Bateman (1950, p. 90) compares pyrometasomatic ore bodies to "scattered plums in a plum pudding, they are difficult to find; they exhibit few 'signboards' pointing to their presence, and costly exploration and development are necessary to discover and outline them." In many such deposits the structure and associated ore controls have never been completely understood.

The purpose of this thesis is to outline and define the ore controls which localized ore within the San Xavier Mine.
Previous Work

The first published report on the East Sierrita Mining Area was by Ransome in 1922. Other published geologic reports include Wilson (1941 and 1950), Lacy (1959), Irvin (1959), MacKenzie (1959) and Cooper (1960). In addition to the above published works, there are several unpublished theses by University of Arizona students. These include Park (1929), Eckel (1930), Mayuga (1942), Whitcomb (1948), Houser (1949), Lutton (1958), Studebaker (1959), Thacpaw (1960) and Waller (1960).

Several mining geologists have been employed by the various owners of the San Xavier Property, and their maps, drill hole records and reports are on file in the office of the Banner Mining Company, Tucson, Arizona. These data form the basis of this study with modifications and inferences by the writer.

Method of Study

This study was begun in June, 1960 and was completed in the late fall of 1960.

Mine level maps were reduced or enlarged to the same scale, 1"=100'. Various surface maps were compiled, modified and enlarged to a common scale of 1"=100'. Drill hole data were generalized and plotted on these maps to aid the geologic interpretation. The use of
existing mine maps was necessitated because the author was unable to map underground in the main workings because of dangerous ground conditions. Cross-sections, based on the author's interpretation of the structure, were made from the 100-foot scale maps. A limited amount of thin section and polished section work was carried out on rock samples collected by the writer during underground examination.

As an aid to understanding the geology and ore controls of the mine, surface and level data were transferred from maps to 24-inch by 36-inch clear acetate sheets, .01-inch thick, and a mine model constructed. A framework to support the plastic sheets and replace the coordinate lines was constructed from .005-inch piano wire and 3/8-inch doweling. The doweling was attached to a wooden base and corner posts. The geology and mine workings were drawn on the acetate sheets using various colors of acetate-base ink. (See Plate 1.)

Problems Related to the Study

Several problems affect the interpretation and study of the data and are noted at this point.

A. Many company geologists have worked on the various mine level maps. As a result, these maps reflect the individual interpretations and nomenclature of each
Plate 1 - Model of the San Xavier Mine
geochemist. The same is true of the diamond drill hole data.

B. The drill cores taken from the San Xavier Mine have been subjected to weathering and destructive forces for several years.

C. The author was unable to verify the underground features mapped in the main mine workings because of the condition of the mine. One short underground survey was made to collect rock samples and take photographs. Fourteen days were spent underground in the upper two levels of the No. 6 Extension Development.

D. Hydrothermal alteration has disguised the original character of many of the rock types present in the area. This appears to be especially true of siliceous clastic rocks as quartzite and arkose.

The writer has often used fault contacts to explain many of the changes in rock types even though it is recognized that many sedimentary contacts are also present. It is often difficult to distinguish which type of contact was present.
DISTRICT GEOLOGICAL SETTING

Introduction

Rocks ranging in age from Precambrian to Recent are present in the East Sierrita Mining Area. The ore bodies usually are found in the Pennsylvanian-Permian limestones or occasionally in Cretaceous-Tertiary (?) igneous intrusives such as the andesite dikes and quartz monzonite stocks. Structural features are varied and complex; they appear to be the main ore control.

Many geologists have studied the East Sierrita Mining Area but there is little agreement among them as to the structural history and origin of the ore deposits. The following outline of the general geologic setting of the area is taken from various publications and modified for brevity. Its purpose is to acquaint the reader with the over-all features of the area and, thus, serve as a background for a discussion of the San Xavier Mine. (See Figure 2.)

Stratigraphy of the District

Most of the Paleozoic section of Southern Arizona is represented in the East Sierrita Area, but the thickness of the various units may differ, possibly as a result of bedding-plane faulting. Several authors have discussed
FIGURE 2. GENERAL GEOLOGIC MAP OF THE EAST SIERRITA AREA

LEGEND

Qal
ALLUVIUM

Helmet Fanglemerate & Breccias

Various Igneous Intrusives

Sedimentary & Volcanic Rocks, Undifferentiated

Limestones Undifferentiated

Sierrita Granite

Faults Contacts

Approximate Scale

Modified from Lacy (1959) & Cooper (1960)
and described the Paleozoic and younger units in the East Sierrita Mining Area (Mayuga, 1942; Bryant, 1955; and Cooper, 1960). The reader is referred to these publications for greater detail on the stratigraphy of the area. The general stratigraphic sequence of the East Sierrita Area is shown in Figure 3.

Igneous Intrusives of the Area

At least two ages of igneous activity appear to be present in the East Sierrita Area (Lacy, 1959 and Cooper, 1960).

Forming the core of the Sierrita Mountains and the basement rock of most of the mining areas is the Precambrian Sierrita granite (Lacy, 1959). It crops out along the western edge of the mining area and is believed to have been encountered in several drill holes extending through the Paleozoic and Cretaceous sections along the eastern edge of the district (San Xavier Hill, Mineral Hill, Mission Mine areas).

The Sierrita granite normally underlies the Bolsa quartzite, but in several places, as San Xavier Hill and Mineral Hill, later Paleozoic and Mesozoic sections are superimposed over it due to thrust faulting.

The second period of igneous activity is represented by diorite, andesite, granodiorite and quartz monzonite porphyry intrusives. The diorite appears to be the oldest followed by andesite dikes and plugs, granodiorite, and
FIGURE 3 - STRATIGRAPHIC COLUMN OF THE EAST SIERRITA MINING AREA

