GEOLOGY AND ORE DEPOSITS OF THE JACKRABBIT AREA,
PINAL COUNTY, ARIZONA

by

Donald F. Hammer

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W. C. LACY                      
Professor of Geology           

Date
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ABSTRACT

The Jackrabbit area is situated at the north end of Slate Mountains, Pinal County, Arizona. Here, low but rugged hills encompass an apparently conformable sequence of Late Precambrian, Cambrian, Devonian, and Mississippian sedimentary rocks and Late Precambrian(?) diabase sills. Dikes and sills of Tertiary andesite porphyry, and associated pebble dikes, intrude these sedimentary and igneous rocks, and alluvium surrounds their tilted, faulted surface exposures.

Severe structural deformation began with local tilting and intrusion of andesite porphyry. Strike movement along major northwest-trending Boundary faults, and compression resulting from an expanding magma chamber, produced thrust faults, drag folds, tear faults, and pervasive bedding plane rupture. Relaxation of stress allowed down-dropping of a structural block along the northwest-trending Boundary
faults, and erosion now reveals a graben of Paleozoic sediments between horsts of Precambrian rock.

Thermal solutions rose through the rocks of the Jackrabbit area effecting sericitization of andesite porphyry, silicification of limestone, and the introduction of ore minerals. Outpourings from springs, and the deposition of travertine, marked the termination of hydrothermal activity.

Gold and oxidized lead, zinc, and silver minerals are found with quartz, limonite, and manganese oxide in northeast-striking veins. These ore minerals also replaced brecciated, silicified Escabrosa limestone along northeast-striking feeding fractures.
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INTRODUCTION

Location, Culture, and Accessibility

The Jackrabbit area is within the Casa Grande mining district in central southern Arizona (fig. 1). The name "Jackrabbit area" may properly be applied to a region of indefinite extent situated at the northern end of Slate Mountains, but for this report, mapping was confined to sec. 31, T. 9 S., R. 5 E., and the E-1/2 sec. 36, T. 9 S., R. 4 E., Gila and Salt River meridian.

Gold and silver deposits within the Jackrabbit area have been exploited intermittently since 1881, with mining activity centered around the Jackrabbit Mine, Turning Point Mine, and the Desert Queen Mine. Mining reached its highest level of activity in 1910, and by this time a sizable community, locally known as Jackrabbit, had grown adjacent to these mines. The mines were equipped with steam generating plants, hoisting and ore handling equipment, pumps, compressors, concentrators, and sundry buildings.

Today, very little remains of the buildings and equipment that were installed at these properties. There is no mining activity within the area, and no human being makes Jackrabbit his home. With the exception of the Turning Point Mine, the underground workings are
Figure 1. Index map showing location of the Jackrabbit area, Pinal County, Arizona. Inset shows location of measured stratigraphic section and offsets to avoid complex structure or poor exposure.
mostly inaccessible.

Casa Grande, the nearest railhead and supply point, is 22 miles north of Jackrabbit and is easily accessible via the paved Casa Grande-Covered Wells highway (fig. 1). Within the area, desert roads and trails give access to the base of the hills at several places.

Physical Features

The area mapped for this report lies well within the Basin and Range physiographic province as defined by Ransome (1903, p. 16). The surrounding mountain ranges are slightly elongate, north-trending, deeply dissected blocks of sedimentary and volcanic rock, that are separated by broad, alluviated valleys. Few peaks within the region exceed 4,000 feet and the valley floors range from 1,200 to 2,500 feet in altitude.

For convenience in reference, the four most prominent hills have been named (pl. 1). Desert Queen Hill is the largest and highest prominence within the area, and Jackrabbit Hill is its continuation to the northwest. Together, these two hills form the northwest-trending "backbone" of the area. Turning Point Hill and Quartzite Hill are isolated outcrops which protrude through the alluvium southwest and northeast, respectively, from these central prominences.

Altitudes within the area range from 1,225 feet at the flat northwest of Jackrabbit Mine to 1,983 feet at the summit of Desert
Queen Hill.

There are no major streams within the area. Small washes drain runoff from the infrequent rains toward both the east and the west, away from the center of the area. Runoff eventually reaches the Santa Rosa Wash, a major north-draining channel in the valley west of Jack-rabbit.

**Climate and Vegetation**

The Jackrabbit area is situated in a desert region which is characterized by extreme summer heat and mild winter temperatures. Rainfall is slight and occurs usually as violent summer storms and as gentle rains during late winter. Climate at Jackrabbit and at Casa Grande is essentially the same and data collected over a 58-year period at Casa Grande indicate a mean temperature of 49.8°F during January and of 91.3°F during July, with a maximum temperature of 122°F in July 1905, and a minimum temperature of 15°F in December 1954. Rainfall averages 8.20 inches yearly.

Low shrubs and cacti, typical of the Lower Sonoran life zone, dot rocky slopes of the hills within the area. Paloverde and mesquite cluster along the larger washes.
Purpose and Scope of Investigation

This report is intended as an evaluation of mineral occurrence within the Jackrabbit area. Any evaluation of known mineral bodies or efficient exploration for hidden ones necessitates a detailed knowledge of the geologic history of the area, the nature and timing of deformation, and the environment of mineral deposition. Consequently, considerable time was devoted to investigation of stratigraphy, structural details, and rock alteration, with the anticipation that the synthesis of this information would enable a coherent reconstruction of the history of mineralization.

The study area is restricted to include the most extensively mineralized part of the northern Slate Mountains. This restriction in geographic coverage, of necessity, limits the study to problems of a local nature. The author has drawn freely upon the work of others to provide the regional geologic setting of the Jackrabbit area.

Fieldwork and Acknowledgments

Fieldwork was started in September 1957, and essentially completed in May 1959. From September 1957 to April 1958, a base map was prepared and the surface and accessible underground workings were mapped. From November 1958 to March 1959, the stratigraphic section was measured. During April and May 1959, the drag folds were
mapped along the south flank of Desert Queen Hill.

At the outset of fieldwork, a transit triangulation survey was conducted to provide horizontal control for the construction of a topographic base map. Vertical control was obtained from elevations shown on the U. S. Geological Survey map of the Silver Reef Mountains quadrangle and from contours drawn stereographically upon U. S. Department of Agriculture Soil Conservation Service aerial photographs. This data was combined to produce a topographic base map to the scale one inch equals three hundred feet. Horizontal and vertical control is fair in the completed map. Aerial geology was mapped upon this base by Brunton compass and pace methods.

After fieldwork began, it became apparent that parts of the sedimentary section are missing within the study area, and that description of the remaining section would be of little value. To provide more accurate stratigraphic information, and to enable a better evaluation of deformation, a relatively undisturbed section of sedimentary rocks, Late Precambrian through Devonian in age, was measured in hills south of the mapped area (pl. 5). The Mississippian Escabrosa limestone was described from outcrops within the mapped area. Refer to the inset map of figure 1 for locations of segments of the measured section.

In an attempt to determine more accurately the movement along the South Boundary fault, an area 450 feet long by 400 feet wide,
A. High area formed by Jackrabbit Hill and Desert Queen Hill. View southwest from Quartzite Hill.

B. View southwest from Desert Queen Hill showing location of measured stratigraphic section.

GENERAL VIEWS OF THE NORTHERN SLATE MOUNTAINS
covering the drag folds along the south flank of Desert Queen Hill was mapped to the scale one inch equals twenty feet (pl. 3). Horizontal control was provided by a grid which was established over the area on 50-foot intervals by transit survey.

Polished sections of sulphide ores and thin sections of oxidized ores and igneous rocks were prepared and examined.

It is a pleasure to acknowledge the assistance extended by the faculty members of the Department of Geology of the University of Arizona. In particular, Dr. Willard C. Lacy gave generously of his time and was a source of aid and constant encouragement. Dr. Evans B. Mayo contributed valuable advice on structural problems encountered during field mapping.

Mr. L. A. Heindl and Mr. Neal E. McClymonds of the U.S. Geological Survey made the results of their work on the Papago Indian Reservation available to the author.

To Mr. Mark Manuel, chairman of the Papago council, to the members of the council, and to the people of the village of Komelik, the author is indebted for permission to work within the Papago Indian Reservation.

Mr. Peter J. Johnson, owner of the Desert Queen group of mining claims, generously gave the author permission to work within his property.

Mr. E. R. Zimmerman, manager of operations at the
Jackrabbit Mine from 1905 to 1912, contributed historical data, and information on the geology of the Jackrabbit Mine.

Mr. Frank Florez assisted the author during surveying for the map of the drag fold area. Mr. James Sell accompanied the author during underground mapping at the Turning Point and Desert Queen Mines.

**Previous Work**

The first description of the stratigraphy of Slate Mountains was published by N. H. Darton (1925). Darton suggested a Paleozoic age for some of the sedimentary rocks.

J. B. Tenney (1934), in an evaluation of the Casa Grande mining district, briefly mentioned the history and geology of mines within the Jackrabbit area.

A measured stratigraphic section and description of sedimentary rocks in the northern part of Slate Mountains was given by W. G. Hogue (1940). Hogue mapped an area adjoining the Jackrabbit area, toward the south.

N. E. McClymonds (1959) presented a resume of the stratigraphy of Slate Mountains and regional correlation with emphasis on the environment of sedimentation.
System | Series | Formation | Map symbol | Thickness (feet) | Section | Character of rock
--- | --- | --- | --- | --- | --- | ---
QUATERNARY | Recent Alluvium | Qal | 0-50+ | | | An unconsolidated accumulation of angular rock fragments, finer sediments and caliche.

MISSISSIPPIAN | Early Mississippian Escabrosa limestone | Me | 436+ | | | A basal unit of reddish siltstone 1 foot thick is overlain by 65 feet of massive, dark-gray, cliff-forming dolomite, 170 feet of massive, dark-to-light-gray limestone, and capped by 202 feet of light-colored, fossiliferous, chert-banded limestone.

DEVONIAN | Late Devonian Martin formation | Dm | 208 | | | Eighty five feet of impure dolomite and dolomitic limestone alternating with interbeds of siltstone and mudstone is overlain by yellowish, thin-bedded, friable siltstone 123 feet thick.

CAMBRIAN | Late Cambrian Abrigo formation (unrestricted) | Ca | 448 | | | The lower unit is 297 feet of calcareous quartzite, irregular quartzitic interbeds and occasional thin beds of impure limestone, thin beds with micaceous, fucoidal bedding planes are characteristic.

| Late Cambrian Troy quartzite | Ct | 463 | | | The middle unit is 37 feet of cliff-forming purple quartzite.

| Late Cambrian Mesal limestone | pEm | 193 | | | The upper unit is 114 feet of reddish, silty, partly dolomitic, thin-bedded limestone.

PRECAMBRIAN | Younger Precambrian Dripping Spring quartzite | pCds | 1179 | | | Reddish dolomite which contains closely spaced, parallel chert bands, and weathers to a characteristic ribbed surface.

| Younger Precambrian Pioneer shale | pEp | 374 | | | A 46 foot thick basal unit of massive, pebbly arkosic sandstone is overlain by 358 feet of arkosic quartzite and sandstone, which is overlain by 231 feet of thin-bedded, well sorted sandstone, and topped by 544 feet of alternating siltstone and quartzite.

| Younger Precambrian Pinal schist | pPs | | | | Alternating quartzite and siltstone or sandstone. The entire formation is reddish in color. Some siltstone units tend to be shaly.

Figure 2: Columnar section of sedimentary rocks in the Jackrabbit area.
GENERAL GEOLOGY

Early Precambrian Rocks

Pinal Schist

Pinal schist, named from the Pinal Mountains south of Globe (Ransome, 1903, p. 22), is nowhere present within the mapped area. It does, however, constitute the bulk of Slate Mountains and was encountered at the base of the stratigraphic section measured to the south of the mapped area.

Within the northern Slate Mountains, the basement rock is a medium gray, quartz-sericite schist comprised of metamorphosed coarse- to very fine-grained clastic sediments. In some coarser grained specimens sedimentary structures are still discernible. Schistosity varies from poor, in thick, coarse-grained units, to well developed, in thin, fine-grained units. It strikes north $10^\circ$ to $12^\circ$ east and dips $80^\circ$ east to vertical. Sericite gives a sheen to foliation surfaces. Quartz stringers are numerous and maintain no specific orientation.

This basement rock was identified as Early Precambrian Pinal schist by its lithology, which is very similar to most published
LATE PRECAMBRIAN SEDIMENTARY ROCKS

A. Quartzite unit in the upper part of the Pioneer shale, exposure south of Desert Queen Hill.
B. Pebble lens near base of the Dripping Spring quartzite, Quartzite Hill.
C. Cross-bedded Dripping Spring quartzite, Turning Point Hill.
D. Mescal limestone banded with chert, Turning Point Hill.
descriptions of Pinal schist, and by its position at the base of the Late Precambrian Apache group.

**Late Precambrian Sedimentary Rocks**

**Apache Group**

The Late Precambrian Apache group is named from the Apache Mountains near Globe (Ransome, 1903, p. 28), and is a sequence of conglomerates, siltstones, quartzites, and limestones which overlie the Pinal schist with profound angular unconformity. This sedimentary pile was tentatively assigned a Cambrian age and subdivided into four formations by Ransome (1903, p. 28-29). The Apache group has subsequently been modified by Ransome (1911, p. 747-748, and 1915, p. 380-388) and by Darton (1932, p. 319) and is now considered to be of Late Precambrian age and to consist of the following five formations (ascending): Scanlan conglomerate, Pioneer shale, Barnes conglomerate, Dripping Spring quartzite, and Mescal limestone. A younger quartzite (Troy) overlies the Mescal limestone with apparent conformity, except where basalt flows intervene, and was included within the Apache group by Ransome (1915, p. 380-388). Darton (1932, p. 319) showed that the Troy quartzite was, at least in part, of Cambrian age, removed it from the Apache group, and assigned to the Apache group a Late Precambrian age.
Pre-Troy sedimentary rocks within the northern Slate Mountains total 1,746 feet in thickness. No absolute criterion for dating these pre-Troy sediments was found, but they are correlated with the Late Precambrian Apache group by their nonfossiliferous character, position above the Early Precambrian unconformity, and lithology which is almost identical with the lithology of the Apache group in its type locality. Very little difficulty was encountered in placing boundaries between formations within the Apache group, owing to abrupt lithologic changes at formalional contacts.

Within the mapped area, the Apache group crops out in Quartzite Hill north of the North Boundary fault, and in Turning Point Hill and Desert Queen Hill south of the South Boundary fault (pl. 1).

**Pioneer Shale**

The thickness of Pioneer shale is 374 feet where measured south of the mapped area. The formation lies with angular unconformity upon an erosional surface of low relief that was carved upon the underlying Pinal schist. The contact is nowhere clearly exposed, but even where the contact can be placed within a few inches, no Scanlan conglomerate is seen.

The Pioneer shale is easily recognizable owing to its distinctive thin-bedded character and to its purplish coloration in weathered outcrops. This formation is divisible into three major lithologic units:
(1) lower, alternating siltstone and quartzite; (2) middle, quartzite and sandstone; (3) upper, siltstone.

The lower unit of alternating siltstone and quartzite is 115 feet thick, thin bedded to laminated, and is characterized by its grayish-red color and by spherical volumes within the rock from which ferruginous pigment has been removed to give the surface a white-spotted appearance.

The middle unit of quartzite and sandstone is 181 feet thick and is comprised of well-sorted, fine-grained arkosic sand. The unit is pinkish to reddish, and is generally lighter in color than either the underlying or overlying units.

The upper unit is 78 feet of grayish-purple, muddy siltstone. It is well sorted and beds are thin to laminated giving an overall shaly appearance to the unit.

**Dripping Spring Quartzite**

Dripping Spring quartzite is 1,179 feet thick where measured south of the mapped area. It overlies the Pioneer shale with apparent conformity. The abrupt lithologic change at the contact does suggest, however, either a hiatus or an abrupt change in the environment of sedimentation.

Dripping Spring quartzite is characterized by the tendency of the lower, thick quartzite units to form massive cliffs, by the abundant
feldspar content of much of the sand, and by significant thicknesses, near the top of the formation, of yellowish to brownish weathering, well-indurated siltstone. Three major lithologic units are recognizable within the Dripping Spring quartzite: (1) lower, arkosic quartzite and sandstone; (2) middle, thin-bedded sandstone; (3) upper, alternating siltstone and quartzite.

The lower unit of arkosic quartzite and sandstone is 404 feet thick. Discontinuous pebble lenses, probably equivalent to the Barnes conglomerate of Ransome (1903, p. 31), crop out within the lowermost 30 feet, but above this horizon, no significant amounts of coarse material are found. Sand grains are generally well sorted. Beds are thin to massive. This unit is resistant to erosion and weathers to form steep slopes and cliffs.

The middle unit is 231 feet of quartzose sandstone which contains only minor amounts of feldspar. The sand is generally well sorted. This unit is characterized by thin beds which weather to subdued topographic forms.

The upper unit is alternating quartzite and siltstone or mudstone 544 feet thick. The rock is comprised of very well-sorted clastic grains. Thin bedding is characteristic. Perhaps the yellow, red, and brown banding of the weathered siltstone is the most distinctive feature of this unit.
**Mescal Limestone**

The Mescal limestone is 193 feet thick where measured south of the mapped area. It lies conformably upon and is gradational downward into the Dripping Spring quartzite. The contact between the two formations is considered to be the top of the highest distinct quartzite bed.

Mescal limestone, in the Jackrabbit area, is a reddish dolomite, characterized by a distinctive lithology. Remarkably parallel, thin, closely spaced chert bands occur throughout most of the formation. Only the uppermost 22 feet of the unit contains an appreciable amount of chert-free dolomite. Mescal limestone weathers to form a characteristic ribbed surface where broken across the beds.

**Late Precambrian Igneous Rocks**

**Diabase**

Sills of intrusive diabase are noted at five different horizons within the measured stratigraphic section. The thickest sill is 185 feet and their combined thickness is 316 feet. Within the mapped area, diabase is noted at three locations: two are within the Dripping Spring quartzite south of the South Boundary fault, and the other is within the Dripping Spring quartzite north of the North Boundary fault.
The diabase sills are deeply weathered and provide no fresh material for study. In hand specimen, freshly broken diabase is greenish and holocrystalline with an ophitic texture. The ophitic texture is especially noticeable on weathered surfaces where the feldspars appear light gray against a greenish background.

Microscopic examination of a diabase specimen from the sill exposed on Turning Point Hill indicates that the rock is comprised of plagioclase (probably andesine), 65 percent; augite, 15 percent; iddingsite, 15 percent; and magnetite, 5 percent. The plagioclase is partly replaced by sericite. Plagioclase crystals form a matted felt-like mesh.

Within the Jackrabbit area, diabase intrudes no formation younger than Late Precambrian Dripping Spring quartzite. It is upon this basis that the diabase intrusions at Jackrabbit are tentatively assigned a Late Precambrian age.

