THE GEOLOGY AND ORE DEPOSITS OF THE SEVENTY NINE LINE AREA, GILA COUNTY, ARIZONA.

by

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A Thesis
submitted to the faculty of the
Department of Geology
in partial fulfillment of
the requirements for the degree of

Doctor of Philosophy
in the Graduate College
University of Arizona

1947

Approved: [Signature] Director of Thesis [Date]
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CHAPTER I

INTRODUCTION

Location, Culture and Transportation

The Seventy Nine mine area is in the southwest corner of Gila County, Arizona (Fig. I) in the Banner mining district, a triangular area in Gila County bounded on the southeast by the Gila River, on the north by the Dripping Spring Valley and on the southwest by the Gila-Pinal county boundaries. The Christmas mine, four miles east of the Seventy Nine mine, has been the largest operation in the Banner Mining District. Referred to the Gila and Salt River Base Line and Meridian, this report describes all of sections 21, 22, 27, 28, and parts of sections 14, 15, 16, 23, 26, 33, 34 and 35 of Township four South, Range 15 East.

Hayden with a population of about 1300 is the largest settlement in the Banner district. A company town, Hayden is the site of the concentrator for the Ray mine of the Kennecott Copper Corporation, 25 miles north, and a copper smelter of the American Smelting and Refining Company operated primarily for the Ray mine concentrates.
Index Map of Arizona
Winkelman, one and one half miles southeast of Hayden near the junction of the Gila and San Pedro Rivers, has about the same population as Hayden. Hayden Junction, two and one half miles northwest of Hayden on the Kelvin-Ray-Superior highway, is the closest settlement to the Seventy Nine mine, four and one half miles north.

Hayden and Winkelman are on a spur of the Southern Pacific Railroad out of Phoenix, which passes through Florence. The railroad ends at Christmas Station eight miles up the Gila River from Winkelman. Winkelman is 78 miles north of Tucson and 44 miles south of Globe via state highway 77. A graveled state highway extends from Winkelman through Hayden 50 miles west to Florence. This road connects at Kelvin, 18 miles distant, with a branch through Ray to Superior, 40 miles from Hayden. A good graded road connects with the Hayden-Kelvin highway near Hayden Junction and climbs 1500 feet in four miles due north to the Seventy Nine mine.

Several poor ungraded roads are found throughout the district leading to old mining properties and prospects. The ghost town of Chilito which had a population of 200 in 1920, is one and one half miles east of the Seventy Nine mine in Chocolate Canyon.
Physiography

Hayden and Winkelman are on the east side of and near the bottom of a typical basin and range type intramontane valley. To the east 3/4 mile, the Dripping Spring Mountains rise abruptly about 1500 feet along a fault scarp. Across the Gila River Valley to the west a gentle rise up the outwash plain of the Tortilla Mountains culminates 4 miles away in rugged topography about 4,000 feet in elevation.

The towns of Hayden and Winkelman are situated on the Gila conglomerate outwash, which rises gradually in elevation east to the Keystone fault contact with the Paleozoic rocks that form the mass of the Dripping Spring range.

The Seventy Nine mine area as here considered, consists of two subdivisions: a northward-trending highly faulted, tilted and transected western belt of Paleozoic sediments 1/2 to 1 mile wide, bordered on the east by the Keystone fault and on the west by the Gila conglomerate, and a central northward trending mountainous belt about 1-1/2 miles wide which extends east of the Keystone fault, embracing the less disturbed, gently dipping strata of the range.

The western belt ranges in altitude from about 2,800 feet on the west to a maximum of 4,200 feet on the ridge north of North Star Gulch (see Plate I). It consists largely of faulted, steeply southward-dipping limestone, with
smaller amounts of shale and conglomerate. It has been complexly faulted, fractured and intruded by a system of porphyritic dikes. Its topography reflects the fault pattern and is rugged.

The central belt ranges in altitude from about 3,000 feet in Chocolate Canyon on the west to about 4,500 feet on the east at Tornado Peak. It consists largely of little faulted, gently southward-dipping limestone, quartzite and shale, underlain by an intrusive diabase. Minor scattered bodies of porphyry cut all rocks. The topography of the central belt reflects the bedrock character, with little faulting involved. Rapid erosion in semiarid climate has formed cliffs and steep slopes upon the resistant limestone and quartzite; medium slopes or rounded hills upon the porphyries; and gentle slopes upon shale and diabase. The trend of the mountain front is roughly normal to the strike of the beds, as shown on Plate I.