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<th>UNIT</th>
<th>APPROXIMATE THICKNESS IN FEET</th>
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<tr>
<td></td>
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<td>Helmet Peak (Bryant, 1955)</td>
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<td></td>
<td>(Irvin, 1959)</td>
<td>Twin Buttes (Lacy, 1959)</td>
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<td></td>
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<tr>
<td>Recent</td>
<td>Alluvium</td>
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</tr>
<tr>
<td>Tertiary</td>
<td>Helmet fanglomerate</td>
<td>10,500'</td>
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<tr>
<td></td>
<td>Igneous intrusives</td>
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<td>Cretaceous</td>
<td>Sediments &amp; volcanics</td>
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<td>Permian</td>
<td>N Rainvalley formation</td>
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<tr>
<td></td>
<td>a Concha limestone</td>
<td>471'</td>
</tr>
<tr>
<td></td>
<td>c Scherrer formation</td>
<td>346'</td>
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<td></td>
<td>o Epitaph dolomite</td>
<td>372'</td>
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<td></td>
<td>p Colina limestone</td>
<td>100'</td>
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<tr>
<td></td>
<td>Absent??</td>
<td></td>
</tr>
<tr>
<td>Pennsylvanian</td>
<td>G Earp formation</td>
<td>500'</td>
</tr>
<tr>
<td></td>
<td>H Horquilla limestone</td>
<td>550'</td>
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<tr>
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<td>Escabrosa limestone</td>
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<td>Sierrita granite</td>
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quartz monzonite porphyry in that order. Later, small andesite dikes were emplaced at scattered locations. The quartz monzonite porphyry is exposed in the southwestern part of the area and in scattered locations south of San Xavier Hill. It is also believed to have been found at depth in the Mission Deposit and at Mineral Hill in the Daisy Mine. The occurrence of the quartz monzonite porphyry near several of the ore deposits (Esperanza Mine, Mission area, Mineral Hill area) may suggest some relationship between the two.

**Structural Relationships of the East Sierrita Area**

Late Cretaceous and Tertiary deformation has formed the major structural features of the East Sierrita Mining District. There is little agreement among geologists on the type, amount, or extent of structural deformation except that it is very complex and, hence, incompletely worked out.

The principal structures in the area appear to be east-trending normal, left-lateral, and thrust faults accompanied by north-striking tears.

The first tectonic event that occurred in the East Sierrita area was probably intense folding of the Paleozoic and Cretaceous sediments along a general north-west axis, with the associated occurrence of bedding-plane faults. The bedding-plane faults account for much of the complexity of the area. Lacy (1959) has recognized 3
principal folds in the district; the Helmet Peak anticline, the San Xavier syncline and the McGee Road anticline.

Following the period of folding it appears that east-west trending normal faults occurred in Mineral Hill, San Xavier Hill and in the Paleozoic outcrops near Twin Buttes. At San Xavier Hill the fault contact of Cretaceous arkose and the Concha limestone was probably caused by normal faulting which later had some reverse movement.

Lacy (1959) recognizes at least two periods of thrust faulting as occurring in the East Sierrita area after folding and normal faulting. The first period involved the formation of east-west trending, southward dipping low-angle thrusts, which often were healed by later igneous intrusions or mineralization. The thrusting also caused reverse movement along the earlier formed normal faults plus the formation of north trending tear faults which offsets earlier structures. Most mineralization followed the first period of thrusting. Some parts of the district show evidence of left-lateral movement which occurred after the first period of thrusting.

Lacy's second period of thrusting is represented by the overthrusting of the San Xavier Thrust Plate onto the Precambrian Sierrita granite. During the overthrust
renewed movement occurred along the earlier structures. The size and extent of this second period of thrusting is unknown.

Cooper (1960) divides the tectonic activity of the East Sierrita area into 2 periods, also; one pre-ore and one post-ore. The structural events of the earlier periods are well disguised but show a general northwest trend. The formation of the Helmet fanglomerate due to landslides followed this earlier period of structural activity.

Cooper's second period of deformation has a general northeast trend and cuts the Helmet fanglomerate. This period is characterized by the formation of the San Xavier overthrust.

Cooper believes the foot of the thrust plate lies about 1½ miles north of Twin Buttes Village, while the north edge of the plate extends well beyond the Mission Mine. The plate includes some Precambrian granite, Paleozoic and Cretaceous sedimentary rocks, plus Cretaceous-Tertiary intrusive rocks, all of which were thrust over Precambrian granite. Direction of movement of the plate would be about N10°W to N30°W, with a very slight dip to the east. The thrust plate cuts the Helmet fanglomerate and is, hence, post-ore.

Using the above reasoning as a foundation, Cooper believes that the San Xavier Thrust Plate lay south of Twin Buttes, and has been thrust northward 6½ miles to
its present position. This would mean that the mines contained in the thrust plate (as Mission, Pima, Mineral Hill, San Xavier, etc.) had their roots in the area below Twin Buttes Village. Some evidence for this is shown by a general alignment of the Mineral Hill Mine with the area of the Minnie, King, and Queen Mines and the San Xavier Mine with the Senator Morgan and Contention Mines, plus other alignments. Other geologists who have studied the area do not believe the San Xavier Thrust was of such great magnitude.

**Economic Geology of the District**

Three general categories of ore bodies occur within the East Sierrita Mining District. Lacy (1959) has divided these into:

A. Small, shallow-seated, low-temperature fissure veins which are often localized along east-west fractures or the intersections of these fractures with north and north-east trending tension fractures. These veins may contain gold and silver plus minor lead, copper and zinc.

B. Contact metasomatic or pyrometasomatic ore bodies of various shapes and sizes. These ore bodies may be chimney-shaped, or flat-lying, depending on structures present. The majority of the ore bodies of the area are of this type. MacKenzie (1959) has recognized a zonal pattern of mineralization at Mineral Hill which extends outward from the contact or heat channelways.
The sequence is iron, copper, zinc, and lead, in that order. Often only one or two zones will be present in a mine. The contact of the intrusive with the limestone may or may not be observable.

C. Disseminated copper and molybdenum ores in intrusive and volcanic rocks, similar to the "porphyry copper" deposits.

**The San Xavier Mine in the District Geologic Setting**

The San Xavier Mine is an example of a pyrometasomatic deposit without a known igneous-limestone contact. It is located in Paleozoic and Cretaceous rocks that lie within the San Xavier thrust sheet.

The individual ore bodies of the San Xavier Mine are usually located at the intersections of northwest, north, and northeast trending shear zones with the major east-west trending normal faults. Hence, the San Xavier Mine is typical, in most respects, of the pyrometasomatic deposits of the East Sierrita Area. Lead and zinc are the major metal values sought with local occurrences of copper mineralization.
GENERAL GEOLOGY OF THE SAN XAVIER MINE

Introduction

The San Xavier Mine is located within one of the Paleozoic limestone hills in the northeastern part of the East Sierrita Mining Area. The main workings of the mine tend to follow the fault contact of the Permian Concha limestone and the Cretaceous arkose. Centers of metallization appear to have been determined by fault intersections, presence of the chemically inactive arkose, and ground preparation due to alteration of the calcareous sediments.