**Paleozoic Sedimentary Rocks**

The Paleozoic sedimentary rocks that crop out within the Jackrabbit area include the Cambrian Troy quartzite and Abrigo formation, Devonian Martin formation, and Mississippian Escabrosa limestone. These Paleozoic rocks overlie the Late Precambrian sediments with apparent conformity, although Darton (1925, p. 36-37) pointed out the evidence for an unconformity between the Apache group and the
CAMBRIAN SEDIMENTARY ROCKS

A. Cross-bedding in upper Troy quartzite, Turning Point Hill.  
B. Thin quartzite beds of the lower Abrigo formation, Turning Point Hill.  
C. Sandy dolomitic limestone of the upper Abrigo formation, Turning Point Hill.
lowermost Paleozoic strata. Bedding attitudes within the Paleozoic section are completely conformable, although a profound hiatus exists between the Cambrian and Devonian beds.

Mississippian Escabrosa limestone is the youngest Paleozoic sediment within the Jackrabbit area. The top of the formation is uncertain, for the youngest beds are overlain by a sill of andesite porphyry. Beneath the sill, however, lie 438 feet of Mississippian limestone. Contrasting this thickness with 400 feet of Escabrosa limestone measured by McClymonds (1959, p. 80) in isolated hills south and east of the Slate Mountains, and 400 to 415 feet of Escabrosa limestone measured in the Vekol Mountains by Carpenter (1947, p. 34), it seems probable that the Mississippian section at Jackrabbit is essentially complete and that the andesite porphyry sill was intruded at or near the top of the Mississippian beds.

The Pioneer stratigraphic work of Hogue (1940) outlined the Paleozoic formations of the Slate Mountains. Within the study area, these formations were distinguished by their position in the stratigraphic sequence, lithology, and fossil content.

Within the mapped area, Paleozoic beds crop out between the North Boundary fault and the South Boundary fault. Desert Queen Hill, Jackrabbit Hill, and Turning Point Hill are blocks of sedimentary rock tilted northwestward. The Paleozoic formations now crop out along the southern and eastern flanks of these hills (pl. 1).
Troy Quartzite

Troy quartzite lies with apparent conformity upon the Late Precambrian Mescal limestone. The lowermost Troy beds contain coarse sand, minor grit, and occasional pebble lenses, but no basal conglomerate marks the contact.

Troy quartzite was named by Ransome (1915, p. 380-388) at Troy Mountain in the Ray Quadrangle. Ransome originally believed the entire Apache group to be Cambrian in age and the Troy quartzite to be the upper unit of the Apache group. Darton (1932, p. 319) removed these fossiliferous Cambrian quartzites from the underlying unfossiliferous Apache group and assigned to the Apache group a Late Precambrian age.

Where measured south of the mapped area, Troy quartzite is divisible into three lithologic units with a total thickness of 463 feet: (1) lower, crossbedded sandstone; (2) middle, grit and sandstone; (3) upper, fossiliferous sandstone and quartzite.

The lower unit is pinkish, coarse- to fine-grained, moderately well-sorted, medium- to very thin-bedded sandstone 201 feet thick. This unit is partly crossbedded, contains a few quartzite beds, and displays scattered lenses of grit and quartzite pebbles.

The middle unit is a sequence of pink to purple grit and sandstone 119 feet thick. The sandstone is fine grained and well sorted,
and the grit consists of very poorly sorted, subangular to subrounded quartz grains.

The upper unit is medium- to very fine-grained, moderately well-sorted quartzite and sandstone 143 feet thick. Hogue (1940, p. 7) found poorly preserved brachiopod remains near the top of this unit. *Scolithus* is abundant at the top of some beds. These fossilized organic remains are adequate proof of the Paleozoic age of the uppermost beds of the Troy quartzite.

In the Vekol Mountains, 10 miles west of Jackrabbit, Carpenter (1947, p. 17) noted basalt flows between the Mescal limestone and the overlying Troy quartzite, and abundant evidence of pre-Troy erosion of Mescal beds. Carpenter (1947, p. 23) also described an erosion surface within the Troy quartzite. This surface is developed upon diabase which is intrusive into the lower, unfossiliferous Troy beds, and is overlain by fossiliferous quartzites of Cambrian age.

No basalt flows, pre-Troy channeling of the Mescal limestone, or erosion surfaces within the sequence of Troy beds are found in the northern Slate Mountains. The apparent conformity of the Mescal limestone and the Troy quartzite, the unfossiliferous character of the lower Troy beds, and the proximity of the Slate Mountains to the Vekol Mountains do, however, raise doubts as to the age of the lower Troy quartzite in the Jackrabbit area.
Abrigo Formation

The term Abrigo limestone was applied by Ransome (1904, p. 21) to Middle Cambrian beds in the Bisbee district. Darton (1925, p. 48-51) described Upper Cambrian fossils collected from the Abrigo limestone. Stoyanow (1936, p. 465) divided the Abrigo limestone, at the type locality, into three formations and restricted the term "Abrigo formation" to the middle unit. Stoyanow (1936, p. 477) extended his subdivision of the Cambrian of southern Arizona to the Santa Catalina Mountains, where he described two units, the Santa Catalina formation and the Southern Belle quartzite, between the Troy quartzite and the Abrigo formation. Stoyanow's nomenclature was used in the Slate Mountains by Hogue (1940). Gilluly (1956, p. 24) has set aside Stoyanow's subdivision of the Cambrian deposits in central Cochise County and returned to the term Abrigo limestone for all beds between the Troy quartzite and the Martin limestone. McClymonds (1959, p. 80) has used the term Abrigo formation for the Cambrian beds above the Troy quartzite in the Slate Mountains. McClymond's usage of the word "formation" is followed in this report because of the diverse lithology of these Cambrian beds.

The Abrigo formation, where measured south of the mapped area, is 448 feet thick and represents a sequence of apparently unbroken sedimentation. These beds can be subdivided into three distinct
lithologic units, each transitional into the one below, and the lowermost unit transitional downward into Troy quartzite.

The lower unit is calcareous quartzite, irregular quartzitic interbeds, and occasional beds of impure limestone. Glauconite can be found throughout the sequence. The entire unit is thin bedded. Bedding planes are micaceous partings which belie the hardness of the thin quartzite beds between them. Fucoid-like concretions are abundant on many bedding planes and are, perhaps, the most distinctive feature of the lower unit. Hogue (1940, p. 9) reported Lingulella and abundant trilobite fragments from the upper part of this unit. Hogue (1940, p. 9) has correlated this lower unit with the Santa Catalina formation, which Stoyanow (1936, p. 477) considered to be of Middle Cambrian age.

The middle unit is purplish, crossbedded quartzite, 37 feet thick. This quartzite is resistant to erosion and stands out in the weathered section as a purplish rib. Hogue (1940, p. 10) has correlated this unit with the Southern Belle quartzite, which Stoyanow (1936, p. 477) considered to be of Middle Cambrian age.

The upper unit consists of 114 feet of reddish, partly dolomitic, thin-bedded limestone. These limestone beds are silty to sandy and the silt-sand layers stand out on weathered surfaces as whisps and ribs. Perhaps the feature most characteristic of this unit is the development of abundant intraformational conglomerate. The limestone weathers light brown and forms subdued topography. Hogue (1940, p. 11) reports
trilobite fragments and small brachiopods, probably Obolus and Lingulella, from this unit. The quartzite bed, described at the top of the Abrigo limestone by Ransome (1904, p. 32) and Gilluly (1956, p. 16), does not crop out within the Jackrabbit area. Hogue (1940, p. 11) has correlated this limestone unit with the Abrigo formation, which Stoyanow (1936, p. 477) considered to be of Upper Cambrian age.

Martin Formation

The Martin limestone was named by Ransome (1904, p. 33) from Mount Martin near Bisbee. Stoyanow (1936, p. 484-491) proposed the terms Picacho de Calera formation and Lower Ouray formation for Devonian strata which crop out to the north of the Bisbee district and are older and younger, respectively, than Martin limestone in the type locality. This terminology was used in the Slate Mountains by Hogue (1940, p. 12-13). Huddle and Dobrovolny (1952, p. 73) applied the term Martin formation to the entire Devonian section in central Arizona, and this terminology was applied in the Slate Mountains by McClymonds (1959, p. 80). In this report, the term Martin formation is applied to all strata of Devonian age in the Slate Mountains.

The Martin formation is 208 feet thick where measured south of the mapped area. It lies with apparent conformity upon the Cambrian Abrigo formation. No pre-Martin channeling of the Abrigo formation was noted in this area. The unimpressive contact between the Abrigo
DEVONIAN AND MISSISSIPPIAN SEDIMENTARY ROCKS

A. Characteristic weathering of silty dolomite beds in the lower part of the Martin formation, Turning Point Hill.  B. View of the middle and upper parts of the Escabrosa limestone showing the cliff-forming cherty-limestone unit, Desert Queen Hill.
and Martin formation actually represents a hiatus spanning Ordovician, Silurian, and Lower and Middle Devonian time. No conglomerate is developed at the base of the Devonian beds, but a sandy dolomite is present at the base of the Martin formation where the section was measured, and a thin bed of grit and sandstone is present at the Cambrian–Devonian contact on Turning Point Hill.

The Devonian strata at Jackrabbit may be divided into two distinct lithologic units which grade into one another with no apparent break in sedimentation.

The lower unit is an 85-foot thick sequence of silty dolomite, siltstone, and mudstone beds. This unit is characterized by frequent changes in lithology. The thickest continuous sequence of lithologically similar beds is 19 feet. Silt and sand intercalated in some of the lower dolomite beds weather to produce a poorly developed ribbing. Dolomite beds of the lower Martin formation are rich in faunal remains. Hogue (1940, p. 12) reports *Cladopora prolifica, Schuchertella* sp., *Schizophoria striatula, Retzia* sp., and *Productella* sp. from these beds. Dolomite beds of the lower unit weather to form bluffs. Stoyanow (1936, p. 484-494) considered the Martin limestone to be of Upper Devonian age.

The upper 123 feet of the Martin formation consists of thin-bedded, incompetent reddish siltstone.
The term Escabrosa limestone was proposed by Ransome (1904, p. 42) for sedimentary deposits of Lower Mississippian age which occur at Escabrosa Ridge near Bisbee. This name has been applied, by other workers, to Lower Mississippian deposits throughout southern Arizona. Huddle and Dobrovolny (1950, p. 86) regard the Escabrosa limestone of southern Arizona to be the same formation as the Redwall limestone of central and northern Arizona.

Within the Jackrabbit area, Escabrosa limestone is 438 feet thick and overlies, with apparent conformity, the Devonian Martin formation. The contact between these two formations is sharp and is placed at the base of a persistent, 1-foot thick bed of brown calcareous siltstone. This formational boundary is based entirely upon lithology, for below it lie the noncompetent siltstones of the upper Martin formation and above it rise massive cliffs of dolomite and limestone, which are typical of the Escabrosa limestone throughout southern Arizona.

Escabrosa limestone within the Jackrabbit area may, for purposes of description, be subdivided into three lithologic units. The lower unit is 65 feet of dark gray, massive, cliff-forming dolomite which is very poor in faunal remains.

The middle unit is massive dark to light gray, non-magnesian limestone 170 feet thick. These middle beds tend to be cliff forming,
contain minor amounts of chert, and yield scattered coral and brachiopod remains. Some beds are fossiliferous fragmental with crinoid remains providing much of the fragmental material.

The upper unit is light to medium gray, non-magnesian limestone 202 feet thick. Beds within the upper unit tend to be thinner than beds within the middle and lower units, and chert constitutes a significant proportion of the rock. Faunal remains are very abundant, and much of the limestone can be termed encrinal. One 4-foot thick bed, located 285 feet above the base of the Escabrosa limestone, is of specific interest, for it contains an abundant and distinctive fauna; Pentremites 2 sp., Spirifer sp.; unidentified crinoid, and fossil trash. This fossiliferous bed is convenient for correlation within the area and possibly can be correlated with the "pentremites horizon" reported by Hadley (1942) to occur 300 feet above the base of the Escabrosa limestone in the Reward Mine area of the Vekol Mountains. Overlying the pentremites horizon in the Jackrabbit area, is a massive, cliff-forming, chert-banded limestone unit. The top of this unit is easily recognizable and has been mapped as an aid to structural interpretation (pl. 1). With the exception of this cliff-forming, cherty limestone unit, the upper Escabrosa limestone is not greatly resistant to erosion and tends to produce rounded topographic forms.
Cenozoic Igneous Rocks

Andesite Porphyry

Dikes and sills of andesite porphyry crop out within the Jackrabbit area (pl. 9). Large intrusive masses at the Jackrabbit Mine and the Turning Point Mine appear to be sills which are branching from a steep feeding structure. A smaller intrusive mass, at the Desert Queen Mine forms a sill which has been downfaulted and preserved from erosion.

Megascopically, the andesite porphyry is dark gray, sometimes greenish, with euhedral black hornblende and biotite, and subhedral feldspar phenocrysts. The rock is well foliated and lineated by hornblende crystals. The foliation is especially conspicuous on weathered surfaces. Within some areas, epidote coats joints and fractures.

Beneath the microscope, feldspar phenocrysts are seen to be oligoclase which is partly replaced by fine-grained sericite and larger plates of muscovite. Biotite and hornblende are euhedral phenocrysts and are mostly altered to sericite. Magnetite forms octohedrons and grains of irregular outline. The groundmass is composed of submicroscopic, felt-like whisps and shreds of sericitized feldspar. Quartz and calcite are found in minor quantities.
TERTIARY ANDESITE PORPHYRY
A. Foliate structure emphasized by differential weathering, Desert Queen Hill. B. Weathered flow breccia, Desert Queen Hill.
It can only be said, with absolute certainty, that the andesite porphyry at Jackrabbit was emplaced after Mississippian time. It seems probable, judging from the complexity of post-intrusion deformation, that these andesitic intrusions are no younger than middle Tertiary time (Heindl, 1960, p. 31-32), and may have accompanied the uplift of Slate Mountains during post-Miocene, pre-Pliocene deformation (Heindl, 1959, p. 3).

Pebble Dikes

Pebble dikes crop out at two localities within the Jackrabbit area. The major dike was intruded into a northwest-striking fault near the crest of Desert Queen Hill. In the minor occurrence, thin smears of pebbles have intruded an obscure, northeast-striking fault on the southeast side of Jackrabbit Hill. As the two intrusions are similar in lithology and mode of occurrence, only the Desert Queen Hill dike will be described.

The pebble dike on Desert Queen Hill is an irregular, tabular mass of intruding material which occupies a fault zone that strikes N. 54° W. and dips steeply southwestward. This fault, and dike, cross a northeast-trending ridge and it can be seen, on the southeast side of the ridge, that the pebble dike occupies only the uppermost 50 feet of the fault zone. The dike attains its maximum thickness, 8 feet, on the southeast side of the ridge and stands out as an erosion resistant rib
(pl. 10). Where the dike attains its maximum thickness, it is comprised of platy, angular rock fragments, contained within a fine-grained, black matrix. The fragments make up as much as 60 percent of the dike and 95 percent are less than one inch in maximum dimension. These platy fragments are aligned in a nearly horizontal attitude. Above and below this thick portion, where the dike narrows, the rock fragments become smaller (90 percent less than half an inch in maximum dimension), more spherical, highly polished, and comprise up to 95 percent of the rock. On the northwest side of the ridge, in its lowermost exposure, the dike loses much of its coherence and pebbly character, and fingers into the brecciated limestone of the fault zone (pl. 11). In places, limestone adjacent to the dike is jasperized.

Under the microscope, the pebble dike material is seen to contain angular to well-rounded fragments that range in maximum dimension from less than 1 mm to 25 mm. The fragments are primarily limestone which has been replaced by flamboyant, crystalline aggregates and interlocking grains of quartz. Most of these fragments are coated by an outer layer of fibrous quartz. Specularite lines cavities in some fragments. Chert and rounded fragments of pink jasperoid are present in minor quantities. The matrix consists of rock flour and finely-grained magnetite. Rare grains of clear quartz are seen in the normally opaque matrix material. Ore minerals are completely lacking within the dike.
PEBBLE DIKE

A. Southeasternmost exposure of pebble dike on Desert Queen Hill.  
B. Closeup of pebble dike showing near horizontal alignment of fragments.
PEBBLE DIKE

A. Northwesternmost exposure of pebble dike (dark) on Desert Queen Hill, showing interfingering with limestone fragments. Pebbly character is almost lacking. View southeast. B. Closeup of dike material invading Escabrosa limestone. Small limestone fragments are engulfed by the dike.
Bleaching and corrosion of limestone adjacent to the dike appear to be more intense at its northwest end than at its southeast end. The position of the bottom of the dike is known at its southeast end, and platy fragments within the dike are aligned in a near horizontal attitude above this bottom as though oriented by near horizontal flowage of the dike material. No quartzite fragments have been recognized within the dike. These factors suggest that the dike originated in limestone, was introduced from the northwest and moved toward the southeast.

Gates (1959, p. 806-814), in a detailed review of the literature concerning breccia pipe formation, concludes that breccia pipes (or dikes) develop through a combination of several mechanisms as follows:

Assume a rising cupola of magma which is crystallizing and building up pressure of volatiles and is perhaps preceded by a cap or auriole of gas. The pressures of magma and gas open cracks overhead; gas rushes into some of these, tearing fragments from the walls which, in turn, assist in further brecciation by abrasion, attrition and wedging; magma rushes into others, quickly chills and evolves more gas which brec-ciates the rock ahead; still others may be filled with breccia formed by rock-bursts. Rapid heating of rocks and conversion of the included water to steam may add to the fragmentation. Thus a helmet of breccia forms ahead of the rising magma by a variety of processes, and this breccia, in turn, becomes intrusive itself.

As andesite porphyry is the only post-Paleozoic intrusive rock exposed within the Jackrabbit area, it seems probable that the pebble dikes have been generated by the andesite porphyry intrusions.

The jasperoid on Desert Queen Hill appears to have formed
after emplacement of the andesite porphyry sill, suggesting that the pebble dike, which contains rounded jasperoid fragments and has partially jasperized walls, formed during the later stages of intrusive activity. The dike occupies a northwest-striking fault, while the earlier andesite porphyry and the later ore minerals were both introduced into northeast-striking faults. This variation in strike of faults open to receive introduced material, suggests a temporary reorientation of compressive stress at the time of pebble dike intrusion.

**Cenozoic Sedimentary Rocks**

**Alluvium**

Late Tertiary(?) and Quaternary alluvium surrounds each of the bedrock prominences and occupies approximately 60 percent of the mapped area (pl. 1). The maximum thickness of this material is unknown, but it probably covers the bedrock only as a thin veneer and very likely does not exceed 50 feet at the point of maximum thickness.