The Gila River Valley extends northwest to Kelvin where it changes direction abruptly and strikes due west. Its margins are formed of typical Gila conglomerate and its inner area is covered by gravel and silt. Recent uplift with accompanying erosion has dissected its surface moderately.

An early Tertiary system of faulting with recurrent movement, which strikes about N 70° E produced a marked effect on the topography in both the western and central belts.
In these belts the drainage generally follows this N 70° E direction, and leads to the forming of many prominent cliffs some of which are as much as 700 feet high. The north-south Keystone fault has left a very prominent scarp along part of the west side of the range as seen in the southern part, Plate I.

Drainage of the western and central belts is by intermittent streams which find their way to the Gila River. Keystone Gulch and Chocolate Canyon runoff drain the central belt and after reaching the Gila conglomerate, merge to flow south to the river. The North Star and Seventy Nine Gulches are smaller drainages in the western belt, which merge in the Gila conglomerate and follow a southwesterly course to the river.

The area is in a youthful state of erosion, land forms are rugged and exposures are excellent.

Climate

The climate of the Seventy Nine mine area is semiarid. Most of the rainfall occurs in two periods, a summer rainy season during July and August, and a winter period of precipitation during December and January. Normally about half the precipitation occurs during the summer period when rains of cloudburst proportions accompanied by heavy run-offs can
be expected. Because of this concentration of rainfall the streams are intermittent. It is dangerous to use the dry washes for motor travel during the heavy runoff seasons and caution should be exercised.

Flora and Fauna

The dry periods separating heavy rains allow only drought-resisting desert types of plants to exist throughout the Seventy Nine mine area. Here are found mesquite, catclaw, desert broom, creosote bush and palo verde with many varieties of cacti such as cholla, prickly pear, hedgehog, yucca and sahuaro.

Wild life is sparingly present. Cottontails and jack rabbits are frequently seen, as are ground squirrels, pack rats, mice and quail. A few javelings, coyotes and deer have been noted. During the summer, rattlesnakes, centipedes and scorpions are sometimes found in shaded area, such as old prospect holes.

Previous Investigations

Although some earlier generalized work was done by Marvine and Gilbert, the first detailed work on the geology

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of central Arizona was that of F.L. Ransome. In 1901 and 1902, as geologist for the U.S. Geological Survey, he studied the geology and ore deposits of the Globe area. The results of this work were published in 1903.\(^2\)


A resume of that part of Ransome's bearing on the Seventy Nine mine area follows:

The oldest rocks in the Globe district are pre-Cambrian crystalline schists, termed Pinal schist. They represent sediments metamorphosed during the revolution that closed early pre-Cambrian time and were further affected by denudation and degradation.

The series of shales, conglomerates and quartzites overlying the Pinal schist is termed the Apache group. It consists of the Scanlan conglomerate, overlain by Pioneer shale, Barnes conglomerate, Dripping Spring quartzite, Mescal limestone and Troy quartzite. It was believed by Ransome to be of Cambrian age.

Above the Apache group occurs a series of limestones ranging in age from Devonian to Pennsylvanian. This was mapped as a unit and called the "Globe limestone". An erosion interval during which extensive faulting occurred followed the limestone deposition. Following or accompanying
the faulting, large masses of diabase were intruded, chiefly as sills.

A long period of erosion, with accompanying faulting followed. Some volcanics were extruded in early Tertiary, followed by faulting and the deposition of valley fill which Gilbert had named the Gila conglomerate. Ransome believed


this conglomerate to be late Tertiary or early Quaternary.

M.R. Campbell, in 1902 studied the Deer Creek area a few miles southeast of the Seventy Nine mine area. Sandstone and shale with associated coal seams were found interbedded with a thick series of volcanic rocks. The sediments and volcanic ejecta were referred to Upper Cretaceous age on fossil evidence.

Intermittently during the years 1910 and 1911, F.L. Ransome and J.B. Umpleby mapped a part of the Ray, Miami and Florence quadrangles. This survey was the first to embrace


the Seventy Nine mine area and is one of the most important on the geology of central Arizona. It corrects some earlier misinterpretations.