History and Production

Colonel C. P. Sykes purchased the San Xavier Mine in 1880 and organized the San Xavier Mining and Smelting Company. Prior to this, there had been only near-surface development work. Wilson (1950) notes that the San Xavier Mine and other prospects in the Sierrita Mountains were known to the early Spaniards and Jesuits of this area. From the period of 1882 to 1913, only intermittent work was done in the area.

In 1913, the Empire Zinc Company purchased the San Xavier Mine, and shipped silver-lead-zinc ore from it until 1918. Around 1913 the mine normally shipped 40
to 50 tons of zinc ore per day, plus some silver-lead-copper ore. About 40 men were employed. During this period, the 270' level of the mine was developed with some exposures of 7% copper ore.

From 1918 to 1943 the San Xavier Mine was inoperative.

In October, 1943, the Eagle-Picher Mining and Smelting Company took control of the San Xavier Mine and constructed a mill at Sahuarita, 9 miles east of the mine. By 1945 the mine was employing about 90 men. The San Xavier Mine continued operations during the period from 1943 to 1952 producing lead and zinc ore.

In 1952 the Eagle-Picher Company closed the mine due to a decline in the price of lead and zinc. At that time approximately 315 men were employed in the mining and milling operations.

Soon after the mine closed, the McFarland-Hullinger Company leased and re-opened the mine. In 1957 McFarland-Hullinger purchased the mine, which was then employing about 35 men.

The Banner Mining Company purchased the San Xavier Mine in November, 1959; at present, the mine is inactive.

The statistics given in Figure 4 on the following page indicate the mine's production.
FIGURE 4 - PRODUCTION OF THE SAN XAVIER MINE - from U. S. Bureau of Mines (1897 - 1958)

YEARS

1897 - 1918 --- approximately 3,000 tons of lead, 6,000 tons of zinc and $200,000 worth of silver recovered.

1918 - 1942 --- general inactivity of the mine.

<table>
<thead>
<tr>
<th>YEAR</th>
<th>TOTAL TONNAGE</th>
<th>AVERAGE GRADE OF ORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1943</td>
<td>16,635 tons</td>
<td>3.1 oz. Ag; .50% Cu; 4.9% Pb; 11.0% Zn.</td>
</tr>
<tr>
<td>1944</td>
<td>53,562 tons</td>
<td>3.5 oz. Ag; .75% Cu; 6.2% Pb; 12.9% Zn.</td>
</tr>
<tr>
<td>1945</td>
<td>40,272 tons</td>
<td>3.8 oz. Ag; .83% Cu; 6.0% Pb; 12.0% Zn.</td>
</tr>
<tr>
<td>1946</td>
<td>46,108 tons</td>
<td>3.2 oz. Ag; .76% Cu; 6.0% Pb; 10.8% Zn.</td>
</tr>
<tr>
<td>1947</td>
<td>58,658 tons</td>
<td>2.7 oz. Ag; .50% Cu; 5.9% Pb; 10.2% Zn.</td>
</tr>
<tr>
<td>1948</td>
<td>72,314 tons</td>
<td>2.4 oz. Ag; .48% Cu; 6.0% Pb; 10.3% Zn.</td>
</tr>
<tr>
<td>1949</td>
<td>82,661 tons</td>
<td>Unknown</td>
</tr>
<tr>
<td>1950</td>
<td>67,456 tons</td>
<td>Unknown</td>
</tr>
<tr>
<td>1951</td>
<td>71,182 tons</td>
<td>Unknown</td>
</tr>
<tr>
<td>1952</td>
<td>42,232 tons</td>
<td>Unknown</td>
</tr>
<tr>
<td>1953 - 1954</td>
<td>Inactive</td>
<td></td>
</tr>
<tr>
<td>1955</td>
<td>about 1,015 tons lead recovered.</td>
<td></td>
</tr>
<tr>
<td>1956</td>
<td>Unknown</td>
<td></td>
</tr>
<tr>
<td>1957</td>
<td>about 750 tons lead and 1,288 tons zinc recovered.</td>
<td></td>
</tr>
<tr>
<td>1958</td>
<td>about 1,400 tons lead and 5,690 tons zinc recovered.</td>
<td></td>
</tr>
<tr>
<td>1959</td>
<td>Unknown</td>
<td></td>
</tr>
</tbody>
</table>

Total tonnage - In excess of 715,540 tons of ore mined. (Where total metal recovery was given, an ore grade average of 6% lead and 11% zinc was used to calculate tonnage.)
Stratigraphy

Late Paleozoic, Cretaceous (?) and Recent sedimentary and volcanic rocks outcrop in the vicinity of the San Xavier Mine and its western extension, Number Six Shaft (Irvin, 1959). The nomenclature of the Late Paleozoic units is uncertain.

Stratigraphic units on unpublished surface maps by Schmitt and Lacy supplemented by a comparison of rock types with the known Paleozoic section at Mineral Hill indicate the following stratigraphic column in the San Xavier area.

<table>
<thead>
<tr>
<th>Age</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tertiary</td>
<td>Recent Alluvium</td>
</tr>
<tr>
<td>Cretaceous (?)</td>
<td>&quot;Arkose&quot; (sedimentary-volcanic sequence)</td>
</tr>
<tr>
<td></td>
<td>Concha limestone</td>
</tr>
<tr>
<td>Permian</td>
<td>Scherrer formation</td>
</tr>
<tr>
<td></td>
<td>Epitaph dolomite (and gypsum)</td>
</tr>
<tr>
<td>Pennsylvanian</td>
<td>Earp formation</td>
</tr>
<tr>
<td></td>
<td>Horquilla limestone</td>
</tr>
<tr>
<td>Mississippian</td>
<td>Escabrosa limestone</td>
</tr>
</tbody>
</table>

The thickness of the units at San Xavier can not be determined because of intense faulting and folding.

Underground mapping done in the past was based upon rock type alteration; hence, there is some question as to what units are present on the various mine levels. It appears that most of the mine workings are confined
within the Concha limestone unit. The south end of the developments usually terminates against a siliceous unit which is probably the Cretaceous arkose. Development to the north has often encountered a "dense siliceous" unit which may be the upper quartzite member of the Scherrer formation.

**Escabrosa Limestone**

Outcropping north of Number Six Shaft in the northwest quadrant of the mapped area is a white to pinkish-brown limestone unit which Mayuga (1942) identified as Escabrosa limestone. This unit has been intensely marbelized giving a coarsely-crystalline, vitreous appearance. The extent of recrystallization present is variable with location.