Where penetrated by exploratory pits and shafts, the alluvium is seen to be heterogenous, coarse, and angular fragments of the bedrock units which have been cemented by travertine. This material is interpreted to be erosional debris resulting from the rapid relative uplift of crustal blocks, simultaneous with profuse discharge from calcareous springs.
Silt and gravel cover the travertine cemented erosional debris to depths of several feet.

**Rock Alteration**

**Alteration Associated With Diabase Intrusions**

Diabase has intruded the Dripping Spring quartzite at three locations within the mapped area (pl. 1). In each instance, the diabase is surrounded by an envelope of darkened, baked appearing sediment. The contact is usually not distinct, for the rock grades from recognizable diabase outward through metasomatized sedimentary material to recognizable sediment. The thickness of the alteration halo varies from a few inches to several feet, generally in proportion to the thickness of the sill. No petrographic examination of the alteration products was made.

**Thermal Alteration of Escabrosa Limestone**

Andesite porphyry has intruded Escabrosa limestone within the Jackrabbit area (pl. 1). The contact between the base of a sill and the underlying limestone is visible at several places on Turning Point Hill, Jackrabbit Hill, and Desert Queen Hill, but limestone capping a sill is preserved only at the crest of Turning Point Hill. In each instance, the effect of the magma upon the intruded limestone is
negligible. The limestone is bleached or stained pink for a few inches from the contact; recrystallization is not extensive, and skarn minerals are absent.

Burnham (1959, p. 916-917) has shown that wollastonite can form in siliceous limestone at temperatures ranging from 400°C to 650°C, with increasing partial pressure of carbon dioxide. This temperature range is probably below the freezing point of andesite porphyry magma and the absence of skarn in limestones adjacent to the magma may, perhaps, be attributed to the dryness of the magma rather than to its low temperature.

Evidence testifying to the relative coolness of the andesite porphyry intrusions at Jackrabbit, is supplied by the internal structure of the rock. Flow breccia is well developed in the andesite porphyry on Turning Point Hill and within the sill on Desert Queen Hill (pl. 9). Each of the andesite porphyry exposures exhibits excellent foliation and lineation due to flowage alignment of hornblende needles. These phenomena are interpreted to indicate marginal chilling and high viscosity of the magma during emplacement, and are evidences of low temperatures.

Thinning of Escabrosa Limestone

One of the most startling alteration effects within the Jackrabbit area, is the wholesale removal of Escabrosa limestone along a zone of thinning. This phenomenon is displayed along parts of the southern and
eastern flanks of Desert Queen Hill (pl. 1). The thinning zone occupies, in a rude way, a stratigraphic position at the top of the dolomite beds near the base of the Escabrosa limestone, but is very irregular and, in places, has extended downward almost to the base of the formation (pl. 12).

Where observed below the thinning zone, the Escabrosa beds are dark gray, relatively undisturbed, exhibit sharp bedding planes, and give no evidence of profound alteration.

In contrast with these dark beds, the overlying zone of thinning is light gray to pink with a sharp, but very irregular lower boundary. Limestone within this zone shows no evidence of bedding, but is recrystallized and contains rare blocks of unaltered limestone, blebs of white calcite, and a few contorted chert bands. This recrystallized zone may be as much as 25 feet thick.

The recrystallized zone grades upward into limestone with bedding planes distinguishable but contorted. These overlying beds have the appearance of being slumped into the irregularities in the base of the thinning zone. Escabrosa limestone has been removed from this zone, shown by measured reductions in stratigraphic thickness as great as 43 feet.

This large-scale thinning may possibly be explained by either or both of two mechanisms: (1) thrust faulting; (2) dissolution of the
A. Cliffs along the southeast side of Desert Queen Hill showing the zone of thinning and the slumping of overlying beds. View northwest.

B. General view of Desert Queen Hill looking northeast. Cliff-forming cherty limestone unit is repeated by faults.
limestone. A low-angle fault cutting through the Escabrosa limestone could account for the removal of part of the Escabrosa beds. Several factors dispute this mechanism: (a) The Escabrosa limestone, where thinned, is a competent, thick-bedded unit that overlies the noncompetent, thin-bedded siltstones of the upper Martin formation. It does not seem likely that thrusting would rupture the massive limestones when movement could be so easily accommodated only a few feet lower in the section. (b) Deep depressions in the lower boundary of the zone of thinning have varying trends. If these are ruptures due to thrusting, it seems likely that they would all have the same trend, parallel to the direction of thrust movement. (c) There is no structural evidence for displacement of the magnitude indicated by the thickness of material removed.

Dissolution seems a likely mechanism for thinning the Escabrosa section. There is ample evidence that solutions have permeated these sediments at least once, and perhaps at several periods, although much of this solutional activity has effected metasomatic replacement of the limestone, not the large-scale dissolution which is so evident within the zone of thinning. Less spectacular thinning of the Abrigo and Martin formations can be seen on Turning Point Hill, suggesting that corrosive solutions were not entirely confined to the Escabrosa limestone, but reacted with calcareous rock wherever faults
and ruptured bedding planes provide access.

The zone of thinning occupies, in a general way, a position at the top of the dolomitic basal beds of the Escabrosa limestone. The dolomite has been conspicuously affected also, where fractures provided ingress, suggesting that the basal dolomite was less readily dissolved than the overlying limestone, except where crushed by faulting.

Northwest-trending faults offset the thinning zone, and the andesite porphyry intrusions, and are, in turn, cut by veins which show no offset. This would seem to place the time of the thinning as definitely prior to ore mineralization, and probably during or later than the andesite porphyry intrusions.

At Turning Point Hill an andesite porphyry sill has invaded the lower Escabrosa limestone. Erosion has removed the entire front edge of the sill so that its effect upon the limestone ahead of it cannot be observed. The zone of thinning exposed on Desert Queen Hill occupies the same stratigraphic position as the sill on Turning Point Hill, suggesting that the thinning of Escabrosa limestone on Desert Queen Hill may represent the alteration effect ahead of a sill which has not as yet been revealed by erosion.
Ribbed Oolitic Limestone

An interesting alteration effect is noted in the weathered Escabrosa limestone along the south end of Desert Queen Hill. Here, limestone beds were shattered into numerous angular fragments bounded by fractures that have since rehealed. Alteration of the limestone is evidenced by siliceous "fronts" paralleling, at varying distances, the bounding fractures. These siliceous "fronts" stand out against the bluish weathered limestone as dark brown ribs (pl. 13).

Microscopic examination of the apparently unaltered centers of the fragments reveals that the limestone was originally composed of very tiny (less than 1/10 mm in diameter) calcareous oolites. These oolites have been partly recrystallized and destroyed between the bounding fracture and the siliceous "front."

Spectroscopic analysis shows the unaltered oolitic centers of the limestone fragments to be slightly magnesian, and the recrystallized rims to be essentially a pure limestone. Within the siliceous "front," between the altered and unaltered limestone, the oolitic nature of the sediment is well displayed, for the oolites have been silicified and are seen to be concentric layers of quartz; some have calcite cores and some are hollow shells. The silicified oolites tend to assume hexagonal outlines. Spectroscopic analysis reveals that this silicified rib contains appreciable quantities of silica, calcium, iron, manganese, magnesium,
RIBBED OOLITIC ESCABROSA LIMESTONE

A. Ribbing exposed on cliff face, Desert Queen Hill. View northeasterly.

B. Closeup of ribbing. View northwest.
and titanium. Iron, manganese, and titanium are not detectable in either the recrystallized rims or the unaltered cores of the limestone fragments.

Solutions, migrating through the shattered limestone blocks, very likely produced this unusual alteration effect. The appearance of the rock suggests that solutions invaded fractures between the limestone fragments, penetrated inward toward the centers of these fragments, and partly recrystallized the limestone as they progressed. Magnesium was apparently extracted from the altered limestone of the fragment rims, and manganese, iron, titanium, and perhaps silica were introduced from an outside source. These elements were concentrated at the inward limit of alteration and recrystallization and are weathering to form the characteristic brown rib.

Jasperization

Escabrosa limestone has been replaced by pink jasperoid beneath the andesite porphyry sill on Desert Queen Hill and on Jack-rabbit Hill, and adjacent to the minor andesite porphyry outcrop north of Desert Queen Mine. These jasperized zones are less than 40 feet thick and consist of completely replaced beds and irregular, nodular replacement bodies.

Immediately beneath the andesite porphyry sill on Desert Queen Hill are limestone beds entirely replaced by pink jasperoid (pl. 14-A).
JASPEROIDAL ALTERATION OF ESCABROSA LIMESTONE

A. Jasperoid (dark) selectively replacing a bed of Escabrosa limestone. View northeasterly, Desert Queen Hill. B. Jasperoid nodule forming in Escabrosa limestone. A shell of quartz spherules encloses a calcite core. Desert Queen Hill.
The beds are banded pink and white; they pinch and swell, but are nowhere more than one foot thick. Solid replacement gives way to nodular replacement along the strike. Microscopic examination of the solid jasper shows it to be cryptocrystalline silica, which is gray and has red pigmentation introduced along fractures. These beds were selectively replaced and are overlaid and underlaid by unreplaced limestone.

Pink jasperoid most commonly occurs as nodules replacing Escabrosa limestone. These nodules are generally spheroidal in shape and may be solid silica or a jasperoid rim surrounding a calcite core. Few nodules exceed 6 inches in maximum dimension, but some are as much as 12 inches in length (pl. 14-B, and pl. 15).

Microscopic examination reveals that the jasperoid is comprised of innumerable spherical aggregates of radiating quartz crystals. Few of these quartz spherules exceed one millimeter in diameter. Calcite in the interstices between the quartz spherules is partly replaced by a mosaic of microcrystalline quartz grains, and bands of fibrous chalcedonic quartz coat the spherules, fill fractures, and line voids within the mass. Specular hematite flakes are included within some of the jasperoid. Pink pigmentation is concentrated at both the inner and outer surfaces of the jasperoid shells.

There is no evidence for dolomitization of the limestone in the vicinity of the jasperized areas.

Field observation suggests that jasperoid nodules began their
JASPERIZED BED OF ESCABROSA LIMESTONE
A. Weathered dip slope of jasperized limestone bed. View easterly, Desert Queen Hill. 
B. Closeup showing nodular character of replacement.
development as spherical aggregates of radiating quartz crystal needles dispersed throughout the limestone. Frequently, these quartz spherules were oriented about a common center and enclosed a spheroidal volume of limestone. These quartz spherules apparently grew in number until they coalesced into a shell enclosing a core of white, crystalline calcite. The shell continued to grow by the addition of quartz spherules to its surfaces.

The peculiar "growth" of the nodular jasperoid, from numerous points of replacement, suggests that some original structure of the limestone, perhaps organic, guided its development. Unfortunately, the limestone of the jasperized areas is sufficiently reconstituted to obscure the original structure of the rock.

Jasper has been reported in many mining districts associated with carbonate rocks. It frequently bears a spatial relationship to ore, although there may be some doubt as to the genetic relationships. At Tintic, Lovering (1949, p. 56-57) found that jasperization preceded the ore-bearing fluids. The mechanism by which silica is transported into limestone is somewhat obscure, but most workers agree that it is a hydrothermal phenomenon. Lovering (1949, p. 56-57) concluded that the jasperoid at Tintic was formed from "nearly neutral bicarbonate solutions that were still undersaturated with bases."

The jasperoid at Jackrabbit is apparently a late-magmatic phenomenon. Its common localization below, but not above, andesite
porphyry sills may be explained by assuming that the jasperizing solutions rose along the same vents followed by the intrusive magma and were diverted outward, beneath the sills, because they could not penetrate the overlying blanket of andesite porphyry.

No ore mineralization has been found in the jasperoid.

Silicified Escabrosa Limestone

Irregular masses of brecciated, silicified Escabrosa limestone have formed adjacent to the northeast-striking veins on Desert Queen Hill. This silicified limestone is light pinkish to greenish gray. Partially replaced limestone containing visible quartz aggregates grades into complete replacement by very fine-grained quartz.

With the aid of the microscope, this limestone is seen to be replaced by spherical radiating fibrous aggregates of quartz and by a mosaic of interlocking quartz grains. Individual quartz fibers do not exhibit visible prism faces but the hexagonal terminations are normally well developed. Most of the quartz fiber aggregates show many successive layers of growth. Spaces between the quartz fiber aggregates are filled with a mosaic of microscopic to submicroscopic quartz grains. No pyrite or ore minerals are found enclosed within this silicified limestone.

Escabrosa limestone was silicified adjacent to northeast-striking veins, particularly at intersections with ruptured bedding
planes and steep faults. This relationship suggests that permeability of
the limestone was a major factor in localization of silicification.

The silicified limestone is thoroughly brecciated. Few breccia
fragments exceed 6 inches and 80 percent are less than 2 inches in max-
imum dimension. Most of the breccia fragments give the impression of
being corroded, and their general appearance is uniform in each occur-
rence. The material which cements these fragments is of two types:
(1) clear, crystalline quartz, pyrite, and ore minerals (pl. 16); (2)
manganoan calcite pervaded by pyrite and minute, acicular quartz crys-
tals (pl. 17). Nonsilicified, relatively unbroken limestone beds under-
lie and overlie the breccia masses.

The process of brecciating localized bodies of silicified lime-
stone is not completely understood. The tectonic activity which un-
doubtedly accompanied mineralization must have aided the brecciation
process. The corroded appearance of the breccia is suggestive that
leaching of unreplaced limestone, and perhaps some of the quartz,
within the silicified bodies, may have been a factor contributing to brecc-
ciation.

Field evidence indicates that Escabrosa limestone was silici-
fied after the development of pink jasperoid and prior to the introduction
of pyrite or ore minerals. The limestone was brecciated after silicifi-
cation was essentially complete. Early pyrite and crystalline quartz
may have been introduced during brecciation.
BRECCIATED, SILICIFIED ESCABROSA LIMESTONE

A. Irregular body of silicified limestone. Stained vertical fractures near top of picture are feeders. Bedding plane and feeding fractures control the shape of the replacement body. View northerly, Desert Queen Hill.  

B. Boundary between brecciated silicified limestone containing ore mineralization (left), and non silicified limestone (right). Desert Queen Mine.
BRECCIATED, SILICIFIED ESCABROSA LIMESTONE

A. Breccia mass underlain by non-brecciated, mineralized limestone. View northerly, Desert Queen Hill. B. Closeup of breccia showing the range of fragment sizes.
Although silicification and brecciation preceded ore mineralization, brecciated, silicified limestone is the host for ore minerals. The fluids that carried the later ore minerals very likely followed the same channels as the solutions that introduced the early silica.

Alteration of Escabrosa Limestone Adjacent to Veins and Replacement Bodies

Many mineralized fault structures, of minor displacement, cut Escabrosa limestone. Most of these appear to have fed small, replacement-type mineral bodies and do not contain significant amounts of ore. Other faults with appreciable displacement may contain potential ore bodies. Alteration of limestone adjacent to both types of mineralized faults is similar.

Along minor mineralized structures, where recrystallization has not been sufficient to obliterate the effects of shearing, the limestone acquires a fibrous appearance from preferential leaching, parallel to the planes of shearing. Pyritohedral pyrite replaces the calcite filling the fault, and to a lesser extent, the limestone of the fault walls. Within the fault zone manganese oxides are abundant.

Where mineralization has been more intense, the limestone within and adjacent to the fault is completely recrystallized. Pyrite replacement becomes more pervasive but is most abundant along planes of shearing. Some acicular quartz crystals develop within the
recrystallized limestone, and black manganese oxides stain both the vein filling and the vein walls. These darker mineralized structures contrast conspicuously with the surrounding limestone.

Small, vein-fed, replacement mineral bodies have formed within the Escabrosa limestone. These mineralized bodies are normally surrounded by an envelope of recrystallized, pyritized, manganoan limestone, but the alteration is generally slight.

A shell of earthy manganese oxides normally lies between the silicified replacement bodies and the surrounding limestone. This manganese oxide shell is generally thicker along the sides and bottom of the replacement bodies than at the top, suggesting that the manganese oxide is supergene.

Alteration of Andesite Porphyry

All andesite porphyry within the Jackrabbit area is altered to some degree. In most specimens, plagioclase phenocrysts are cloudy and some are epidotized; hornblende and biotite phenocrysts have a greenish or silvery appearance against a greenish-gray groundmass. In more highly altered specimens, the rock is bleached and plagioclase phenocrysts are soft and clayey.

Microscopic examination reveals that even in the less altered specimens, both the phenocrysts and groundmass are extensively sericitized. This sericitic alteration may be due, in part, to deuteric
processes, but much of it probably represents a pervasive hydrothermal alteration of the andesite porphyry.

Adjacent to veins, the andesite porphyry is highly altered. Microscopic examination of this altered rock reveals: (1) a marked increase in quartz content, both as veinlets and as grains growing within the groundmass; (2) a pervasive conversion of the sericitized oligoclase phenocrysts and sericitized feldspathic groundmass to hydromica; (3) conversion of much of the biotite and hornblende phenocrysts to muscovite; (4) extensive pyritization. The porphyritic texture of the rock is obliterated within several feet of the vein walls. Farther away from the vein, the quartz and clay content diminishes and the rock becomes more sericitic.

Argillic alteration is limited to the andesite porphyry adjacent to veins, and seems to have been effected by solutions which moved outward, into the walls from these veins. It apparently was superimposed upon a more pervasive sericitic alteration.

This alteration study is not sufficiently comprehensive to link recognized alteration stages in andesite porphyry with corresponding alteration stages in the limestone.
Alteration Related to Spring Waters

Thin-bedded, silty, calcareous units of the Abrigo and Martin formations crop out along the southern and eastern sides of Desert Queen Hill and Turning Point Hill and have been locally leached and bleached adjacent to bedding planes and fractures. This alteration is well developed where the beds have been extensively fragmented. Even within the most affected units, however, cores of the fragments are generally unaltered, retain their characteristic sedimentary lithology, and are oriented parallel to the general bedding attitude (pl. 18). Where alteration is well developed, altered material may constitute as much as 60 percent of the rock.

The product of alteration is a light gray to white, porous, calcareous substance. Where the siltstones of the upper Martin formation have been affected, the altered material is a uniformly bleached mass of small rock fragments and calcium carbonate cement. The altered rocks appear to contain less silt and magnesium than their unaltered counterparts.

Examination of the altered material indicates that it is primarily re-worked calcareous rock. The alteration process was apparently one of leaching and material removal rather than one of material addition. The increased porosity and leached appearance of the altered rock support this suggestion. The color boundary between
ALTERATION RELATED TO SPRING WATERS

A. Porous mass of small rock fragments in calcium carbonate cement derived from calcareous siltstone of the upper Martin formation. Turning Point Hill.

B. Calcareous residue along fractures and bedding planes derived from leaching of silty, dolomitic limestone of the upper Abrigo formation. Desert Queen Hill.
bleached and unbleached rock is generally abrupt and its position is controlled, in part, by minor fractures, suggesting a progressive encroachment of alteration outward away from the solutional conduits.