In the mine workings of Number Six Shaft a similar light-colored, coarsely crystalline limestone occurs in fault contact below an unidentified Pennsylvanian or Permian limestone unit, which may well be altered Concha limestone. Wilson (1950) recognized the light-colored unit as being Escabrosa. This fault contact strikes approximately east-west and dips 45° to 80° south. The Escabrosa limestone is not found underground in the main mine workings.

No mineralization or alteration except the marbleization has been found in the Escabrosa limestone of the
East Sierrita Area. This lack of mineralization may be due to the pure composition of the Escabrosa in the area. Little iron, silica, or magnesium was available in the original limestone to be converted to alteration silicates during metamorphism.

Naco Group

Gilluly, Cooper, and Williams (1954) defined the Naco Group as including all the Pennsylvanian and Permian units in southeastern Arizona. However, not all of these upper Paleozoic units are represented in the San Xavier Area. Bryant (1955) has suggested that the Earp, Colina and Epitaph formations of the Naco Group be referred to as the Andrada formation in the central and western parts of the state.

Horquilla Limestone and Earp Formation

Early geologists in the East Sierrita Area often mapped the Horquilla limestone and the Earp formation as one unit, the Naco formation. The contact between the two units appears to be gradational and the lithology similar. Commonly, if the amount of silt and shale beds present in the limestone is less than 50%, that part of the unit is called Horquilla limestone; but if the shale or fine clastic content is over 50% it is called Earp. The term Andrada formation is often used locally where the Earp, Colina and Epitaph formations are indistinguish-
Mayuga (1942) recognized surface outcrops of the "Naco formation" occurring in the west-central portion of the mapped area. Here the unit is a very fine to medium crystalline, greenish-gray limestone-siltstone complex which weathers to a greenish-brown, rough surface. It appears this unit is in structural contact with the Escabrosa limestone.

Because of alteration it is uncertain if either the Horquilla or Earp formations occur underground in the mine workings. In the Extension workings, some of the highly altered and bleached limestone may be Horquilla-Earp, having been faulted in with the Escabrosa. Likewise, in some of the west-central workings of the 340' and 660' levels, near coordinates 100,000 and 100,200N and 99,500 to 99,700E, it is possible that the "dense siliceous" indicated is really altered Horquilla-Earp. Examination of this area was not possible.

The siltstone content may furnish silica, iron and magnesium to be incorporated with calcium to form the silicates such as tremolite, wollastonite, hedenbergite, garnetite, pyroxenes and similar minerals during metamorphism.

The Pennsylvanian-Permian boundary is usually placed within the Earp formation.

The Horquilla and Earp formations may be favorable
units for ore localization in some areas in Southern Arizona (Wilson, 1950); however, no ore is known to have occurred in these rock units in the mine area.

**Epitaph Dolomite**

Outcropping in the southwestern and central parts of the mapped area are exposures of dolomite which is probably the Epitaph dolomite. It is a purplish-gray to white, fine to medium crystalline, calcareous rock which usually weathers to a buff color. In places it appears slightly recrystallized. On San Xavier Hill, the general strike of the bedding is about N65°W with a dip of 50° to 60° south. It is in both stratigraphic and fault contact with the surrounding units.

Occurring near the top of the Epitaph formation is a sandy, gypsiferous unit, referred to locally as the Andrada gypsum. It appears that this unit outcrops in the upper central portion of the map.

Underground occurrences of the Epitaph are uncertain, but it is believed that some of the unaltered and unmineralized limestones in the northern parts of the levels may be Epitaph dolomite. On the 820' and 900' levels the gypsum indicates the presence of the Epitaph.

**Scherrer Formation**

Mayuga (1942) recognized a limestone unit lying
between two quartzite units in the San Xavier area. These three units probably represent the Scherrer formation. This formation consists of three members: a lower, light gray, fine to medium-crystalline quartzite; a middle, gray, sandy limestone; and, an upper, gray, medium-crystalline quartzite. All weather to a brownish-gray.

The Scherrer formation outcrops in a bow-shaped pattern along the middle portions of the map, generally following the outlines of the arkose and Concha limestone outcrops.

Recognition of the Scherrer underground is made extremely difficult because of silica alteration present. The quartzite and alteration silica have been mapped underground as one group, the "dense siliceous." However, much of the dense siliceous material which lies north of the Concha limestone underground must be the upper quartzite member of the Scherrer.

Usually it is considered that the quartzite members of the Scherrer formation are unfavorable as a site for mineral deposition, although, locally, some small areas may show slight traces of mineralization. The quartzite members may be a source for much of the siliceous alteration present. The area of altered limestone and slight mineralization occurring just north of Number 7 Shaft on the 420', 500', 580' and 660' levels may represent the middle limestone unit of the Scherrer formation. Dense
siliceous rock occurs in front of this altered limestone, and one long diamond drill hole on the 580' level shows quartzite lying in back of the limestone.

**Concha Limestone**

Exposed throughout the middle portions of the mapped area adjacent to the Cretaceous arkose is a dark gray to black, fine to medium-crystalline limestone which contains an abundance of calcite stringers and some chert. It is often intensely altered to silicate minerals. Mayuga (1942) mapped this unit as a middle part of the Manzano group which would be the equivalent unit of Bryant's Epitaph dolomite. The maps by Schmitt (1932) and Lacy (1956) show this formation to be higher up in the Permian section and, hence, probably Concha limestone. Its stratigraphic location and contact with the upper quartzite of the Scherrer formation, plus a comparison with the Concha of the Mineral Hill section, tends to verify the conclusion that it is Concha limestone.

Around the mine site the bedding strikes about N75°W to N85°W and dips 40° to 60° south. The eastern portion of the Concha maintains this general east-west trend, but in the western area the bedding tends to strike N45°W. Bedding-plane faults have distorted the thickness of the unit; it is estimated to exceed 285' in the center of the mine workings.

Most of the mine workings and ore bodies lie with-
in the Concha limestone.

**Cretaceous (?) Arkose**

Extending along the southern portion of the San Xavier area is a sedimentary-volcanic unit called the Cretaceous arkose (Mayuga, 1942; Lacy, 1959; Cooper, 1960). The fault contact of the arkose with the Concha limestone is often covered with alluvium, as is most of the arkose itself. Mine workings usually end upon entering the arkose which is non-mineralized. Cooper (1960) lists the sedimentary unit as including arkose, sandstone, quartzite, shale, conglomerate, graywacke, and a few thin beds of limestone. The volcanic sequence includes andesite and rhyolite.

The part of the Cretaceous unit which lies adjacent to the mine workings is mostly arkose. The arkose here is fine-grained, gray, clastic rock which usually weathers to a brownish color on the surface. Some alteration to silicate minerals may be present along the contact with the Concha limestone. The feldspars of the arkose are usually decomposed; the quartz grains are subangular to round.

**Recent Alluvium**

Alluvium composed of materials from older formations occurs in most of the valleys and stream beds of the area.
Igneous Rocks

No igneous rocks are exposed in the mine workings at San Xavier; one diamond drill hole and two churn drill holes have encountered igneous rock at depths exceeding 1,085 feet. In all cases the holes were caving badly and recovery was poor. The recovered samples were logged as medium-grained granite, containing quartz, light-colored feldspars, and a rather small percentage of mafic mineral.

The igneous rock encountered could be the parent of the hydrothermal solutions (usually considered the quartz monzonite porphyry in the East Sierrita area), or the rock could be the Sierrita granite on which the Permian and Cretaceous sequence has been overthrust.

Structure

Orogenic events which occurred at the end of the Cretaceous and the beginning of the Tertiary periods have formed the structural features of the East Sierrita Area. Folding and normal faulting of the older formations appears to have been followed by a great overthrusting of these units over the Precambrian Sierrita granite (Mayuga, 1942; Lacy, 1959; Cooper, 1960). Offsetting of former structures, renewed movement along former faults, and slip-strike faulting seem to have occurred simultaneously with and after the overthrusting. The San Xavier Mine
was subject to and affected by most of the tectonic activity of the area. Evidence of movement is often concealed, however, by the alteration and healing of the fault planes.

Folding

The earliest structural event which affected the Paleozoic sediments of San Xavier Hill appears to have been folding along a west-northwest trending axis. The strike of the bedding planes in the area of the San Xavier Mine generally averages between N60°W and N70°W, with a dip of about 45° to 60° southwest. The general appearance of the surface outcrops shows the Cretaceous and younger Permian units on the outer fringes of the main outcrops, with older Permian, Pennsylvanian and Mississippian units in the more central parts.

Park (1929) believed the San Xavier Mine workings to be located on the tilted limb of a monocline. Lacy (1959) noted an anticlinal form to the outcrops of San Xavier Hill. The strike of the bedding in the sediments and the stratigraphic location of various units substantiates the anticlinal hypotheses. It appears that the mine workings are located on the south limb of a steep anticline whose axis trends about N65°W. This anticline may have a slight plunge to the southeast because the older units are exposed more in the northwest parts of
Accompanying the period of folding must have been numerous bedding plane faults, although they are extremely difficult to find. In tracing the movements of later faulting, through the various levels of the mine, several instances of changes in the dip of the faults to conform to the general dip of the bedding were noted. Bedding plane faults may be the reason for the thinning of the Concha limestone around the 580' to 820' levels.

Normal Faulting

Generally, east-west trending normal faulting seems to have occurred toward the close of the period of folding (Lacy, 1959). This is to be expected when the compressional forces are released and the folded strata adjusted.

The contact of the Cretaceous arkose with the Concha limestone is the result of normal faulting, although the fault contact is seldom traceable on the surface due to alluvial cover (See Plate 2). Underground, however, the fault contact shows a strike of approximately N80°E to N90°E, and a dip of about 55° to 80° south. Later reverse movement and the effects of earlier-formed bedding plane faults would account for the variation in dip. Following the period of normal faulting, northwest, north, and northeast trending high-angle off-sets to the
Plate 2 - Cretaceous arkose - Concha limestone contact
(Pencil on fault, arkose left, limestone right.)
Location: 150' level, No. 6 Shaft Development, Coordinates 99,260 N, 98,510 E.
normal faults formed.

North of the mine site the contact of the Scherrer formation and the Concha limestone may be the result of normal faulting. The underground level maps show a distinct east-west trend of faulting with similar dips, but tracing these faults throughout the mine is very difficult because of offsetting and later renewed movement along the normal faults.

The few steep, north-dipping normal faults which occur in scattered locations on the level maps were probably formed during the thrusting by a release of compression in certain areas of the thrusting.

The intersections of normal faults with the offsets has been very important in forming brecciated centers that were susceptible to alteration and sulfide mineralization by upward moving hydrothermal fluids.

Offset Faulting and Thrusts

At least two periods of low-angle, east-west trending thrust faulting have occurred in the East Sierrita Area (Lacy, 1959). The first period of thrust faulting was pre-ore as shown by the number of associations of the intersection of low angle thrusts with normal faults and offsets and the formation of ore bodies.

In the south end of the 100' and 150' levels of the Number Six Shaft Development, several low-angle thrusts
occur. The strike of these faults varies between $N75^\circ W$ to $N80^\circ E$, dip averages about $15^\circ$ to $24^\circ S$. Very few of these low-angle thrusts were mapped in the main workings of the San Xavier Mine but their occurrence seems necessary to explain the horizontal offsets of the arkose-Concha contact as shown in cross-section. Alteration and mineralization have concealed many of these low-angle faults. (See Plate 3 and 4.)

Probably associated with the thrusting are the numerous northwest, north, and northeast trending tear faults which are found offsetting the normal faults. It is believed that during periods of intense thrusting of brittle or flexible materials as limestone and quartzite, many small tears would occur in the rocks due to small differences in forces and the angle at which they were applied. These offsets occur on every level. The strike usually varies between $N45^\circ W$ to $N45^\circ E$. The dip may be either east or west and is usually at a steep angle (over $55^\circ$). In the main workings of the San Xavier Mine, where mapping is most complete, (coordinates $100,000N$ to $100,200N$; $100,000E$ to $100,600E$), three distinguishable north-trending offsets of the arkose-Concha contact occur. The magnitude of these offsets is usually less than 150 feet but seem to increase with depth. The intersections of the offsets with the normal faults and the low-angle thrusts are important in forming brecciated
Plate 3 - Low angle thrust intersection with an earlier formed normal fault. Location: 100' level, No. 6 Shaft Development, coordinates 99,320 N, 98,440 E. Looking west.
Plate 4 - East-west trending south dipping low angle thrust. Location: 150' level, No. 6 Shaft Development, coordinates 99,280 N, 98,500 E. Looking south.
centers which were susceptible to alteration and mineralization.