These altered calcareous rocks are spatially related to travertine aprons deposited upon the present bedrock surface. Much of the alluvial material within the area is travertine cemented detritus, attesting to the abundant outpouring of calcareous spring waters. This relationship cannot but suggest that the alteration was effected by waters which issued at the surface as springs. The abundance of travertine yet remaining suggests that springs were active until relatively recent times, probably during much of the time oxidation and leaching of the mineral bodies were taking place.

Significance of Rock Alteration

Rock alteration at Jackrabbit is of great potential significance as a guide to ore. Sericitic and argillic alteration of andesite porphyry become most pronounced in the vicinity of the major productive veins. This study was not sufficiently detailed to suggest the presence or absence of undiscovered veins in andesite porphyry, but such a study is technically feasible.

Mineral staining of the limestone readily discloses feeder faults, or channelways along which mineralizing solutions have moved. Ore minerals have replaced the limestone at favorable locations adjacent
to these feeder structures. Appreciation of the function of these structures as feeders should guide exploration for replacement mineralization.

Of somewhat less direct practical significance, alteration provides a clue to the history of intrusion and mineralization which may tentatively be summarized as follows: (1) intrusion of dry, viscous andesite porphyry magma as dikes and sills; (2) injection of pebble dikes concurrent with the development of pink jasperoidal alteration; (3) release of corrosive solutions which effected thinning of the calcareous units; (4) silicification of Escabrosa limestone adjacent to northeast-striking veins; (5) brecciation (by solution?) of the silicified limestone; (6) early (barren) mineralization marked by the introduction of crystalline quartz, pyrite and manganese minerals into northeast-striking veins and masses of brecciated silicified limestone; (7) late (productive) mineralization marked by the introduction of lead, zinc, gold, and silver minerals into northeast-striking veins and masses of brecciated, silicified limestone; (8) leaching of calcareous sediments by thermal(?) waters which issued at the surface as springs.
Structure

Summary of Deformation

Precambrian and Paleozoic Deformation

The evidence for profound deformation is recorded in schistose rocks of the Early Precambrian era. During the Late Precambrian and Paleozoic eras, central southern Arizona was a fluctuating basin of deposition which was elevated to or above the level of the sea at the end of Late Precambrian time (Darton, 1925, p. 37) and during Ordovician, Silurian, early Devonian, and late Mississippian times (McClymonds, 1959, p. 82). These crustal fluctuations were epirogenic, and Late Precambrian and Paleozoic sediments are uniformly parallel bedded throughout the section at Jackrabbit. Intrusion of diabase into the Late Precambrian sediments, a widespread phenomenon, normally inflated the sedimentary pile; deformation was minimal.

Mesozoic Deformation

No Mesozoic rocks lie within the northern Slate Mountains.

Heindl (1959, p. 3) stated:

The Triassic and Jurassic periods in southern Arizona were times of uplift and erosion. Locally, there were pre-Cretaceous intrusions and eruptions of volcanic rocks, but, in general, the uplift was epirogenic....
During Late (Jurassic) and Cretaceous time, the development of the northeast-trending Sonoran geosyncline (in southeastern Arizona) was accompanied by orogeny, intrusion, eruption, and continental sedimentation as well as typical marine sedimentation.

Carpenter (1947, p. 40) reported more than 600 feet of supposed Cretaceous continental sediments resting upon Pennsylvanian limestone in the Vekol Mountains. Richard and Courtright (1954, p. 1905) noted over 5,000 feet of Cretaceous continental deposits overlying Paleozoic limestones in the Silver Bell Mountains. McKee (1951, pl. 3) indicated that several hundred feet of lower Cretaceous strata probably were deposited over the Slate Mountain area, but that evidence for upper Cretaceous sedimentation is lacking.

These data suggest that the Jackrabbit area was uplifted during parts of Triassic and Jurassic times, and that part of the upper Paleozoic beds were eroded. During early Cretaceous time, continental sediments may have covered the area, but these have been completely removed by erosion during late Cretaceous or Tertiary time. No evidence within the area suggests significant deformation during Mesozoic time.

Cenozoic Deformation

Of southern Arizona Heindl (1959, p. 3-4) wrote:

Post-Miocene, pre-Pliocene thrust faulting and associated uplift are the dominant structural features within the present mountain ranges.... Thrusting was in part
contemporaneous with and in part followed by the intrusion and extrusion of sequences of igneous material ranging in composition from rhyolite to andesite and by the deposition of sedimentary rocks. Much of the mineralization in this region is associated with the Mesozoic-Tertiary deformation and intrusion.

The last stage of Tertiary volcanism older than the Tertiary-Quaternary valley fills included the extrusion from local sources of extensive andesitic and basaltic flows, associated with some rhyolitic deposits. The distribution of these late Tertiary volcanic rocks suggests that they were deposited in large valleys. This surface and volcanic rocks deposited on it were warped into broad crenulated folds. More or less contemporaneously, the high-angle faulting that characterizes the present basin-and-range structure and topography was superposed roughly parallel, or at acute angles, to the trends of the warping.

This description of the igneous and structural history of southern Arizona since middle Tertiary time corresponds closely with the history recorded in rocks of the Jackrabbit area after emplacement of the andesite porphyry. Most of the warping and complex faulting appears to have accompanied or followed this intrusive interval, suggesting that the emplacement of andesite porphyry at Jackrabbit was a middle Tertiary to late Tertiary event.

Structure of the Andesite Porphyry

Internal Structure

Andesite porphyry at Jackrabbit has developed excellent foliation and lineation, primarily from flowage alignment of hornblende crystals (pl. 9). The pattern of this internal structure suggests the
shapes of the intrusive bodies, the mode of intrusion, and the nature of post-intrusion deformation.

**Shapes of Intrusive Bodies**

The arcuate pattern of steep foliation, in andesite porphyry adjacent to the Jackrabbit vein, suggests that the magma rose steeply through a constricted opening at this position. The more gently dipping foliation and well-developed lineation southeast of the Jackrabbit shaft, indicates that here the magma moved laterally into the upper Escabrosa limestone as a sill-like mass.

At Turning Point Hill, foliation with a moderate northerly and northwesterly dip and well-developed north- to northwest-plunging lineation suggest that this magma was introduced north of Turning Point Mine, in an area now covered by alluvium, and spread southerly and southeasterly into the lower Escabrosa limestone as a sill-like mass.

Foliation with a moderate northwest dip, and lineation with a northwest plunge, suggest that the andesite porphyry at Desert Queen Mine is the infaulted remnant of a sill. This sill probably was, at one time, continuous with the sill southeast of Jackrabbit Mine.

The minor andesite porphyry outcrop on Desert Queen Hill between the Jackrabbit Mine and the Desert Queen Mine contains the only south-dipping foliation and southerly plunging lineation within the mapped area. The origin of this anomalous outcrop is not clear, but
it may be an apophysis of an underlying sill.

Mode of Intrusion

Limestones of the Jackrabbit area exhibit abundant structural evidence that they were forcefully intruded by the andesite porphyry magma. Features such as large-scale rupturing of bedding planes in the intruded sedimentary rocks, drag folds overturned to the southeast, tearing of sedimentary rocks parallel to the direction of intrusion, and silling of large masses of cool magma into a thick limestone sequence, indicate forceful intrusion as the prevailing mode of emplacement.

Localization of Intrusions

Hogue (1940, p. 18) described the Dividend fault as a major northeast-trending structure that contains an andesite porphyry dike some 250 feet thick. This fault and dike are about half a mile southwest of Turning Point Hill, directly in line with and striking toward the Turning Point and Jackrabbit intrusions. This alignment of intrusive centers suggests that intrusions at the Turning Point Mine and at the Jackrabbit Mine rose along the same major, northeast-striking fault zone. Although the Dividend fault is not readily discernible within the mapped area, the recognition of its presence is vital in understanding the intrusive history at Jackrabbit.
Post-Consolidation Faulting

Examination of the foliation pattern at the three major andesite porphyry exposures indicates that each has been offset by faults. At both the Jackrabbit Mine and the Turning Point Mine, foliation strikes into limestone walls with marked angularity. Each fault strikes slightly north of west and shows normal movement with the south side down. At Desert Queen Mine, lineation plunges, at moderate angles, into the northeast-striking Desert Queen vein system, indicating major normal movement along northeast-striking faults after the introduction of andesite porphyry and before the advent of mineralization.

Faulting

Boundary Faults

The Boundary faults are major west-northwest-striking structures along the north and south margins of the Jackrabbit area (pl. 1). Between these faults, a graben which contains intruded and mineralized Escabrosa limestone was downdropped 2,000 to 3,000 feet. The North Boundary fault does not crop out, but its structural effect is quite apparent. Its vertical component of displacement is estimated to be 3,000 feet with the south side relatively downdropped (pl. 4). Its horizontal displacement is not known.
The South Boundary fault is composed of two branches interconnected by sigmoid-like fault structures. The history of movement along the South Boundary fault zone has, no doubt, been complex. The obvious movement has been dip-slip, and along both branches, the dip-displacement has dropped the north sides. The vertical component of this movement is about 1,000 feet along the south branch, and about 900 feet along the north branch. Along both branches, displacement tends to increase toward the southeast.

The direction of horizontal movement along the South Boundary fault zone is difficult to determine. Evidence is noted to suggest both left-lateral and right-lateral movement.

Left-lateral movement along parallel, northwest-striking faults should tend to open tension fractures with a northeast strike. The northeast-striking sigmoid structures that connect branches of the South Boundary fault, and the northeast-striking veins, form the pattern that theory predicts for tension fractures opened by left-lateral movement along the Boundary faults.

Right-lateral movement is suggested by the swing in strike of beds adjacent to the South Boundary fault, and by the curvature of tear faults into the South Boundary fault on Turning Point Hill. The small drag folds and thrusts along the south flank of Desert Queen Hill (pl. 3) are interpreted to represent the complex structure generated by a northeast-trending anticline which is asymmetric and oversteepened to
northwest; this is the theoretical attitude of an anticline generated by a northwest-striking, right-lateral strike fault (Moody and Hill, 1956, p. 1214).

Variation in apparent vertical displacement, associated drag folds, and intense brecciation (pl. 19) are criteria suggesting strike movement along fault zones (Moody and Hill, 1956, p. 1214). These features all occur in association with the South Boundary fault, however, the apparent lack of major offset in the Dividend fault zone argues against any large-scale horizontal movement since the formation of the Dividend structure. It seems likely, in view of the conflicting evidence, that both right-lateral and left-lateral movements have occurred along the Boundary faults, but in neither case was the movement extensive.

Mayo (1958, p. 1172) described the Texas lineament as:

"...great belt of transverse structures (which) forms the southern border of the tectonic framework of the western U.S. ... Strands within the belt, as in southern Arizona, are marked by nearly east-west faults and elongated or aligned intrusions. The entire zone in southern Arizona may be more than 150 miles wide." Because the Boundary faults at Jackrabbit are parallel to its trend, they may be part of the Texas lineament.

Left-lateral movement is predominant along faults that compose the Texas lineament (Mayo, oral communication), and this may account for the evidence of left-lateral movement along the South
BRECCIA ALONG THE SOUTH BOUNDARY FAULT
A. Brecciated Mescal limestone forming an erosion-resistant rib. View northwest, Turning Point Hill. B. Closeup of Mescal limestone breccia fragments showing varying degrees of rotation.
Boundary fault. Evidence of right-lateral movement may derive from temporary, local reorientation of compressive stress, as when andesite porphyry magma pushed its way along the Dividend fault zone into the higher levels of the crust.

Neither vein structures nor any mineralization is found to cross the Boundary faults into the late Precambrian sedimentary rocks. The extensive breccias along the South Boundary fault zone have been prospected by surface pits and underground exploration, but neither the fault outcrops, the dumps, nor the accessible underground workings, indicate hypogene mineralization. The apparent lack of hypogene mineralization in open breccias along the South Boundary fault indicates that the Boundary faults were tight structures at the time this mineralization took place. Probably much of the movement, and most of the brecciation, occurred after mineralization. Sparse pyritization and silicification of the Mescal limestone adjacent to the fault suggests that movement on the South Boundary fault began before the deposition of ore minerals.

Thrust Faults and Drag Folds

Low-angle faults cut through sedimentary rocks in two locations. A single thrust, associated with a drag fold on the south side of Turning Point Hill, cuts limestones of the Martin formation adjacent to the andesite porphyry intrusion. The drag fold is overturned to the
southeast, suggesting that both the fold and thrust fault formed from compressive stresses directed southeastward at low angles (pl. 1).

A group of thrust faults cut the drag fold area along the south side of Desert Queen Hill (pl. 3). The Mescal limestone has been crushed, contorted into drag folds, and thrust faulted. The apparent direction of thrusting is southeastward. This deformation appears to have been generated by strike faulting along the South Boundary fault.

**Bedding Faults**

Ruptured bedding planes are common throughout the entire sedimentary section but are conspicuously concentrated in the limestone-siltstone sequences. The Mescal limestone, Abrigo formation, Martin formation, and upper Escabrosa limestone have undergone severe deformation by rupture along bedding planes. Such faulting, perhaps accompanied by dissolution, may cause thinning of beds. Conspicuous examples of thinning are noted at Turning Point Hill, where 114 feet of dolomitic limestone of the upper Abrigo formation is reduced to 50 feet, and 200 feet of Martin formation is reduced to 160 feet.

Neither the amount of displacement nor the direction of motion along these bedding plane faults is known. If the bedding faulting accompanied intrusion and the known thrusting, movement along the beds would have been southeastward, away from the andesite porphyry intrusion.
Tear Faults

A series of curved, northwest-striking, southwest-dipping fractures have broken the limestones of Turning Point Hill between the andesite porphyry sill and the South Boundary fault. Movement along these fractures was slight, but predominantly along the strike, and had the effect of extending the center of the hill to the southeast (pl. 1). These tear faults may reflect southeastward acting compressive stresses generated within the sedimentary rocks by an expanding magma chamber.

Normal Faults

The Desert Queen Hill-Jackrabbit Hill anticlinal arch has collapsed along a series of northwest-striking, southwest-dipping normal faults. Many of these faults have had only slight movement along them, but some, particularly those adjacent to the South Boundary fault, show vertical displacements as great as 150 feet. Hinge-type movement appears common with the greater displacements toward the southeast.

Movement along these northwest-striking normal faults must have begun as early as the last stage of intrusive activity, for the pebble dike on Desert Queen Hill is injected into one of them. Certainly most of the movement along these structures took place prior to mineralization, for they are distinctly older than the veins which cross them without offset.
Almost all northeast-striking faults within the Jackrabbit area are mineralized (pl. 1). The Jackrabbit vein, Turning Point vein, and the vein system at the Desert Queen Mine are northeast-striking, southeast-dipping normal faults which show several tens of feet of dip displacement. The system of feeder veins southeast of Desert Queen Mine has not offset the structures it crosses. Only the Boundary faults appear to have been active since the formation of the veins.

The confinement of mineralization almost exclusively to northeast-striking faults suggests that tensional forces acted along a northwestward direction at the time of mineralization. Northeast-striking tension fractures parallel the Dividend fault zone and may have been formed upon relaxation of southeastward acting compressive stress which accompanied intrusion of this zone. Northeast-striking tension fractures may have resulted from strong regional compression directed northeastward and southwestward. Northeast-striking tension fractures could have been generated by left-lateral movement along the Boundary faults.

Flexuring

Sedimentary rocks between the North Boundary fault and the South Boundary fault are warped into a gentle, northwest-plunging syncline and anticline. Turning Point Hill, north of the South Boundary fault, is a very shallow syncline and the Jackrabbit Hill-Desert Queen
Hill high area is an anticline which has partially collapsed along north-west-striking normal faults. These flexures may have been produced by movement along the Boundary faults, but, more likely, are a manifestation of the widespread Late Tertiary warping described by Heindl (1959, p. 3-4).

Tilting

All sedimentary units of the Jackrabbit area, south of the North Boundary fault, have northerly to northwesterly dips. Northwest-dipping late Precambrian and Paleozoic strata crop out all along the western flank of Slate Mountains and were clearly tilted as a result of the elevation of this mass of early Precambrian schist. The date of this event is not known. We may only presume that the Slate Mountains were uplifted late in Tertiary time, during development of the basin and range topography.

Mineralization appears to have occurred after tilting of the sedimentary rocks, suggested by the formation of most replacement bodies up dip from their feeding structure (figs. 6 and 7).

History of Tertiary Deformation

A history of Tertiary deformation at Jackrabbit can be reconstructed from the foregoing observations. Any such reconstruction must be regarded as a working hypothesis, for much of the information
upon which it is based is subject to multiple interpretations.

During Middle Tertiary to Late Tertiary time, crustal stresses acting within the Jackrabbit area produced left-lateral movement along major, west-northwest-striking Boundary faults. At some time during this interval, possibly contemporaneous with the elevation of Slate Mountains, the limestone blocks between the Boundary faults were warped into a broad syncline and anticline, and andesite porphyry magma invaded the northeast-striking Dividend fault zone.

The magma rose along the Dividend fault, pushed the wallrocks aside, and forced its way into the middle Paleozoic calcareous sedimentary rocks as sills. This forceful intrusion locally reoriented the crustal stress at Jackrabbit to produce limited right-lateral movement along the South Boundary fault. Compressive stress, directed southeastward as a result of the expanding magma chamber, produced drag folds and thrust faults, bedding faults, and tear faults.

Near the end of this intrusive interval, the Jackrabbit Hill-Desert Queen Hill arch partially collapsed along a series of northwest-trending normal faults. At a somewhat later time, minor adjustment took place along a set of northeast-striking tension fractures, and these fractures were mineralized to form the Jackrabbit, Desert Queen, and Turning Point veins.

After mineralization, relaxation of stress allowed downdropping of the structural blocks between the Boundary faults.
General Statement

Mineral deposits within the Jackrabbit area are, almost without exception, thoroughly oxidized. Oxidation was complete to the lowest (400-foot) level of the Jackrabbit Mine (E. R. Zimmerman, oral communication). The only hypogene ore minerals found is remnant galena in limestone replacement bodies east of the Desert Queen Mine (fig. 7). From remnant hypogene mineralization and from oxide minerals, a very simple suite of hypogene sulphide minerals may be postulated. Paragenesis and mineralogy are believed to be essentially similar for both veins and replacement bodies.

Hypogene Minerals

Ore Minerals

Galena (PbS) - Galena is found as residual grains in cores of cerussite masses within incompletely oxidized replacement pods. Galena was deposited as cavity filling in vuggy, crystalline quartz-pyrite
replacement masses, and within brecciated, silicified fault fillings.

**Sphalerite** (ZnS) - No hypogene zinc mineral was found, but because secondary zinc minerals are abundant, it may be assumed that primary zinc minerals were present. In mineral bodies of the western United States, sphalerite is the most common hypogene zinc mineral, and is, therefore, the most likely hypogene zinc mineral to have formed within the Jackrabbit area.

**Silver** - The form of hypogene silver has not been determined. There is a consistent association between silver and galena, and silver and cerussite, which is a direct oxidation product of galena. From this association, we may conclude that silver was deposited contemporaneously with galena, probably as microscopic intergrowths of silver and lead sulphide (Emmons, 1917, p. 625).

**Gold** - Gold is present in the Jackrabbit mineral bodies but was not observed in any of the specimens examined. The form of hypogene gold has yet to be determined, but as the gold is free-milling and only partly recoverable by gravity-amalgamation processes, it is likely that gold was contained within base metal sulphides and has been liberated by oxidation.
**Gangue Minerals**

**Quartz (SiO₂)** - Quartz is the most abundant gangue mineral. Within the limestone replacement bodies, quartz, growing at the expense of brecciated, fine-grained silicified limestone, becomes coarsely crystalline with euhedral crystals projecting into vugs. In the veins, quartz replaces brecciated fault fillings, and quartz crystals encrust the surfaces of breccia fragments. The growth of this early crystalline quartz apparently began prior to deposition of the earliest pyrite.

**Pyrite (FeS₂)** - Pyrite is found wherever mineralizing fluids appear to have been present. Minute crystals, of pyritohedral habit, replace andesite porphyry and limestone walls of mineral bodies, and are intimately admixed with ore minerals. Pyrite is enclosed by and deposited upon crystalline quartz, and was the earliest sulphide mineral.

**Manganese** - No hypogene manganese minerals are found in the Jackrabbit area, but rhodochrosite (MnCO₃) could have released much of the manganese so prevalent now as black oxides.
Minerals of Uncertain Origin

General Statement

The oxidized mineral bodies at Jackrabbit exhibit a suite of minerals which cannot be ascribed, with confidence, to either the hypogene or supergene facies. These minerals are distinctly later than the sulphide deposition and, although they formed within an oxidizing environment, the origin of certain elemental constituents is obscure. This suite of minerals does not appear to be forming within the zone of oxidation at present.

Ore Minerals

Willemite \((\text{ZnSiO}_4)\) - Willemite is the most abundant zinc mineral. It formed as masses of tiny, honey-brown to clear, short, hexagonal prisms, filling fractures and replacing limestone wallrocks adjacent to mineral bodies. Willemite formed contemporaneously with or later than manganese oxides, as manganese oxide dust is enclosed within some willemite crystals.

Vanadinite \((\text{PbClPb}_4\text{VO}_4)_3\) - Vanadinite forms beautifully crystallized masses, scattered hexagonal prisms, and crusts. Coarse, crystalline vanadinite masses were deposited with earthy manganese oxides in vugs in limestone vein walls and some vanadinite crystals.
enclose particles of manganese oxides. Tiny prisms and crusts formed farther away from the oxidized mineral bodies as though precipitated from migrating solutions. Vanadinite has not been observed forming directly from either galena or cerussite. A few tiny crusts of vanadinite coat willemite, suggesting that some vanadinite formed later than willemite.

**Pyromorphite** \((\text{PbCl})\text{Pb}_4\text{(PO}_4\text{)}_3\) - Pyromorphite forms rare encrustations or tiny hexagonal domes coating fault breccia or within vugs in silicified wallrock. It appears to be contemporaneous with vanadinite but the relationship is nowhere clearly demonstrated.

**Descloizite** \((\text{R}_3\text{V}_2\text{O}_8\text{'}\text{R(OH)}_2)\) - Descloizite forms tiny, red orthorhombic crystals which coat vanadinite at the Turning Point Mine. Descloizite is clearly later than vanadinite, where the two are found together, and encrusts and is intergrown with earthy manganese oxides. Descloizite grows upon, and is coated by late, clear, crystalline quartz.

**Gangue Minerals**

**Manganese Oxides** (composition not determined) - Black, earthy manganese oxides accompany all mineral bodies. They form stains and sooty encrustations in the walls of veins, and saturate the limestone adjacent to replacement bodies. The formation of most of these manganese oxides by downward percolating waters is suggested
by their abnormal concentration along the sides and bottoms of replacement bodies.

Quartz (SiO₂) - Late clear, crystalline quartz was deposited contemporaneously with desclaozite in the Turning Point Mine. This late quartz formed as multiple, scalenohedral terminations. Prism faces are not well developed.

Chalcedony, of probable hot-spring derivation, coats rock fragments and covers small vanadinite crystals in breccias along the South Boundary fault.

Supergene Minerals

Ore Minerals

Cerussite (PbCO₃) - Cerussite is a direct oxidation product of galena. It forms as pearly-white crusts and masses at the site of deposition of hypogene galena. All cerussite specimens examined spectroscopically contain substantial amounts of silver.

Hydrozincite (2ZnCO₃·3Zn(OH)₂) - Hydrozincite forms thin white crusts lining cavities and filling fractures in oxidizing mineral masses. Much of the pulvrent yellow limonite which results from the oxidation of mineral bodies contains zinc in the form of hydrozincite.

Silver (Ag) - One specimen of quartz vein material from the
dump of the Jackrabbit Mine was found to contain native silver. The silver forms flakes and thin sheets within fractures in the rock.

**Cerargyrite (AgCl)** - Cerargyrite has been reported in ores from the Jackrabbit Mine (E. R. Zimmerman, oral communication), but the author was unable to verify its presence.

**Limonite (hydrated iron oxide)** - Limonite forms red to yellow, earthy masses within vugs in oxidized ores, and encrustations staining rocks adjacent to all mineral bodies. Limonite derived from pyrite ranges from brick red to dark brown in color, while limonite derived from lead and zinc minerals is yellowish to brownish in color and may contain some jarosite. Spectroscopic analyses indicate that the yellow limonite contains substantial amounts of lead and zinc as well as iron, and may, locally, be classed as ore.

**Paragenesis**

Crystalline quartz was the earliest mineral formed during hypogene metallization at Jackrabbit. Before deposition of this early quartz ceased, deposition of pyrite began and pyrite continued to form after the cessation of quartz deposition. Later, gold, argentiferous galena, and sphalerite (?) were deposited in vugs in the sponge-like quartz-pyrite masses. Some manganese carbonate minerals may have formed at this time.
Following the deposition of hypogene sulphide minerals, the minerals of uncertain origin formed. These minerals were stable compounds in the environment prevailing at the time of initial oxidation, but do not appear to be forming in the zone of oxidation today. The earliest of these was willemite which was, at least in part, contemporaneous with earthy manganese oxides. Vanadinite appears to be slightly later than willemite. Pyromorphite may have formed simultaneously with vanadinite, but this relationship is obscure. Descloizite is later than vanadinite, where the two are found together, and contemporaneous with late, clear crystalline quartz.

Willemite crystals exposed in surficial excavations have a leached or corroded appearance, suggesting that willemite is not entirely stable in the present oxidizing environment. Cerussite is, in many specimens, being derived directly from galena. Hydrozincite and cerussite are stable minerals in the present environment.

Environment of Oxidation

Within the veins and replacement bodies, an acid environment, derived from oxidizing pyrite, undoubtedly prevailed. Both zinc sulphide and manganese carbonate (probable constituents of the hypogene mineral bodies) are readily dissolved by sulphuric acid and would, no doubt, migrate in solution until the acidity was neutralized by contact with limestone wallrock. Here, adjacent to the limestone on the outer
margin of the mineral bodies, the manganese precipitated as an oxide and the zinc precipitated as a silicate.

The abundant manganese oxides and sulphuric acid in the oxidizing mineral bodies undoubtedly provided an ideal condition for the secondary enrichment of gold. Any contact with the limestone wallrocks would tend to precipitate the dissolved gold (Emmons, 1917, p. 312). It is possible that the high gold values which encouraged the early prospectors were derived from supergene enrichment.

Takahashi (1960, p. 1097) reported the preferential formation of hydrozincite in the arid environment at Goodsprings, Nevada. Hydrozincite is the stable zinc mineral in the arid environment existing at Jackrabbit today. Willemite, although rarely reported from oxidized lead and zinc deposits of the western United States, is actually not an uncommon mineral. Takahashi (1960, p. 1087) found supergene willemite in the Goodsprings district, Nevada. Peterson (1950, p. 104) has noted willemite in oxidized lead and zinc deposits near Globe, Arizona. Willemite at Jackrabbit replaces and encrusts limestone wallrock adjacent to the mineral bodies. It does not appear to be completely stable, however, in the present oxidizing environment. This apparent change in the stable form of zinc suggests a change in the physiochemical environment at Jackrabbit from the time of initiation of oxidation to the present. Takahashi (1960, p. 1099) suggested that willemite is a stable mineral at elevated temperatures. Perhaps the willemite in
the mineral bodies at Jackrabbit indicates a heated environment at the
time of initial oxidation.

Anglesite (PbSO₄) was probably the stable lead mineral during
the earlier (acid) stages of oxidation. Upon the complete oxidation of
pyrite, the prevailing environment must have changed from acid to
neutral or alkaline, wherein cerussite (PbCO₃) became the stable form
of lead.

Spring waters discharged within the Jackrabbit area since the
latest episode of major faulting (as shown by travertine aprons on the
present erosion surface), and springs appear to have been active during
an extended period of time. Late chalcedonic quartz, also probably
deposited by spring waters, lines vugs and encrusts breccia fragments
within fault zones. The temperature of these spring waters is not known,
but as this is a region of late Tertiary volcanism it seems likely that
they were, at least in part, heated. We are reminded that a thermal-
spring environment probably existed during much of the time the Jack-
rabbit mineral bodies were undergoing oxidation. These thermal waters
may have provided the heated surroundings necessary to fix the transient
zinc ions as willemite, and could have introduced the vanadium and
chlorine which combined with lead in the mineral bodies to produce
vanadinite.
Origin of Vanadium

Vanadinite is widespread throughout the Jackrabbit area, but is most frequently noted in the vicinity of galena-cerussite masses. Vanadate ions are readily soluble in water and are precipitated by reacting with heavy metal ions (Takahashi, 1960, p. 1112). The mobile vanadate ions were apparently carried into the vicinity of the oxidizing lead minerals and there precipitated as insoluble lead vanadates.

The origin of vanadium found within the oxidized zones of many lead and zinc deposits of the southwestern United States has long been a source for controversy. Newhouse (1934, p. 209-220) suggested that minute quantities of vanadium contained within primary galenas, sphalerites, and pyrites is a common source. Emmons (1917, p. 420) concluded that four sources of vanadium in mineral waters is possible: (1) igneous rocks; (2) sediments derived from igneous rocks; (3) primary ore minerals; (4) organic salts derived from plants and animals. Peterson (1938, p. 50) believed that vanadinite and wulfenite at Mammoth, Arizona, are hypogene and were introduced into the veins along with earthy manganese oxides by highly corrosive solutions after the main period of sulphide deposition. Takahashi (1960, p. 1112) suggested that vanadium contained within shales at Goodsprings, Nevada, was the source for vanadate ions in supergene vanadium minerals. Hewett and Fleischer (1960, p. 1-53) pointed out that primary
manganese oxides and associated minor metals, tungsten, barium, vanadium, lead, and zinc are commonly introduced by hot springs associated with late Tertiary volcanism in the southwestern United States.

It is suggested that oxidation of some lead and zinc deposits in the southwestern United States during late Tertiary time may have been effected by a mixture of mineral-bearing magmatic fluids and oxygenated meteoric water (which, perhaps, issued at the surface as springs), and that the juvenile component of these waters could have introduced the abnormal concentrations of exotic elements, which are so characteristic of some of these deposits.

Classification of Mineral Deposits

At Jackrabbit, oxidation has almost completely destroyed the hypogene sulphide mineral assemblage, the most usable criterion for classifying mineral deposits. In the absence of primary ore minerals, factors such as the vuggy, brecciated character of veins, widespread silicification and quartz overgrowths on breccia fragments, sericitic alteration, and abundant manganese minerals suggest that these deposits formed at relatively shallow depths, perhaps within the leptothermal zone as defined by Graton (1933, p. 187).
Description of Vein Deposits

Form

Vein deposits within the Jackrabbit area are mineral fillings in open spaces and mineral replacement of breccia and wallrocks along fault zones. Crustification is rare, but in some veins, well-formed quartz crystals radiate from the surfaces of breccia fragments. Veins vary from mere stained fractures to as much as 10 feet in thickness. Vein systems may be traced along their strike as far as 2,000 feet.

Walls of veins are frequently sharp, with slickensided gouge planes as structural boundaries. In other faults, however, the vein matter is "frozen" to the walls and the thickness of the vein is controlled by the extent of brecciation and the degree of mineral replacement of the wallrock.

Mineralogy

No primary ore minerals are found in the veins at Jackrabbit. Available evidence suggests that the mineralogy of the veins is similar to that deduced for the replacement bodies, quartz, pyrite, galena, and sphalerite(?), with associated silver and gold. This hypothesis is further substantiated by the formation of the same suite of secondary minerals in both veins and replacement bodies. Secondary minerals include willemite, vanadinite, pyromorphite, descloizite, manganese oxides,
hydrozincite, cerussite, native silver, and limonite. Cerargyrite has been reported from the Jackrabbit vein (E. R. Zimmerman, oral communication).

Alteration

Vein deposits have formed in both andesite porphyry and Escabrosa limestone. Brecciated andesite porphyry is pyritized, silicified and replaced by metallic minerals within the veins, while the wallrocks are pyritized, silicified, sericitized, and argillized. Alteration of the limestone adjacent to the veins includes staining by manganese oxides, pyritization, and silicification. Bleaching occurs, but appears to be a minor feature. Bleached limestone has a porous, leached appearance and is probably produced by acids released from oxidizing pyrite. Brecciated limestone of the vein zones is frequently replaced by very fine-grained silica which terminates in overgrowths of coarse, crystalline quartz.

Ore Controls

Ore mineralization appears to be localized where branching premineral faults intersect the major vein structures at small angles. Brecciation of the wedge of rock within such intersections would increase the permeability of the rock mass and should induce an increased flow
of mineral-bearing fluids through it. The increase in surface area of the brecciated rock would also facilitate its replacement by ore and gangue minerals.

Origin

Vein deposits at Jackrabbit were apparently derived from mineral-forming fluids which rose along the more permeable parts of northeast-striking faults and deposited part of their mineral load by filling open spaces and replacing brecciated rock within the fault channelways. These mineral-forming fluids were later than, but possibly related to, the andesite porphyry intrusions and apparently were introduced from depth along the Dividend fault zone.

Description of Limestone Replacement Deposits

Form

Irregular bodies of quartz and sulphide minerals have replaced structurally favorable masses of Escabrosa limestone adjacent to steeply dipping "feeding" faults. All of the observed replacement bodies are small; the largest probably does not contain more than several hundred tons of mineralized rock.

In each instance the replacement bodies have formed up dip from the point of entry of the mineralizing fluids (figs. 6 and 7). This
consistent relationship suggests that the limestones were mineralized after they were tilted to their present northwestward dip.

Primary ore mineralization is not found outside of masses of silicified limestone. This early silica is microcrystalline to cryptocrystalline, gray to yellowish, and contains no pyrite. It is distinctly earlier than the crystalline quartz which immediately preceded the deposition of ore minerals, and is usually highly brecciated. The brecciation of this early silicified limestone preceded the ore mineral deposition, for the later quartz sulphide bodies are not greatly broken. Later fluids, probably those immediately preceding ore mineral deposition, attacked the early silicified limestone, corroded it and reconstituted it to a fine-grained to crystalline, vuggy, quartz mass which provided the locus for ore mineral deposition.

Mineralogy

Crystalline pyrite has grown within the limestones adjacent to replacement bodies, has encrusted fragments of brecciated silicified limestone, and is contained within the later crystalline quartz of the mineralized bodies. Argentiferous galena and sphalerite(?) filled vugs within the crystalline quartz masses. Secondary lead and zinc minerals have formed in the limestone adjacent to these quartz masses and manganese oxides have stained the surrounding limestones black.

The limestone replacement bodies appear to have contained a
simple primary mineral assemblage consisting of quartz, pyrite, galena, and sphalerite(?) with silver and gold. Oxidation has not been as complete within these replacements as it has been within the veins, and cores of hypogene galena remain within some of the cerussite masses. Supergene minerals found within the replacement bodies include willemite, vanadinite, pyromorphite, manganese oxides, cerussite, and hydrozincite. Associated iron oxides contain lead and zinc.

Alteration

Alteration of limestone adjacent to some replacement bodies is limited to recrystallization and pyritization. In other occurrences, a partial shell of fine-grained, siliceous limestone has formed along the sides and bottom of the bodies. Black manganese oxide staining is conspicuous in limestone adjacent to all mineralized bodies.

Ore Controls

Limestone replacement bodies at Jackrabbit form where a steep, northeast-striking feeder vein intersects a bedding plane fault or a steep northwest-striking fault. Permeability appears to be a more important factor than the chemistry of the limestone, for three intersecting structures (feeder vein, bedding fault, and northwest-striking fault) provide an exceptionally favorable locus for replacement mineralization.
Origin

The limestone replacement bodies at Jackrabbit appear to be genetically related to the same mineral-bearing fluids which produced the vein deposits. Without doubt, these replacement bodies were being formed at the same time mineral matter was being deposited within the veins.

History of Mining

According to Wilson (1934, p. 17):

From 1884 to 1893 the country went through a severe deflation of commodity values. The copper and silver markets fell rapidly resulting in a relative rise in the price of gold. On the demonitization of silver in 1893, practically all silver mining ceased, and only the richest and largest copper mines continued to operate.

From 1893 to 1900, miners from all the old silver camps of the West again turned to the search for gold....

In 1881 the discovery of rich, surface silver ores in the Jackrabbit vein attracted attention to the district. During these early years, the more promising prospects were investigated and most of the mineral production was made. The Turning Point and Desert Queen deposits were exploited, primarily for their gold content, and both flourished and declined between 1898 and 1910. The final closing of the Jackrabbit Mine in 1912, brought to an end this early era of mining.

Since 1912, various promotional schemes and the endeavors of
individuals to profitably exploit these deposits have resulted in intermittent mining activity, apparently with very little financial return. At present, all of the mines and prospects within the area are idle.

There are, to the author's knowledge, no accurate production records for the mines of the Jackrabbit area. It is probable that the combined production of the three major mines (Jackrabbit, Turning Point, and Desert Queen) will not greatly exceed $1,000,000.

**Jackrabbit Mine**

**History, Development, and Production**

The Jackrabbit vein was first located in the year 1881, by Mr. Al Robard. The prospect was purchased from Robard by Judge John D. Walker, who undertook the development of the Jackrabbit Mine (E. R. Zimmerman, oral communication). The director of the mint reported for the calendar year 1883: "The (Jackrabbit) vein is found in contact between lime and porphyry, and is small but exceedingly rich. The average of the shipments of the ore is over 300 ounces to the ton. The deepest shaft is down 90 feet. This claim has paid its way since its discovery." Judge Walker and his brother Lucian are reported to have produced about $1,000,000 in silver and gold from the surface to the water table at 165 feet (E. R. Zimmerman, oral communication).