The period of mineralization of the San Xavier Mine seems to have occurred after the end of the first period of thrusting. No intrusive igneous contact has been found which could have been a source for the mineralizing solutions.

Three drill holes near San Xavier encountered a possible fault zone and then a granitic-type rock at a depth of 1,000 to 1,075 feet. Cooper (1960) states that San Xavier Hill is located within the San Xavier Thrust Plate. The drill hole data are the only evidence present to indicate the second period of overthrusting. However, it is not known if both periods of thrusting occurred continuously or at different times.

Later Movement

During and after the periods of thrusting, renewed movement along some of the older structures seems to have occurred. Earlier formed normal faults probably had reverse and strike-slip movement. On several of the level maps these normal faults appear to cut across some of the later-formed north-trending offsets. This would indicate the normal faults were subject to strike-slip movement during some later time. In one instance on the 420' level, a small ore body was found to have been cut
off by an east-striking fault.

Summary of Structural Events

The following sequence of structural deformation in the San Xavier Mine is suggested:

1. Folding of Paleozoic and Mesozoic sediments along a northwest axis forming an anticlinal structure. Development of bedding-plane faults during folding.

2. East-west trending normal faults develop when the compressional forces which caused the folding are released.

3. Low-angle thrusts begin which strike east-west and dip at very shallow angles to the south. The thrusting is accompanied by the formation of north-south trending tear faults which offset earlier structures.

4. Onset of mineralization which alters the limestone breccia formed at fault intersections and followed by deposition of sulfide minerals.

5. Probable overthrust of the San Xavier Thrust Plate onto the Precambrian Sierrita granite, accompanied by renewed movement along former fault planes.

Mineralogy

The mineralogy of the San Xavier Mine is similar to that of most pyrometasomatic deposits. A difference is that the San Xavier is a lead-zinc mine whereas in many pyrometasomatic deposits copper is the primary ore
Sulfide minerals present in the mine include galena, sphalerite, chalcopyrite, molybdenite, pyrite, and bornite. Non-sulfide metal minerals present include malachite, azurite, chrysocolla, magnetite, hematite, limonite, aurichalcite, chalcanthite, jarosite, siderite, and pyrolusite. Park (1929) and Mayuga (1942) observed some lead and zinc carbonates and sulfates present in the oxidation zone which may extend down to a depth of over 400 feet.

Gangue minerals include calcite, gypsum, garnet (probably andradite), chlorite, epidote, hedenbergite, hornblende, kaolin, quartz, and tremolite. Most of these gangue minerals occur in the altered limestone and were formed by the reaction of hydrothermal fluids and the impure Concha limestone.

Ore Controls

Ore Body Locations and Shapes

The majority of the ore bodies in the San Xavier Mine were located in the area bounded by the coordinates 99,700N to 100,300N and 99,700E to 100,800E. These ore bodies have been mined out but the size and shape of the stopes gives a good representation of the general features of the original ore bodies. Few of the stoped areas above the 340' level were mapped; hence, their
shape and location are unknown to the author. (See Plate 5.)

The area containing the ore bodies can be roughly divided into four ore zones, with each zone having the general outline of an inverted cone; i.e., the apex of the cone at the lower levels of the mine, and the wider portions of the cone extending upward toward the middle parts of the mine. Each ore zone is composed of several individual chimney or cylindrical-shaped ore bodies which are arranged to give the overall inverted cone appearance.

The size of the individual ore bodies varies with depth. The ore bodies between the 700' and 900' levels were seldom over 50' in diameter. Those bodies above the 740' level often exceeded 200' in diameter. The height of the individual ore bodies can not easily be determined because one usually extends into another. The isolated pod or tabular shaped ore bodies are usually under 50' in height and 100' in diameter.

The angle of inclination of the chimney-shaped ore bodies appears to have been controlled by the adjacent Concha-arkose contact. The angle of the dip of this contact is between 55° and 80° south. Since the ore zones are composed of the individual ore bodies, the inclination of the axis of these zones is approximately the same as that of the ore bodies. The direction
Plate 5 - Stope on 420' Level.
Coordinates 100,060 N, 100,490 E, looking to the West.
Stope outline shows approximate shape of the former ore body. Base of stope is about 20 feet wide. Ore body was inclined upward to the north. Square-set stoping was necessitated because of heavy ground conditions.
of inclination of the axis of the ore zones is about north-south to N15°W.

The effect of low angle thrusts upon the shape of the ore bodies is shown in the cross-sections. Wherever a low-angle fault intersects the arkose-Concha contact, the ore body tends to flatten out so as to conform with the angle of the thrust.

Structural Control of Ore Bodies

The shape of the stopped areas which represent the general outline of the ore bodies indicates that structural features were the dominant ore control in the San Xavier Mine. Bedding-plane faults, alteration, and possible post-silicate, pre-ore movement have hidden or disguised these structural features, making the task of mapping and determining the structural contacts most difficult.

In general, three fault systems appear to have controlled the areas of ore localization. These are the east-west normal fault system, the north-south offset system, and the east-west striking low-angle thrust system. The level maps and cross-sections show that the majority of the ore bodies lie adjacent to the arkose-Concha contact which strikes approximately N80°E to N90°E, and dips 55° to 80° south. Similar normal faulting occurs throughout the Concha.

Usually lying within or adjacent to the ore bodies is a north-south trending tear fault which has offset the
arkose-Concha contact. These tear faults strike between N40°W and N30°E. Apparently, the tear faults are often concealed due to alteration; their location is indicated primarily by the offsets of the arkose-Concha contact and by their mapped occurrences on some levels. The stoped-out areas on the 340', 420', 500' and 580' levels best illustrate this structural control. The third direction of faulting that appears to control ore localization is the east-west striking, southward dipping, low-angle thrusts. Few of these thrusts were mapped within the mine workings, but their presence is shown in the south drifts of the Number Six Shaft Development and are also indicated in cross-section by the vertical offsets of the arkose-Concha contact. Coincident intersection of these three faults would result in the formation of a chimney-shaped area of brecciated limestone. This brecciated area affords greater permeability and surface area to rising hydrothermal fluids.

The offsets of the arkose-Concha contact have resulted in the formation of inclined, inverted troughs composed of a dense arkose or siltstone cover containing brecciated limestone inside. These troughs usually overlie the adjacent ore body and were important to its formation.

No mineralization occurs in the Cretaceous arkose. The reason may be that the arkose was not reactive with
the rising fluids nor as permeable as the limestone.
It appears that the arkose troughs deflected the rising
hydrothermal fluids and forced their concentration in
the adjacent brecciated limestone.

In areas where the low-angle faults have over­
thrust the arkose, ore bodies tend to form immediately
under the overhanging arkose and, also, a second ore
body may form a hundred feet or so north of the first
ore body. This is well illustrated between the 420' and
500' levels in cross-section along the 100,000E coordi­
nate. The reason for the formation of the northern ore
body could be due to the overthrust arkose blocking the
inverted trough of arkose and forcing the rising fluids
to move out and around the obstacle.

Stratigraphic Controls

The Concha limestone is the preferred formation
for ore localization in the San Xavier Mine. This
preference for ore deposition was aided by the occurrence
of fault intersections forming brecciated centers within
the unit.

Occurrences of Epitaph dolomite and gypsum under­
ground are uncertain. Some of the northern exposures
of limestone and gypsum in the 820' and 900' levels are
probably Epitaph. These exposures are unaltered and un­
mineralized. The degree of fracturing may not have been
as extensive in the Epitaph as it was in the Concha.

The quartzite members of the Scherrer formation do not appear to have been susceptible to the formation of alteration silicates or mineralization. In the central levels of the mine, an altered and slightly mineralized limestone occurs in back of a dense siliceous unit, north of Number 7 Shaft. This unit may be the middle limestone member of the Scherrer formation. The dense siliceous units which lie to the north and south of this limestone would represent the upper and lower quartzite members. The dense siliceous material may have allowed concentration of the mineralizing fluids and hence, deposition of ore within the central limestone.

The overlying Cretaceous arkose formation is not a favorable unit for alteration or ore localization. This may be due to its high, unreactive silica content and to a decrease in permeability, relative to the limestone. The "arkose" is really a sedimentary-volcanic sequence containing much arkose and siltstone. Because of this varied composition, it is believed to be a less permeable unit than the Concha limestone. The arkose is stratigraphically important to ore deposition because it can act as a barrier to rising hydrothermal solutions and thereby cause an increase in concentration and time of reaction in the adjacent limestone.
The Concha limestone, especially the brecciated parts, affords a permeable and reactive host rock to the hydrothermal fluids entering along the fracture channelways. The bedding of the limestone usually parallels the east-west direction of faulting. This combination of parallel bedding and faults increases permeability to upward rising hydrothermal fluids. The breccia exposes many surfaces to replacement activity; the chert and calcite stringers may increase the limestone's reactive activity with the fluids. The overlying arkose concentrates the fluids in this favorable environment to allow ore deposition.

Alteration

Map study indicates that the areas which have been mineralized and contain ore were usually the areas which underwent the most intensive alteration. These mineralized areas often contain a high percentage of garnet or hedenbergite as the alteration silicates. Thus, a general prerequisite for the formation of ore would be ground preparation by fracturing and brecciation, followed by intense alteration with the formation of garnetite and/or hedenbergite. The most favorable areas for alteration are located adjacent to the arkose contact.
The underground rock unit mapped as dense siliceous presents a problem in the interpretation of the alteration aureoles. This unit could be quartzite or a silicified limestone. Probably it is both. The irregular outline of the dense siliceous unit in cross-section would tend to indicate that during the processes of alteration, some of the silica in the Scherrer quartzite member was mobilized and transferred into the adjacent Concha limestone. The silica in the ore fluid probably formed some of the dense siliceous materials also. Schmitt (1948) states that much of the silica present in pyrometasomatic deposits may have come from the alteration of aluminous rocks below the visible zone and not from the magma itself.

An irregular halo of alteration surrounds the ore bodies and would be useful as a guide to ore. Cross-sections show that a thin shell of altered limestone and then the Cretaceous arkose usually lies south of the ore body. To the north of the ore body is usually the same thin shell of altered limestone and then an outer layer of dense siliceous containing unaltered limestone pods. Beyond the dense siliceous lies altered and unaltered limestone.

Thin sections of a few selected samples of intensely altered limestone contained the common alteration silicates andradite and grossularite garnet, diopside,
tremolite, limonite, hydromica, clays, chlorite, epidote and sericite. Andradite garnet often comprised over 50% of the rock. The ore formed later than most of the alteration products as shown by the metallic minerals replacing silicates, especially the andradite garnet. A small amount of quartz was formed interstitially to the ore and garnet contacts, probably the result of excess silica remaining after ore deposition.

Gossan Cappings

Three large, and several small gossan cappings occur in the Concha limestone outcrops around the San Xavier Mine area. Two of the larger cappings lie above the main mine workings and seem to be surface expressions of parts of the two eastern ore zones. The lower of these two gossans is located around the intersection of an east-west normal fault and an offsetting northwest tear. The third large gossan is located near the alluvium-Concha limestone contact in the eastern position of the area. It appears to be associated with east-west normal faulting and north-east offsets. Its association with ore is unknown.

Most of the gossans are composed of an abundance of limonite, hematite, and clay in a framework of calcite and silica. Isolated cellular boxworks of galena and pyrite were found along with the cellular sponge struc-
ture of sphalerite. Pyrite is not found in any great quantity in the mine workings although some small areas were noted on level maps in the eastern parts of the workings near the ore zone. It is believed that these gossan cappings represent the oxidized pyritic zones occurring in the ore zones. Gossan capping can not be used by itself in the San Xavier Mine area to determine the presence of ore, but may serve as an indicator for areas deserving further exploration.

Paragenesis

Polished section study of ore specimens from the mine were inconclusive as to the paragenetic sequence of ore deposition because of the limited number of samples which could be obtained. The few sections studied indicate two periods of sphalerite deposition. The suggested paragenetic sequence is gangue, pyrite, sphalerite and chalcopyrite (1st stage), galena, and sphalerite (2nd stage). Some blebs of chalcopyrite in sphalerite were found indicating probable exsolution of the two minerals and, therefore, simultaneous deposition.

Summary of Ore Controls

The following appear to be the dominant ore controls in the San Xavier Mine:

1. Chimney-shaped brecciated centers of altered
limestone formed at the intersection of east-west normal faults and the north-south offsets and the south-dipping low-angle thrusts. These brecciated centers formed channelways for the rising ore fluids.

2. Presence of the overlying Cretaceous arkose formed an inverted, trough-shaped, dense, reflecting surface which forced the solutions to remain in the more permeable limestone.