A. B. Richmond (1919, unpublished report) notes that W. C.
Smith and John Moran operated the property for about a year during 1889 or 1890. A 10-stamp, pan-amalgamation mill was erected during this time and operated for about three months.

According to Tenney (1934, p. 22), the Jackrabbit Mine was acquired in 1892 by the Casa Grande Copper and Gold Mining Company, which was financed from Denver. This company developed the property intermittently during the succeeding 10 years, and constructed a cyanide plant in 1901, which was not a financial success.

By 1903, the vein had been developed and mined to the water table (165 feet). Stoping was more or less continuous along the southernmost 200 feet of outcrop. Three inclined shafts were sunk in the vein. Stoping was conducted from the two southernmost shafts, and the northernmost shaft was used for hoisting.

In 1904, the Jackrabbit property was purchased, by its present owner, the Tube City Mining and Milling Company of McKeesport, Pennsylvania. This organization retained E. R. Zimmerman as manager and Percy S. Rider as field engineer and proceeded to sink a vertical, two compartment shaft to a depth of 420 feet against a heavy flow of water. The original inclined hoisting shaft was deepened to 250 feet and considerable drifting and crosscutting was done on the 250-foot level. Four mining claims were entered for patent in 1908 (fig. 3).

During this period of development, a watercourse was intersected in a drift heading northeast of the vertical shaft on the 400-foot
Figure 3. Map of patented mining claims, Jackrabbit area, Arizona.
level. This additional water increased the mine output to approximately 1,000,000 gallons per 24 hours. A Prescott high-duty, steam-driven pump, with a rated capacity of 1,000 gallons per minute against a 1,000-foot head, was installed on the 400-foot level to handle this flow of water. Water, pumped from the Jackrabbit Mine, supported a thriving farming operation in the fertile Santa Rosa Valley west of the mine.

A winze being sunk in the vein below the 250-foot level was intended to connect with a drift which was being driven southwestward on the 400-foot level, to complete a ventilation circuit. This work was halted in 1912, prior to completion, by the death of Mr. J. W. Painter, president of the organization.

The Tube City Mining and Milling Company produced only a few pounds of sacked high-grade ore from their operation. Since 1912, no work of consequence has been undertaken at the Jackrabbit Mine. During the time of the author's fieldwork, none of the underground workings were accessible.

Geology

The Jackrabbit vein occupies a northeast-striking normal fault which dips about 70° southeast. At the surface, Escabrosa limestone forms the footwall and andesite porphyry forms the hanging wall of the vein. At approximately 60 feet below the surface, andesite porphyry forms the footwall as well as the hanging wall, and this condition
continues to the deepest workings (E. R. Zimmerman, oral communication).

At the surface, the footwall limestone is somewhat recrystallized and stained by black manganese oxides. The hanging wall andesite porphyry is bleached (sericitized), stained pinkish to purplish by limonite, and is mottled black by manganese oxides. A network of quartz veinlets laces the andesite porphyry adjacent to the vein.

The Jackrabbit vein is terminated toward the northeast by a steep, north-trending fault, and is terminated toward the southwest by a steep, northwest-trending fault (E. R. Zimmerman, oral communication). In neither case are field relations sufficiently clear to determine whether these terminating faults are of premineral or postmineral age.

Two hundred feet north of its southernmost exposure, the Jackrabbit vein bends toward the northeast. The vein appears to split at this point, with the split opening toward the southwest. It may be more than coincidental that most of the production has been derived from the southwesternmost 200 feet of the vein.

As the underground workings are inaccessible, the shapes of the ore bodies and the exact extent of the stoped ground could not be determined. Assay data to indicate the tenor of the vein either above or below the water table are lacking, although the near-surface ores are reputed to have been rich.
Three minor mineralized faults have been mapped southeast of the Jackrabbit vein and subparallel to it. These veins indicate minor displacement, show much weaker mineralization than does the Jackrabbit vein, and are probably not of great economic importance, although small ore shoots may occur within them.

The northeast-striking Jackrabbit vein is in alignment with the projection of the Dividend fault zone, suggesting that the Jackrabbit fault resulted from post-intrusion normal faulting along the Dividend fault zone.

Examination of the internal structure of the andesite porphyry at the Jackrabbit Mine reveals an arcuate arrangement of steeply dipping foliation, suggesting that here was a conduit through which the andesite porphyry was introduced from depth. It may be more than coincidental that here, also, was developed the most productive mineral deposit within the area.

The greatest productive potential remaining in the Jackrabbit deposit possibly lies in enriched continuations of the vein to the north and to the south of the terminating faults. The vein matter is completely oxidized to below the 400-foot level, even though the water table stands only 165 feet below the surface today, suggesting that a deeper, drowned, horizon of secondary enrichment may exist. The probability of structurally controlled ore shoots in the vein below the water table should be considered by anyone undertaking future exploration of this
Turning Point Mine

History, Development, and Production

The first development of the Turning Point vein was in 1898 (Tenney, 1934, p. 22). Three fractional claims were entered for patent April 23, 1901, and patent was issued two years later to the Turning Point Gold Mining and Milling Company (M. W. Carpenter, unpublished report). In 1902, a 10-stamp mill was built, but after a short run, the mine and mill were closed. A small amount of high-grade ore was stoped and shipped in 1911 (Tenney, 1934, p. 22).

M. W. Carpenter (unpublished report) gave the following account of the Turning Point Mine:

I first saw the property in 1913, several years after the final shut down. The old mill was standing, housed in a frame building, a store and several other houses were grouped around, all in charge of a watchman.

The mill consisted of a rock breaker and two five-stamp batteries discharging onto amalgamating plates and followed by vanner tables. The meagre information I have gathered from men who knew more or less about the operation is to the effect that recovery of metals in amalgam and concentrate was probably around 60 percent. The only figures I have on values are '$6.00 to $7.00 per ton from the vein just as mined', and that pockets of high grade were sometimes found in the vein running over $100 per ton....

Power was from a steam plant fired on wood brought
in by the Indians. A steam pump in the shaft raised water to run the mill. At that time the mine was making 40,000 gallons of water per 24 hours.

In 1926, Martin Fishback and S. M. Dendy organized the Turning Point Mining Company, a corporation to exploit the Turning Point Mine. The accomplishments of this organization are not known to the author.

A. M. Peck, C. S. McNatt, and Marshall Bartlet rehabilitated the mine in 1938, and constructed a 40-ton gravity mill on the property. After a run of several months, this organization abandoned its operation.

In 1942, the Turning Point Mining Company, comprised of F. C. Merrell, D. C. Hutchins, and F. W. Mitchell, began cyaniding material from the dumps of the Turning Point Mine. This operation continued intermittently until 1946. The mine is idle at present, but underground workings are accessible.

The Turning Point vein is developed by a stulled, inclined shaft which has been sunk in the vein to below the water table. Water stands in the shaft 255 feet below the collar, measured along the incline. Levels have been developed at 74, 145, 184, and 213 feet, measured along the incline, below the collar of the shaft. An aggregate of 850 feet of drifting and crosscutting has been done on these four levels and approximately 30 percent of the developed vein has been mined.

No production figures are available for the Turning Point Mine, but the total value of minerals produced is undoubtedly small. The
present owners of the Turning Point Mine are O. T. Manning, E. L. Harris, and W. M. Mischer.

Geology

The Turning Point vein is localized within a northeast-striking normal fault which dips approximately $65^\circ$ southeast. The collar of the shaft is situated in a sill of andesite porphyry. The vein and shaft penetrate this sill into the underlying Escabrosa limestone. Limestone is first encountered in the footwall of the vein at 128 feet, inclined distance, below the collar of the shaft. Thirty feet below this contact, limestone is encountered on the hanging wall side of the vein, and the dip of the vein flattens to $50^\circ$.

The outcrop of the Turning Point vein is inconspicuous. The portion of the outcrop which initially attracted attention to the vein is now covered by dump. West of the shaft, the vein passes beneath Escabrosa limestone which caps the andesite porphyry sill. The Turning Point fault appears to have cut the andesite porphyry and underlying limestone, but not the overlying limestone cap. Here, brecciation along bedding planes and minor manganese oxide staining provide the only clues that a major mineralized structure lies beneath. An apparent extension of the Turning Point vein crops out within Escabrosa limestone 400 feet northeast of the shaft. Here, the fault structures are silicified and mineralized, and the adjacent limestones are stained by abundant
manganese and iron oxides.

Underground exploration has shown limited mineralization within branching faults in the footwall of the Turning Point vein, but mineralization has been most intense in the highly fractured rock within the Turning Point fault and in the wedges of broken rock at the intersections of branching faults. Essentially all of the mine production has come from a single irregular ore shoot, within the 100 feet of vein west of the shaft. This ore shoot was been mined intermittently down to the lowest level, but the widest ore bodies and the highest grade ore appears to have been found within andesite porphyry above the lower limestone contact. Mineralization appears to weaken downward where both vein walls are limestone.

Enrichment near the top of this ore shoot may be explained by four mechanisms that could have acted singly or in combination: (1) supergene enrichment could tend to concentrate gold values near the top of the ore body; (2) the overlying limestone cap was apparently not broken by the Turning Point fault and may have posed a restrictive barrier to the passage of rising mineral-forming fluids with attendant increased mineral deposition beneath the barrier; (3) fracture characteristics of the andesite porphyry may have tended to increase permeability of rock within the sill; (4) the vein flattens where it enters the lower limestone and any normal displacement along it would tend to increase the permeability of that portion of the vein above the zone of
flattening.

The Turning Point vein is limited toward the west by a steep, north-striking fault zone. This fault zone has been penetrated only on the 74-foot level and the limited crosscutting done did not disclose a westward extension of the vein. Mineralization diminishes markedly a short distance northeast of the Turning Point shaft.

Study of the foliation and lineation patterns within the andesite porphyry intrusion at Turning Point Mine suggests that the intrusion originated to the north or northwest of the Turning Point shaft, an area now covered by alluvium, and spread southward and eastward into the lower Escabrosa limestone. A narrow, north-trending band of horizontally lineated andesite porphyry to the southwest of Turning Point shaft (pl. 1) is interpreted to be the expression of intrusion along an underlying fault through which magma rose into the lower Escabrosa limestone. This postulated dike would intersect the Turning Point fault a few feet west of the present workings, at the position of the north-trending fault zone which has limited westward exploration. The mineral bodies at Turning Point Mine are later than the andesite porphyry intrusion, but may be genetically related to it. Mineralization above, or adjacent to, a center of igneous intrusion, suggests the possibility that mineral-forming fluids were introduced along the same structures which guided the intrusive magma.

The greatest potential for future mineral production from the
Turning Point Mine probably lies in the 600 feet of unexplored vein which is partially exposed northeast of the shaft. The vein-split junction 300 feet northeast of the shaft would provide a likely target for exploration.

Search for the westward extension of the Turning Point vein, west of the north-striking, west-dipping fault zone against which past operations ceased, might be profitable. This area of exploration would include that portion of the vein above the postulated andesite porphyry dike.

Desert Queen Mine

History, Development, and Production

The Desert Queen ore bodies were first exploited in 1905, by the Desert Queen Gold Mining Company (Tenney, 1934, p. 22). This organization constructed a concentrator, low on the western slope of Desert Queen Hill, which consisted of four Tremain steam stamps with amalgamation plates. About 60 percent of the metal values were recovered from the ores treated in this plant (P. J. Johnson, oral communication). Ore was mined from limestone replacement bodies and from veins on the hill above the concentrator, and was conveyed to the mill by a 300-foot long aerial tram. Six hundred feet of track and rail bed were constructed along the hillslope south of the concentrator and connected with a 150-foot long haulage adit which had been driven to
the vein (fig. 4). This ambitious development was not completed, but apparently extractive drifts were to have been driven in the vein at the haulage adit elevation.

Seven shallow shafts and numerous cuts and pits were sunk along the Desert Queen vein zone and some ground was stoped. Near the highest topographic exposure of the vein, a timbered vertical shaft was sunk to a depth of approximately 70 feet, and was connected with the shallow stopes along the vein zone.

The Desert Queen Gold Mining Company patented six mining claims (fig. 3) which are, at present, owned by Mr. Peter J. Johnson of Douglas, Arizona.

In 1938, Mr. R. L. Dye leased the Desert Queen property and shipped to the Hayden smelter of the American Smelting and Refining Company, six railroad cars of material which included mill tailings, stockpiled ore, and some of the richer parts of exposed ore bodies. The property has been idle since that time, and, at present, most of the underground workings are inaccessible.

No grade or production figures pertaining to the early operations are available. Mr. Dye shipped about 210 tons of material, which averaged about 0.03 ounces of gold and 2.0 ounces of silver per ton for a total value of about $2,200.
Figure 4. Plan of haulage adit, Desert Queen mine, showing irregular nature of vein mineralization.
Veins of the Desert Queen deposit form two distinct northeast-trending fault systems (pl. 1). The eastern vein system (pl. 20) is a complex network of branching and coalescing fractures in Escabrosa limestone, and can be traced for 2,200 feet along the strike. These fractures show no measurable offset, despite the length and continuity of the system. They are marked by minor silicification and pyritization of the fault strands. These veins fed small mineral bodies which replaced masses of brecciated silicified limestone.

The western vein system formed within faults which underwent marked normal displacement prior to mineralization (pl. 21). It is along this vein system that the andesite porphyry sill at Desert Queen Mine was downfaulted and preserved from erosion. These faults are silicified and stained by manganese and iron oxides, continuously, for 1,800 feet along the strike, and at favored locations, the fault fillings are sufficiently mineralized to constitute ore. All of the productive veins have been within Escabrosa limestone. Masses of brecciated, silicified limestone formed adjacent to the veins. Within these breccia masses, minor replacement mineral bodies have developed (fig. 5). One significant replacement body was mined within a ruptured bedding plane where it was cut by the western vein system.

Permeability appears to have been the primary factor affecting
MINERALIZED FRACTURES IN ESCABROSA LIMESTONE

A. Mineral striping of limestone marks the eastern vein system, Desert Queen Mine. View southeasterly.
A. Looking northwest from top of Desert Queen Hill. Mine dumps in the foreground are part of the Desert Queen Mine.

B. Turning Point Hill showing location of the Turning Point Mine. View southwesterly.
Irregular replacement of brecciated, silicified limestone by quartz, iron oxides, and manganese oxides.

Mineralized, brecciated limestone
Escobroso limestone
Andesite porphyry
Unmineralized fault showing dip
Mineralized vein
Strike and dip of beds
Raise

Figure 5. Plan of shallow stopes on Desert Queen vein showing relationship between faulting and mineral deposition.
mineral replacement. Within the veins, so far as could be determined from the surface, stoping was restricted to the brecciated rock within and adjacent to fault junctions. Replacement bodies formed wherever feeding faults encountered limestone sufficiently fractured by bedding-plane rupture or by high-angle faulting (figs. 6 and 7).

The deeper workings along the veins are not accessible, but where stoping reached the surface, excavations average about 6 feet in thickness. The shape or continuity of ore shoots could not be determined. Replacement bodies are small and the largest one exposed will probably not exceed several hundred tons of mineralized rock.

The ore bodies at Desert Queen Mine do not bear any apparent genetic relationship to the andesite porphyry exposed nearby. Mineralization is all later than the sill and is contained within faults that offset it. Mineralization at Desert Queen Mine was undoubtedly introduced at the same time as the mineralization at the Jackrabbit Mine and the Turning Point Mine. At these mines, mineralization appears to be spatially related to intrusive conduits. This relationship may be true at the Desert Queen Mine, also, if the Desert Queen vein systems should represent mineralization above the foreward edge of an unexposed andesite porphyry sill.

The vein systems at Desert Queen Mine are extensive and mineralization is widespread. The veins have not been explored at
Mineralized fractures
Brecciated, silicified limestone

All bedding planes show evidence of movement

Limestone replaced by quartz, iron, manganese and lead oxides
Feeding fracture

Figure 6. Cliff face on south flank of Desert Queen Hill showing influence of bedding planes on mineral replacement of Escabrosa limestone.

Replacement body contains silicified limestone, quartz, iron and manganese oxides, cerussite and galena.

Figure 7. Vertical section through replacement body in Escabrosa limestone, Desert Queen Hill.
depth or extensively along the strike. The limestone vein walls and calcareous fault fillings would tend to inhibit migration of gold values and secondarily enriched gold ore is not anticipated. According to assays supplied by Mr. Johnson, it seems probable that exploration along the western vein system could develop a moderate tonnage of material that would contain between 0.20 and 0.30 ounces of gold and 2.0 ounces of silver per ton.

The limestone replacement mineral bodies at Desert Queen Mine are small and discontinuous, although probably higher in silver content than are the vein deposits. Thorough exploration along feeding faults could disclose several of them. These replacement bodies would be difficult to mine because of their erratic occurrence. As there does not appear to be any specifically favorable replacement horizon within the Escabrosa limestone, exploration for replacement bodies could be guided by the projection of fault structures to intersect the feeding veins.

**Mineral Potential of the Jackrabbit Area**

Mineralization within the Jackrabbit area should be of interest to the "small" miner. It is doubtful that any of the exposed mineral bodies or developed veins could be exploited profitably at the present elevated cost of underground mining, but during periods of economic recession, sufficient tonnage of gold and silver ore might be proven to justify the construction of a small concentrator, and capital outlay for
equipping and developing the Turning Point and Desert Queen properties. Consolidation of the management of these properties could increase the efficiency of their operation and enhance the value of both.

The Jackrabbit Mine yielded a greater quantity of enriched, near surface ore than either the Turning Point Mine or the Desert Queen Mine, suggesting a greater potential for economic mineralization at depth. Very little is known of the Jackrabbit vein below the water table, however, and the cost of handling the excessive water flow would make deep exploration a relatively expensive undertaking.

Enriched ores, such as were exploited in the Jackrabbit vein above the water table, could be mined profitably today. It is toward discovery of such enriched ore that exploration effort might profitably be applied. Mineral occurrence tends to maintain a suggestive spatial relationship to the conduits along which andesite porphyry magma was introduced. These conduits appear to be aligned along the northeast-trending Dividend fault zone. Much of the Dividend fault is covered by alluvium, particularly where intersected by the northwest-trending Boundary faults. It is toward the alluviated Dividend fault zone that the prospector of tomorrow might well apply his energies.
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APPENDIX A

Detailed Stratigraphic Section:
Northern Slate Mountains

Mississippian:

Escabroso limestone:

Andesite porphyry sill.

74* Limestone, medium-light-gray (N 6) and pinkish-gray
(5YR 8/1), fossiliferous fragmental, crystalline in
part; thin bedded (12 in. to 3 in.); contains large
horn coral and colonial hexacoral; weathers light
brownish gray (5YR 6/1), rough; forms moderate
slope; bleached and silicified by overlying andesite
porphyry. Base covered ......................... 40

73. Limestone, dark-gray (N 4), finely crystalline;
medium- to thin-beded (18 in. to 6 in.), contains
chert bands as much as 24 inches long and 2 inches

*Number of measured units above the base of section.
Mississippian—Continued

Escabrosa limestone—Continued

thick, spacing between bands varies from 24 inches to 2 inches; weathers light brownish gray (5YR 6/1), jagged; forms cliff. Base covered .................. 5

72. Limestone, light-gray (N 7), finely crystalline; medium- to thin-bedded (18 in. to 6 in.), contains heavy chert bands in lower 30 inches, chert bands are as much as 120 inches long and 10 inches thick. The upper 4 feet contains abundant but poorly preserved remains of Eumerita(?). On weathered surfaces these brachiopods show as bands of white spots. This is a distinctive faunal zone, useful for correlation. Unit weathers light brownish gray (5YR 6/1), silty; forms cliff. Base is bedding fault ................................................................. 12

71. Limestone, medium-dark-gray (N 4), finely crystalline; medium- to thin-bedded (18 in. to 6 in.); contains unidentified brachiopod, chert bands as much as 24 inches long and 2 inches thick with 2-inch average spacing between bands; weathers brownish gray (5R 5/1), jagged; forms cliff.
Base covered ............................................................... 17
Mississippian—Continued

Escabrosa limestone—Continued

70. Limestone, medium-gray (N 5) with very light gray (N 8), dolomitic limestone in lower 2 feet, fossiliferous fragmental, silty; medium- to thin-bedded (36 in. to 6 in.); contains abundant crinoid columnals, tetracoral and brachiopod fragments; weathers pale yellowish brown (10YR 6/2), sandy to jagged; forms cliff. Base sharp .......................... 18

69. Limestone, medium-light-gray (N 6), sandy; medium- to thin-bedded (36 in. to 3 in.), bedding planes irregular; weathers pinkish gray (5YR 8/1), sandy; forms cliff. Base irregular ......................... 9

68. Limestone, light-gray (N 7), fossiliferous fragmental and coarsely crystalline; weathers light gray (N 7); forms bluff. Base undulating ...................... 1

67. Limestone, medium-light-gray (N 6), fossiliferous fragmental and sandy; thin bedded (12 in. to 3 in.); weathers light brownish gray (5YR 6/1), rough, even textured; forms cliff. Base irregular .......... 14

Break in section; units 66 through 62 were measured 350 feet east of unit 67.
Mississippian—Continued

Escabrosa limestone—Continued

66. Limestone, cherty, light-gray (N 7), pinkish, increasingly silty toward base; entire unit contains chert bands 1 inch to 8 inches thick, as much as 15 feet long, and spaced 2 to 12 inches apart; lower 10 feet is covered; weathers grayish orange (10YR 7/4), smooth; forms cliff and steep stair-step slope. Base covered .............................................. 33

65. Limestone (Pentremites horizon), light-gray (N 7), pinkish, silty; thin bedded (12 in. to 6 in.); contains abundant and distinctive fauna Pentremites 2 sp., Spirifer centronatus(?), unidentified crinoid, crinoid columnals, and fossil trash; weathers grayish orange (10YR 7/4), fossils are silicified and weather to relief, useful for correlation; forms stair-step slope. Base sharp and flat .......................... 4

64. Limestone, medium-light-gray (N 8), encrinal;
medium- to thin-bedded (30 in. to 6 in.), bedding poorly developed; weathers light gray (N 7), rough, even-textured; forms bluff. Base covered .......... 27

63. Limestone, medium-light-gray (N 6), fossiliferous fragmental and sandy, medium bedded (30 in. to
Mississippian—Continued

Escabrosa limestone—Continued

12 in.); contains irregular chert bands 1 inch to 8 inches thick and 1 foot to 5 feet apart; weathers light gray (N 7), rough; forms irregular bluff. Base flat ... 22

62. Limestone, medium-light-gray (N 6), fossiliferous fragmental and sandy; massive, bedding indistinct; contains a persistent chert band 3 feet to 5 feet above the base, chert band is 18 inches thick; weathers light gray (N 7), rough, even-textured; forms cliff. Base is bedding fault ................. 28

Break in section; units 61 through 53 were measured 1,300 feet northeast of unit 62.

61. Limestone, medium-dark-gray (N 4), fossiliferous fragmental and sandy, fine, even grained; medium bedded; unit contains scattered chert nodules; two light blue beds in lower part are composed of 10 percent poorly sorted, frosted quartz grains; weathers brownish gray (5YR 4/1) and pale yellowish brown (10YR 7/4), color-banding is characteristic of weathered surface, rough; forms blocky cliff. Base
Mississippian—Continued

Escabrosa limestone—Continued

undulating ...................................................       23

60. Limestone, very-light-gray (N 8), finely crystalline;
medium bedded (30 in. to 12 in.); 5 feet above base,
2-foot thick bed of buff limestone contains numerous
small (1 mm) silica nodules; weathers medium light
gray (N 6) to very light gray (N 9), pronounced
color banding, rough, even-textured; forms blocky
slope. Base slightly undulating .............................. 13

59. Dolomite, dark-gray (N 3), fossiliferous fragmental
and sandy, fine, even grained; medium bedded (30
in. to 12 in.); contains abundant tetracoral and
brachiopod remains, scattered calcite nodules;
weathers brownish gray (5R 4/1), rough, slabby;
forms blocky slope. Base sharp and flat  ..................... 17

58. Limestone, light-gray (N 7), very finely crystalline;
medium bedded (30 in. to 12 in.) with thin bedding
(8 in. to 1 in.) in lower 2 feet; weathers pale
yellowish brown (10YR 6/1), rough, even-textured;
forms bluff. Base irregular ................................. 11

57. Limestone, medium-dark-gray (N 4), finely crystalline;
medium- to thin-bedded (18 in. to 6 in.); contains
Mississippian—Continued

56. Limestone, medium-light-gray (N 6), fossiliferous fragmental; medium bedded (24 in. to 12 in.); contains Syringopora sp., unidentified tetracoral, crinoid columnals and chert nodules; weathers light gray (N 7), rough, even-textured; forms blocky slope.

Base covered ............................................................ 10

55. Limestone, light-gray (N 7), becomes darker in upper 10 feet, fossiliferous fragmental and crystalline; medium bedded (36 in. to 18 in.); contains Syringopora sp. and unidentified tetracoral, cherty horizon 3 feet below top; weathers very light gray (N 8), rough, even-textured; forms cliff. Base irregular ..................... 28

54. Dolomite, medium-gray (N 5), finely crystalline, sandy in part; medium- to thin-bedded (36 in. to
Mississippian—Continued

Escabrosa limestone—Concluded

3 in.); weathers dark gray (N 3) to light brownish gray (5YR 6/1); forms cliff. Base covered ............... 65

53. Siltstone, calcareous, grayish-red (5R 4/2); composed of coarse silt (1/16 mm to 1/32 mm), well sorted; subangular to subrounded grains; calcareous cement; weathers pale red (10R 6/2), gritty; forms bluff.

Base irregular, sharp .................................................... 1

Total Escabrosa limestone ........................................... 438

Break in section; units 52 through 33 were measured 16,700 feet southwest of unit 53.

Devonian:

Martin formation:

52. Siltstone, pale-red (10R 6/2) to grayish orange (10YR 7/4); composed of very fine silt, well sorted; thin bedded (3 in. to 1 in.); friable- to firmly cemented, argillaceous and calcareous cement; near top, unit contains beds of light brownish gray (5YR 6/4), silty dolomite 6 inches to 8 inches thick; unit weathers light brown (5YR 6/4) to pale yellowish brown (10YR 6/2), smooth surface; forms covered slope. Base
Devonian—Continued

Martin formation—Continued

sharp and flat ............................................ 123

51. Dolomite; medium-gray (N 5), finely crystalline;
    medium- to thin-bedded (24 in. to 6 in.), bedding
    planes undulate; contains abundant brachiopod re-
    mains; weathers light brownish gray (5YR 6/1);
    smooth, sandy surface; forms cliff. Base sharp
    and flat .............................................................. 5

50. Siltstone, pale-yellowish-brown (10YR 6/2), to pinkish
    gray (5YR 8/1); coarse silt (1/16 mm to 1/32 mm),
    well sorted; composed of subrounded, frosted quartz
    grains; very thin bedded (2 in. to 1/2 in.); friable,
    calcareous cement; weathers grayish orange (10YR
    7/4) to very pale orange (10YR 8/2), gritty surface;
    forms covered slope. Base covered .................. 19

49. Dolomite, medium-gray (N 5), finely crystalline;
    medium- to thin-bedded (30 in. to 2 in.); upper part
    contains quartz geodes and abundant crinoid remains;
    central part is silty; lower 30 inches is a sandstone
    composed of coarse (1 mm to 1/2 mm), well sorted,
    subrounded quartz grains in a calcareous cement;
    occasional clear quartz grains occur throughout
Devonian—Continued

Martin formation—Continued

unit; weathers pale yellowish brown (10YR 6/2), sandy, silt-sand layers stand out on weathered surfaces as whisps and ribs; forms bluff. Base covered ............................ 16

48. Mudstone, calcareous, light-brown (5YR 6/4); laminated (1/2 in. to 1/8 in.); weathers moderate orange pink (5YR 8/4), smooth; forms slope. Base covered .......... 7

47. Quartzite, medium-light-gray (N 6) to white (N 9); medium grained (1/2 mm to 1/4 mm); medium bedded (36 in. to 12 in.); unit contains 30 percent dolomite and ranges from sandy dolomite to pure quartzite; bedding plane at top of unit contains abundant, poorly preserved colonial bryozoans and is an excellent marker horizon; weathers moderate yellowish brown (10YR 5/4), rough, sandy; forms bluff. Base undulating .............................. 5

46. Dolomite, medium-dark-gray (N 4), very finely crystalline; medium bedded (18 in. to 12 in.); up to 45 percent of unit poorly preserved coral and brachiopod remains; weathers dark gray (N 3) smooth, with light colored fossil trash weathering to relief;
Devonian—Continued

Martin formation—Continued

forms bluff. Base undulating .................................................. 7

45. Limestone, dolomitic, medium-gray (N 5), finely crystalline; thin bedded (12 in. to 2 in.); contains clear calcite nodules; weathers pale yellowish brown (10YR 6/2), sandy; forms cliff. Base covered ............ 4

44. Siltstone, calcareous, pale-brown (5YR 5/2); very fine grained; very thin bedded (1 in. to 1/2 in.); calcareous cement; weathers light brownish gray (5YR 6/1), silty; forms bench. Base covered .......................... 4

43. Dolomite, grayish-black (N 2) to pale red (5R 6/2), finely crystalline; medium bedded (36 in. to 18 in.); contains Favosites(?), scattered sand grains and a few calcite nodules; weathers pale yellowish brown (10YR 5/2) to light brown (5YR 6/4), sandy; forms cliff. Base undulating .............................. 12

42. Dolomite, medium-dark-gray (N 4) to grayish red (5R 4/2), very finely crystalline; medium- to thin-bedded (24 in. to 6 in.), contains continuous coarse sandy layers and a few thin chert bands; weathers medium brownish gray (5YR 5/1) to pale red (10R 6/2), rough; forms cliff. Base sharp but irregular,
Devonian—Continued

Martin formation—Continued.

probably a bedding fault ........................................ 6

Total Martin formation .......................... 208

Unconformity: not apparent.

Cambrian:

Abrigo formation:

41. Limestone, silty to sandy, partly dolomitic, grayish-red (5R 4/2) to pale red (5R 6/2); coarse- to medium-crystalline; thin- to very-thin bedded (8 in. to 1/4 in.); uppermost units are silty dolomite but grade downward into sandy dolomitic limestone, contains intraformational conglomerate throughout; weathers light brown (5YR 6/4), sand layers stand out on weathered surfaces as whisps and ribs; forms steep, rubble-covered slope. Base covered ........... 114

40. Quartzite, grayish-red-purple (5RP 4/2); medium grained (1/2 mm to 1/4 mm), well sorted; composed of subangular to subrounded quartz grains; thin- to medium-bedded (36 in. to 2 in.); calcareous and ferruginous cement, poorly cemented; unit is 95 percent crossbeds; basal 2 feet are thin- to very
Cambrian—Continued

Abrigo formation—Continued

thin-bedded (3 in. to 1 in.) and friable; weathers pale red purple (5RP 6/2), sandy surface; forms dip slope, ridge, and cliff. Base sharp and flat .................... 15

39. Quartzite, grayish-red-purple (5RP 4/2); medium grained (1/2 mm to 1/4 mm), well sorted; composed of subangular to subrounded clear quartz (95 percent) and greenish (5 percent) grains; medium bedded (36 in. to 12 in.), 95 percent crossbedded; siliceous cement; weathers brownish gray (5YR 4/1), smooth surface; forms cliff. Base gradational ...................... 22

38. Quartzite, calcareous, grayish-blue (5PB 5/2) to pale brown (5PB 7/2), calcareous horizons are brownish; very fine grained (1/8 mm to 1/16 mm), and well sorted; composed of subangular to subrounded clear to pink quartz and a few glauconite grains; thin bedded to laminated (12 in. to 1/16 in.), bedding planes irregular, micaceous, and current marked; calcareous cement, well cemented; calcareous material forms silty limestone interbeds and lenses; some interbeds are poorly cemented, fine grained sandstone; weathers pale red (5R 6/2), smooth to
Cambrian—Continued

Abrigo formation—Continued

sandy, layered; forms steep slope. Base gradational. 52

Andesite porphyry sill, 4 feet thick.

37. Quartzite, pale-red-purple (5RP 6/2); very fine sand to coarse silt (1/8 mm to 1/32 mm), well sorted; composed of subangular to subrounded quartz grains; medium bedded to laminated (4 in. to 1/8 in.), bedding planes are irregular, micaceous, and show minor fucoid-like concretions; calcareous and siliceous cement, well cemented; a few interbeds are irregular, well cemented, calcareous siltstone; some beds contain as much as 40 percent glauconite; weathers grayish red purple (5RP 4/2) to light brownish gray (5YR 6/1), smooth, layered; forms steep slope. Base gradational ....... 50

36. Quartzite and limestone, interbedded. Quartzite, sandy to shaly, grayish-red-purple (5RP 5/2); very fine sand to coarse silt (1/8 mm to 1/32 mm), well sorted; composed of subangular to subrounded clear to pink quartz grains; medium bedded to thinly laminated (5 in. to 1/16 in.), bedding planes are irregular, micaceous, with
Cambrian—Continued

Abrigo formation—Continued

minor fucoid-like concretions and current markings; calcareous and siliceous cement, good to fair cementation; in central part of unit quartzitic beds are separated by sandy interbeds; in lower part of unit quartzitic shale, formed by irregular interlamination of sand and mud layers, is common; weathers pale red purple (5RP 6/2), smooth to sandy or silty, layered. Limestone, silty, grayish-red-purple (5RP 5/2), finely crystalline; thin bedded (10 in. to 2 in.); in upper part of unit limestone beds contain much quartzitic intraformational conglomerate, in lower part of unit limestone beds may contain as much as 35 percent glauconite and only minor intraformational conglomerate; weathers pale reddish brown (10R 5/4), silty. Unit is alternately quartzite, shaly quartzite, and limestone in no regular sequence, limestone comprises 10 percent of total volume; unit weathers to a steep slope which becomes gentle in the lower part. Base gradational...

35. Quartzite and limestone, interbedded. Quartzite, calcareous, grayish-red-purple (5RP 4/2) to pale
Cambrian—Continued

Abrigo formation—Continued

red purple (5RP 7/2); very fine sand to coarse silt (1/8 mm to 1/32 mm), well sorted; composed of subangular to subrounded clear quartz grains; very thin bedded to laminated (2 in. to 1/4 in.), bedding planes are irregular and micaceous with minor fucoid-like concretions; calcareous cement, good to fair cementation, some thin interbeds are sandy; weathers grayish purple (5P 4/2) to pale purple (5RP 6/2), rough, layered. Limestone, silty, grayish-red-purple (5RP 5/2), finely crystalline; thin- to very thin-bedded (10 in. to 1 in.); contains thin (3/4 in. to 1/4 in.), parallel quartzite plates and much quartzite intraformational conglomerate; weathers pale reddish brown (10R 5/2), silty. Unit contains 25 percent limestone but becomes less calcareous toward the top; weathers to a gentle stair-step slope with thinner units eroding faster than thicker units. Base irregular ....................... 46

34. Quartzite, grayish-blue (5PB 5/2) to greenish gray (5GY 6/1); very fine sand to coarse silt (1/8 mm to 1/32 mm), well sorted; composed of subangular
Abrigo formation—Continued

to subrounded clear to pink quartz grains; thin
bedded to thinly laminated (3 in. to 1/16 in.)
with one 14-inch thick bed 22 feet above the base;
bedding planes irregular, micaceous, with abun­
dant fucoid-like concretions; calcareous cement,
well cemented; unit consists of regular quartzite
beds (60 percent in upper part and 40 percent in
lower part) and irregular quartzitic interbeds,
interbeds are extremely uneven, discontinuous;
interlaminated quartzite lenses which are sepa­
rated by layers of micaceous silt; a few beds
contain as much as 20 percent glauconite;
weathers dusky yellowish brown (10YR 2/2) to
pale yellowish brown (10YR 6/2), smooth to
rough, layered with interbeds eroding more
rapidly than the regular quartzite plates; forms
bluff and steep slope. Base gradational ............. 67
Total Abrigo formation ........... 448

Troy quartzite:

33. Quartzite, pinkish-gray (5YR 8/1); medium- to
fine-grained (1/2 mm to 1/8 mm); composed of
Cambrian—Continued

Troy quartzite—Continued

moderately well sorted, subangular to subrounded quartz grains; medium- to thin-bedded (36 in. to 8 in.), bedding planes irregular; siliceous and argillaceous cement; tops of beds tend to be sandy and a few thin, sandy interbeds are found near top of unit, uppermost beds exhibit numerous Scolithus; weathers light brownish gray (5YR 6/1) to yellowish gray (5Y 8/1) with desert varnish, smooth; forms dip slope and ridge. Base sharp and flat ...................... 87

Break in section; units 32 through 23 were measured 100 feet southwest of unit 33.

32. Sandstone, pinkish-gray (5YR 8/1); fine- to very fine-grained (1/4 mm to 1/16 mm); composed of well sorted, subangular to subrounded quartz grains; thin- to very thin-bedded (10 in. to 1 in.); argillaceous cement; contains up to 25 percent of quartzite described as follows:

Quartzite, pale-red-purple (5RP 6/2); medium- to fine-grained (1/2 mm to 1/8 mm), well
Cambrian—Continued

Troy quartzite—Continued

sorted; composed of subangular to subrounded quartz grains; siliceous and calcareous cement; weathers grayish red purple (5RP 4/2).