3. The Concha limestone provides a permeable and reactive unit for silicate alteration and ore deposition. This unit is made especially favorable because of its stratigraphic location below the arkose and the presence of many fault intersections and brecciated centers within the limestone.

4. Altered limestone areas which contain mostly garnetite and hedenbergite are most favorable for ore deposition.

5. Less favorable, but still important, are altered limestone areas which lie adjacent to the less permeable and unreactive dense siliceous rock.

**Origin of the San Xavier Mineralization**

The problem of satisfactorily explaining the origin of the San Xavier mineralization is complicated by two factors; the absence of a known igneous intrusive from which the hydrothermal fluids could have originated,
and the magnitude and time of thrust faulting which has occurred in the area. The San Xavier orebody is classified as a pyrometasomatic deposit because of such characteristic features as alteration silicates, ore body distribution, ore body shapes, presence of a reactive limestone, ore textures, and structures. The presence of a parent igneous intrusive as a source of the fluids is a requirement for a pyrometasomatic deposit, although its location may not be obvious.

Late Cretaceous-Tertiary intrusives, ranging in composition from diorites and andesites through quartz monzonites, syenites and to rhyolites are present in the East Sierrita Mining Area (Mayuga, 1942; Lacy, 1959; Cooper, 1960). MacKenzie (1959) noted intrusive igneous bodies in the Mineral Hill mines just north of San Xavier Hill. Journeay (1959) found similar intrusives in the Pima Mine. In contrast, Cooper (1960) states that the ore deposits which are found in the San Xavier Thrust Plate (San Xavier Mine and others) all had their roots, before thrusting, below Twin Buttes Village, 6½ miles to the south of their present location. He believes the quartz monzonite intrusive found there to be the source of the hydrothermal fluids which formed the deposits.

The ore bodies of the San Xavier Mine have nearly bottomed at a depth of 900 feet. Two drill holes indicate
the probable presence of Sierrita granite at a depth of about 1100 feet, with altered and unaltered limestone occurring between the 900' level and the granite. No data has been found to prove the presence of the source intrusive at depth below the mine.

Andesite dikes are present in the Cretaceous section to the south of San Xavier Hill. Schmitt (1948) has suggested that possibly volcanic emanations are the source of the hydrothermal fluids which form pyrometasomatic ore deposits. Schmitt's hypothesis of volcanic emanations could explain the ore localization at San Xavier, although the andesite dikes in the arkose show no lead or zinc mineralization.

There is not enough evidence present in the San Xavier Mine to determine whether mineralization occurred before, simultaneous with, or after the emplacement of the San Xavier Thrust Plate. If thrusting occurred after mineralization the igneous intrusive which gave off the fluids that formed the ore bodies would be located to the south of the present mine location. If thrusting occurred before or simultaneous with ore formation, the intrusive body may lie at depth somewhere in the vicinity of the present mine site, possibly to the east. The sparse occurrence of copper in the mine may be due to
fracturing, occurring at the time the ore fluid was richer in lead and zinc.
POTENTIAL OF THE SAN XAVIER MINE AREA

Level maps indicate that ore has bottomed at depth in the main parts of the San Xavier Mine. Several explanations are possible for this decrease in mineralization. The main channelways that carried the hydrothermal solutions may have been by-passed by the workings. Also, one particular zone of the Concha limestone may have been the most favorable for ore localization, and this zone may have been terminated. Another reason may be that the bedding planes in the Concha limestone have changed direction and, hence, the Concha became less permeable. Little ore remains within the area of extensive workings. On the basis of ore controls discussed previously, there appear to be several promising areas for future exploration to the east and west of the main site.

A large gossan capping is located on the east side of the San Xavier Hill, near coordinates 100,600N and 102,750E. Some sphalerite with cellular sponge boxwork were noted in this capping; in general, it is similar to the gossan capping which lies above the two eastern ore zones of the main mine. It is believed that arkose underlies the alluvium to the east of the gossan; a fault contact of the Concha-arkose should occur near the present
boundary of the alluvium. Several faults appear to intersect this contact. Hence, fault intersections, brecciation, and presence of the overlying arkose seem to control the position of this capping. Two diamond drill holes (coordinates 100,195N, 102,563E and 100,108N, 102,652E) were drilled to test for ore at depth, but little mineralization was found. It is the opinion of the writer that this ore body is inclined slightly in a northeast direction, following the arkose contact and could not have been found by the two drill holes to the south.

Near coordinates 100,090N, 102,980E, a structurally favorable area for ore localization occurs. A north-trending tear fault has offset the Concha-arkose contact, forming an inverted trough-shaped channelway. The proposed ore body should trend approximately north-south and be inclined about 55° to the south.

A third area of possible mineralization may occur under the alluvial cover, approximately 400 feet east of coordinates 100,000N, 103,500E. In this area it appears the Cretaceous arkose has been offset to the north, although no surface evidence of this is available. This ore body should trend slightly to the southeast.

More surface geology should be done before drilling sites are chosen.
At coordinates 100,100N, 101,500E, a north trending offset to the Concha-arkose contact occurs. This area was penetrated by a drift in the arkose on the 660' level, but no ore was found. Diamond drill hole results indicate that altered limestone lies to the north of the drift. Further underground drilling may prove ore to lie in the area of the altered limestone; the structural features and arkose contact show a favorable situation.

Copper, lead, and zinc ore may lie at depth below the 250' level of the Number 6 Shaft Development. Some ore has been produced from the upper levels. The controlling structural features and a large exposure of garnetite are exposed on the surface. The possible ore zone would seem to trend southeastward, as the garnetite exposure does, with a dip of approximately 50° to 55° southeast. The eastward fringes of this ore zone seem to have been encountered in the most western parts of the 340' and 660' levels, coordinates 98,750N, 98,850E. The grade of ore may be low; mineralization was encountered in these western drifts but little stoping was done.
REFERENCES


SAN XAVIER MINE

30', 53', 73' LEVELS

SCALE: 1' = 100'
PLATE T

COMMON LEGEND FOR LEVEL MAPS

ARKOSE
ALTERED LIMESTONE
DENSE SILICEOUS
Gypsum
Ore known inferred
Faults
Left菲E backing
Right菲E backing
Density backing
Shale

ORN TO MODIFIED FROM BANNER COMPANY MAPS & RECORDS.
E9791
1960
147
Pl. 7
E9791
1960
147
Pl. 10
E9'91
1960
147
Pl. 15
E9791
1960
147
Pl. 16
E9791
1960
147
Pl. 19