Unit weathers pale pink (5RP 8/2) to pale red (10R 6/2) with much desert varnish; some beds develop liesgang rings; forms dip slope. Base gradational .... 56

31. Grit, grayish-red-purple (5RP 4/2); granules to very fine sand (4 mm to 1/16 mm), very poorly sorted; composed of subangular to subrounded quartz grains; thin- to very thin-bedded (6 in. to 1 in.); argillaceous cement, moderately well cemented; weathers pale pink (5RP 8/2) with much desert varnish; forms ridge and steep slope. Base covered .................. 20

30. Sandstone, pale-red-purple (5RP 6/2); medium- to fine-grained (1/2 mm to 1/8 mm), well sorted; composed of subrounded to clear quartz grains; thin- to very thin-bedded (12 in. to 1 in.), 10 percent crossbedded; argillaceous cement, well cemented; basal 10 feet is coarse sand and grit; weathers grayish red purple (5RP 4/2) to pale
Troy quartzite—Continued

Base sharp and flat .................................................. 75

29. Grit, grayish-red-purple (5RP 4/2), granules to very fine sand (4 mm to 1/16 mm), very poorly sorted; composed of subangular to subrounded quartz grains; thin- to very thin-bedded (6 in. to 1 in.); argillaceous cement, friable; weathers grayish red purple (5RP 4/2); forms crumbly slope. Base gradational ........ 24

28. Sandstone, pale-red-purple (5RP 6/2) to pale red (10R 6/2); medium- to fine-grained (1/2 mm to 1/8 mm), well sorted; composed of subangular to subrounded quartz grains; medium- to very thin-bedded (36 in. to 1/2 in.), thick and thin beds alternate, 90 percent crossbedded; siliceous cement; unit contains a few thin quartzite beds in upper 17 feet and scattered lenses of quartzite pebbles in lower portion; weathers pale red purple (6RP 6/2), smooth; forms steep slope and cliff. Base covered ................................. 161

27. Sandstone, pale-red (5R 6/2); coarse- to medium-grained (1 mm to 1/4 mm), fair sorting, beds of fine and coarse material alternate in lower part;
Cambrian—Continued

Troy quartzite—Continued

composed of subangular to subrounded quartz grains; thin- to very thin-bedded (3 in. to 1/2 in.); siliceous and calcareous cement; unit contains a few large feldspar grains; weathers grayish red (5R 4/2), irregular surface; forms gentle slope. Base covered ...

| Total Troy quartzite | ... | 463 |

Late Precambrian:

Mescal limestone:

26. Dolomite, pale-red (5R 6/2), finely crystalline dolomite alternates with beds of thinly banded, cherty dolomite; medium- to thin-bedded (36 in. to 2 in.); dolomite weathers grayish orange pink (5RP 6/2) with sandy surface, chert weathers dark gray (N 3) and forms ribs; unit weathers to form a gentle slope. Base covered .................. 22

25. Dolomite, cherty, grayish-red (5R 4/2), finely crystalline; medium- to thin-bedded (36 in. to 6 in.); entire unit contains remarkably parallel chert bands as much as 2 inches thick and 2 inches to 1/4 inch apart, minor(?) bedding
Late Precambrian—Continued

Mescal limestone—Continued

fault cuts unit 34 feet above the base; weathers pale yellowish brown (10YR 6/2) to yellowish gray (5Y 7/2), silty, chert ribbed; forms steep slope. Base is diabase sill ........................................ 49

Diabase sill 15 feet thick.

24. Dolomite, cherty; same as unit 25. Base gradational . 34

23. Dolomite, cherty, grayish-red (5R 4/2), finely crystalline; medium- to thin-bedded (36 in. to 6 in.); beds with abundant chert (bands up to 2 inches thick and 2 inches to 1/4 inch apart) alternate with beds containing less chert; weathers pale yellowish gray (10YR 6/2) to yellowish gray (5Y 7/2), rough, chert-ribbed; forms steep slope. Base is diabase sill .... 88

Diabase sill 109 feet thick.

Total Mescal limestone .............. 193

Break in section; units 22 through 4 were measured 1,550 feet east of unit 23.

Dripping Spring quartzite:

22. Siltstone, calcareous, grayish-red (5R 4/3); very
Late Precambrian—Continued

Dripping Spring quartzite—Continued

fine silt (-128 mm); bedding indistinct; lower part of unit is cherty and contains minor limestone beds in lower 2 feet; entire unit is baked by the overlying diabase sill; weathers grayish red (5R 3/2), smooth; forms rubbly bench. Base gradational .................. 36

21. Quartzite and mudstone interbedded. Quartzite, white (N 9) with some reddish banding in upper part; medium- to fine-grained (1/2 mm to 1/8 mm), moderately well sorted, becoming finer grained and better sorted toward the top; composed of subangular to subrounded, clear quartz and minor milky feldspar grains; thick- to medium-bedded (60 in. to 24 in.); argillaceous cement; weathers pinkish gray (5YR 8/1), forms bluff. Mudstone, grayish-red (5R 5/2); very fine grained. Entire unit forms a stair-step slope. Base covered ......................... 67

20. Siltstone, grayish-red (5R 4/2) to pale red (5R 6/2); composed of coarse- to very fine-grained silt, unit becomes finer grained toward the top, well sorted; thin- to very thin-bedded (4 in. to 1/2 in.); argillaceous cement; basal 4 feet is described as
Late Precambrian—Continued

Dripping Spring quartzite—Continued

follows:

Sandstone, grayish-red (5R 4/2); medium grained; composed of clear quartz grains in a limonitic cement.

Unit weathers grayish red (5R 4/2) to pale red (10R 6/2) with some bleaching of ferruginous pigment in thinner beds, smooth; forms covered slope. Base covered ............................................................... 117

19. Quartzite, arkosic, very light-gray (N 8); medium grained (1/2 mm to 1/4 mm), well sorted; composed of subangular to subrounded, clear quartz and 10 percent cloudy feldspar grains; thick- to medium-bedded (60 in. to 12 in.) with 10 percent of unit laminated (-1/4 in.); siliceous and argil­laceous cement; weathers very light gray (N 8), smooth; forms steep slope and cliff. Base sharp and flat ................................................................. 81

18. Siltstone, calcareous, medium-light-gray (N 6) to light brownish gray (5YR 6/1); composed of coarse- to very fine-silt, with coarse grained quartzite bed at base; well sorted; siliceous and
Late Precambrian—Continued

Dripping Spring quartzite—Continued

calcareous cement, well indurated; interlaminated limonitic lenses in thin bedded zones; weathers medium gray (N 5) to brownish gray (5YR 4/1), smooth; forms moderate slope. Base sharp and flat .......................................................... 126

17. Siltstone and quartzite, interlaminated. Siltstone, light-gray (N 7); composed of fine silt, well sorted with a few coarse grained lenses; very thin bedded to laminated (1 in. to 1/8 in.), bedding planes irregular; siliceous cement, well indurated; weathers pinkish gray (5YR 8/1), smooth. Quartzite, very light-gray (N 8); very fine grained (1/8 mm to 1/16 mm), well sorted; composed of subrounded clear quartz grains; thin bedded- to laminated (8 in. to 1/8 in.), bedding planes irregular; siliceous cement, well cemented; contains minor limonite concentrations; weathers light gray (N 7), smooth; quartzite forms irregular lenses in siltstone and becomes more prevalent toward the top of unit.

Unit forms a gentle slope. Base covered .......... 117

Diabase sill, poorly exposed, 7+ feet thick.
Dripping Spring quartzite—Continued

16. Sandstone, pale-red-purple (5RP 6/2), very fine grained (1/8 mm to 1/16 mm); well sorted; composed of sub-rounded, clear quartz grains; thin bedded to laminated (8 in. to 1/8 in.), bedding planes sharp; siliceous cement, well indurated; weathers grayish red purple (5RP 4/2), smooth surface; forms dip slope. Base covered ......................................................... 80

15. Sandstone, pale-red-purple (5RP 6/2) to pale pink (5RP 8/2); medium- to fine-grained (1/2 mm to 1/8 mm), fair sorting; composed of subangular to subrounded pink quartz and pink to white feldspar grains; thin bedded to laminated (8 in. to 1/4 in.); argillaceous cement, moderately well cemented; weathers pale red purple (5RP 6/2) to pinkish gray (5YR 8/1) with some desert varnish, rough; forms dip slope. Base covered ......................................................... 39

14. Sandstone, pale-red-purple (5RP 4/2); fine- to very fine-grained (1/4 mm to 1/16 mm), well sorted; composed of subrounded clear to pink quartz grains; thin- to very thin-bedded (6 in. to 1 in.), bedding planes are sharp but irregular; argillaceous
Dripping Spring quartzite—Continued

Cement, well indurated; contains minor limonite concentrations; weathers grayish red purple (5RP 5/2) to pale red (10R 6/2), smooth; forms dip slope. Base covered ........................................... 6

13. Sandstone, very light-gray (N 8); medium- to fine-grained (1/2 mm to 1/8 mm), fair sorting; composed of subangular to subrounded clear quartz and white feldspar grains; thin bedded (12 in. to 6 in.), bedding planes irregular, shaly; argillaceous cement, moderately well cemented; weathers pinkish gray (5YR 8/1) with desert varnish, dimple-shaped depressions are characteristic of weathered bedding planes, sandy surface; forms dip slope.

Base covered ....................................................... 17

12. Sandstone, grayish-orange-pink (10R 8/2) to light brownish gray (5YR 6/1); very fine grained (1/8 mm to 1/16 mm), fair sorting; composed of subangular to subrounded clear quartz grains; thin bedded to laminated (8 in. to 1/8 in.), thickness of beds varies laterally, bedding planes tend to be shaly; argillaceous cement; some beds contain irregular
Late Precambrian—Continued

Dripping Spring quartzite—Continued

concentrations of limonite; weathers pinkish gray
(5YR 7/1) with desert varnish; forms stair-step
dip slope. Base gradational .................. 89

11. Quartzite, pale-red (5R 6/2) to grayish pink (5R
8/2); coarse- to very fine-grained (1 mm to 1/16
mm with 90 percent less than 1/4 mm), poor to
fair sorting; composed of subangular to subrounded
clear quartz and pink feldspar grains; medium-to
thin-bedded (24 in. to 2 in.), tends to be irregular
and shaly along bedding planes; siliceous and
argillaceous cement; contains irregular limonite
concentrations in lighter colored beds; weathers
grayish red (5R 5/2) to pale red (5R 7/2) with
desert varnish; forms stair-step dip slope. Base
covered. Unit is locally disturbed ............ 77

10. Quartzite, grayish-orange-pink (10R 8/2); medium-
to very fine-grained (1/2 mm to 1/16 mm), fair
to excellent sorting; composed of subangular to
subrounded clear quartz and pink feldspar grains;
thin- to very thin-bedded (12 in. to 1/2 in.),
bedding planes are ripple marked; argillaceous
Late Precambrian—Continued

Dripping Spring quartzite—Continued

cement; some beds tend to be sandy; weathers pale red (10R 6/2) to moderate orange pink (10R 7/4) with desert varnish; forms dip slope. Base gradational

9. Sandstone, arkosic, grayish-orange-pink (10R 8/2); coarse- to medium-grained (1 mm to 1/4 mm), fair sorting; composed of subangular to subrounded clear quartz and pink to white feldspar grains; medium- to thin-bedded (24 in. to 2 in.), 50 percent cross-bedded, bedding planes are ripple marked; argillaceous cement, well indurated; contains minor limonite segregations; weathers grayish red (5R 4/2) to pale red (5R 6/2) with desert varnish, smooth; forms dip slope, ridge, and cliff. Base sharp and flat

8. Quartzite, pale-red (5R 6/2); medium- to fine-grained (1/2 mm to 1/8 mm), well sorted; composed of subangular to subrounded clear to pink quartz grains, a few beds contain up to 15 percent feldspar; thick- to medium-bedded (120 in. to 12 in.), 50 percent crossbedded, bedding planes are ripple marked;
Late Precambrian—Continued

Dripping Spring quartzite—Continued

argillaceous and siliceous cement, well cemented;
lower beds contain much segregated limonite;
weathers grayish red (10R 4/2) with desert varnish,
smooth; forms cliff. Base sharp ...................... 106

Andesite porphyry sill 30 feet thick.

7. Quartzite, arkosic, pale-red (5R 7/2); medium
grained (1/2 mm to 1/4 mm) becoming finer grained
toward the top, well sorted; composed of subrounded
clear quartz and cloudy feldspar grains; medium- to
thin-bedded (36 in. to 6 in.), minor crossbedding,
some bedding planes are shaly; argillaceous and
siliceous cement, moderately well cemented; unit
contains a few quartzite pebbles; weathers pale red
(5R 6/2), rough, weathered surfaces exfoliate;
forms cliff. Base flat ...................... 24

6. Sandstone, arkosic, grayish-pink (5R 8/2); coarse-
to medium-grained (1 mm to 1/4 mm), poorly
sorted; composed of subangular to subrounded
clear quartz and pink feldspar grains; thick- to
medium-bedded (120 in. to 24 in.), 50 percent
crossbedded; argillaceous cement; contains
Late Precambrian—Continued

Dripping Spring quartzite—Continued

lenses of quartzite pebbles within lower 30 feet;
weathers pale red (5R 6/2) with desert varnish,
smooth; forms cliff. Base covered ......................... 46

Total Dripping Spring quartzite ......................... 1,179

Pioneer shale:

5. Siltstone, muddy, grayish-purple (5P 4/2) to yellowish gray (5Y 7/1); very fine grained, becomes slightly coarser toward the top, well sorted; thinly bedded to laminated (12 in. to 1/4 in.), beds are of irregular thickness and tend to thicken in lower 30 feet; argillaceous and siliceous cement, well cemented; contains a few sandy lenses; weathers grayish purple (5P 3/2) to pale greenish yellow (10Y 8/2), smooth; forms steep slope. Base covered ..................... 78

4. Quartzite, arkosic, grayish-pink (5R 8/2); medium-to fine-grained (1/2 mm to 1/8 mm), fair sorting; composed of subangular to subrounded clear quartz and pink feldspar grains; thin- to very thin-bedded (12 in. to 1/2 in.), 10 percent crossbedded; argillaceous cement; some beds are sandy; weathers
Pioneer shale—Continued

moderate orange pink (10R 7/4), smooth; forms steep slope. Base covered ............................... 38

Break in section; units 3 through 1 were measured 1,000 feet north-east of unit 4.

Diabase sill, 185 feet thick, thins laterally.

3. Sandstone, quartzitic; grayish-red (5R 5/2) to grayish orange pink (10R 8/2); medium- to fine-grained (1/2 mm to 1/8 mm), fair sorting; composed of subangular to subrounded clear quartz and pink feldspar grains; thin- to very thin-bedded (12 in. to 1/2 in.), 25 percent crossbedded; argillaceous cement, firmly cemented to friable; weathers grayish red (5R 5/2) to grayish pink (5R 8/2), smooth; forms stair-step slope. Base sharp and flat ............................... 33

2. Quartzite, moderate-red (5R 5/4) to grayish orange pink (10R 8/2); very fine sand to silt (-1/8 mm), well sorted; composed of subangular to subrounded clear quartz and pink to white feldspar grains; thin- to very thin-bedded (6 in. to 1/2 in.), minor cross-bedding and ripple marking in top 10 feet; siliceous
Late Precambrian—Continued

Pioneer shale—Continued

cement, well cemented; unit is characterized by white
spheres from which the ferruginous pigment has been
removed; weathers grayish red (5R 5/2) to light
brownish gray (5R 6/1) with some desert varnish,
smooth; forms gentle slope. Base covered .......... 110

1. Quartzite and siltstone, interlaminated. Quartzite,
grayish-red (5R 5/2); medium- to very fine-grained
(1/2 mm to 1/16 mm), fair sorting; composed of
subrounded, clear quartz grains; thin bedded to
laminated (4 in. to 1/4 in.); argillaceous cement,
fair cementation but some thinner beds are poorly
cemented sand; weathers dusky red (5R 4/4),
smooth. Siltstone, grayish-red (5R 5/2); very
fine silt, well sorted; thin- to very thin-bedded
(4 in. to 1 in.); argillaceous cement; characterized
by white spheres from which the ferruginous pigment
has been removed; weathers grayish red (5R 5/2),
smooth. Unit forms a gentle slope. Base covered .... 115

Total Pioneer shale .................. 374

Unconformity, contact not observed.
Early Precambrian:

Pinal schist:

Quartz-sericite schist, medium-gray (N 5) to medium light gray (N 7); composed of metamorphosed coarse-to very fine-grained clastic sediments; schistosity varies from poor in thick, coarse grained units to good in thin, fine grained units, schistosity strikes north 10 to 12 degrees east and dips 80 degrees east to vertical; sericite gives sheen to foliation surfaces, quartz stringers are numerous; weathers brownish gray (5YR 4/1) to light brownish gray (5YR 6/1) with some desert varnish, irregular, blocky to laminated; forms generally subdued topography but is elevated to hills by faulting.

Summary:

Total Paleozoic sediments:

- Escabrosa limestone .................................................. 438
- Martin formation .......................................................... 208
- Abrigo formation .......................................................... 448
- Troy quartzite ............................................................ 463

Feet

1,557
Summary—Continued

Total Late Precambrian sediments:

<table>
<thead>
<tr>
<th>Formation</th>
<th>Feet</th>
</tr>
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<tbody>
<tr>
<td>Mescal limestone</td>
<td>193</td>
</tr>
<tr>
<td>Dripping Spring quartzite</td>
<td>1,179</td>
</tr>
<tr>
<td>Pioneer shale</td>
<td>374</td>
</tr>
<tr>
<td></td>
<td>1,746</td>
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</tbody>
</table>

Total measured section ............................................. 3,303
EXPLANATION

Contact between silicic and bedrock
Fault, dashed where inconclusively located,
U, upthrown side, D, downthrown side
Inferred fault
Thrust fault, triangles point toward upper plate
Crushed zone
Axes of anticline
Axes of syncline

TECTONIC DIAGRAM OF THE JACKRABBIT AREA, PINAL COUNTY, ARIZONA

SCALE 1:5000
Refer to plate 2 for location of this area.

Geo logy by D. F. Hammer 1959

EXPLANATION

Detritus

UNCONFORMITY

Martian Formation

Brecciated and Recrystallized Mescal Limestone

Fault

Mescal Limestone

Deposits and Intercalated Malleritarian Materials

Bedding

Points on strike and dip of beds

Dashed where approximately located

Points of triangles are toward thrust plate

Strike and dip of overturned beds

Strike of vertical beds

Axis of anticline

Axis of syncline, indicates plunge

"Approxi mate MEAN DECLINATION 1958"

1775'

1750'

1725'

1700'

1675'

1650'

1625'

1600'

GEOLOGIC MAP AND SECTIONS SHOWING DEFORMATION ON SOUTH FLANK OF DESERT QUEEN HILL, PINAL COUNTY, ARIZONA

SCALE 1:240