A summary of Ransome's work follows:

The oldest rock is Pinal schist, underlying nearly 1300 feet of strata assigned to the Apache group. Conformably above the pre-Cambrian Apache group, is 325 feet of the Martin limestone of Devonian age. Conformably above the Martin is approximately 1000 feet of Carboniferous Tornado limestone named after Tornado Peak, which lies within the area covered by this report, (Plate I).

M.R. Campbell, probably was first to find fossils in the Troy quartzite. Those date it as Middle Cambrian. Ross, found a few specimens in the Christmas area to the southeast. Through fossil evidence and stratigraphic position the Troy was separated from the underlying members of the Apache group. The earlier members were referred to late pre-Cambrian, Troy to Middle Cambrian age.

Ransome concluded that throughout this area of central

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6 Campbell, M.R., op. cit. page 243.

Arizona, after deposition of the Tornado limestone, the region was uplifted, eroded and intruded by diabasic magmas. Then followed more erosion and possibly deposition of Cretaceous sediments, although none are now found here.

During early Laramide Time, minor andesitic eruptions took place followed somewhat later by intrusive masses of acidic to intermediate rocks. Mineralization came next probably genetically related to these acid intrusives of Early to Middle Tertiary. A long period of erosion ensued.

Late in Tertiary times, the region to the north of the Seventy Nine mine area was buried under dacite flows, after which it was intricately faulted. Erosion of mountains and deposition of the Gila conglomerate in the fault troughs followed. Minor faulting followed deposition of the Gila in recent time.

Ross, spent 2 months in the summer of 1922 mapping the Saddle Mountain mining district and Christmas area to the immediate southeast of the Seventy Nine mine area. His report also included investigations of the mines and prospects of the Banner mining district. Ross gives one of the earliest descriptions and histories of the Seventy Nine mine.

Ross concluded that within the Christmas area, much
volcanic material was extruded and ejected during Upper Cretaceous time. Associated with this were numerous basic dikes and small intrusive porphyritic bodies.

J.B. Tenney in 1941-42, mapped the surface geology in the immediate vicinity of the Seventy Nine mine shaft, Seventy Nine Gulch and the then active 5th and 6th levels of the mine. This private company report was not accessible to the writer, but copies of Tenney’s maps were examined.

N.P. Peterson, geologist for U.S. Geological Survey, during 1943 worked on the geology of the Christmas mine area. During his course of field work, the geologic section, exposed so well to the north of Tornado Peak (Plate I), was measured.

Purpose and Scope of the Examination

This report is the result of a field problem undertaken as partial fulfillment for an advanced degree at the University of Arizona. The field work was done during the summer of 1946 and short intervals in the fall of 1946 and spring, 1947. It totals over 4 months. Laboratory investigations were made during the school year, 1946-47. The topographic map of the Ray quadrangle, published by the U.S. Geological Survey in 1902, reprinted in 1917, was used for the general areal geologic map of the Seventy Nine mine-
Tornado Peak area, Plate I. It was enlarged to a scale of 1 inch equals 1000 feet from the conventional 1 inch equals 1 mile, redrafted and a contour interval of 100 feet used in place of 50 feet. A second, more detailed map, Plate II, of the Seventy Nine Lead-Copper Company's property and the immediately adjacent area was made. This map is on a scale of 1 inch equals 200 feet, and has a contour interval of 50 feet in order to include as much detail as possible. The geology and topography of this map were plotted using a plane table and alidade.

The geology of all levels of the mine workings were plotted, 2nd, 3rd, 4th, 5th, 6th and 7th using company level maps. Only the 5th, 6th and 7th levels have been reproduced in this report, as they are closely associated with the present known ore bodies.

Acknowledgments

The completion of this investigation and report has required the help and advice of many individuals covering a wide field. Many thanks to the faculty members of the University of Arizona, College of Mines, Doctors B.S. Butler, M.N. Short, A.A. Stoyanow, and F.W. Galbraith, and Professors E.D. McKee and H.E. Krumlauf for their many valuable suggestions and helpful criticisms of the field work and manuscripts covering their specialized fields of interest.
Dr. Butler spent time in the field with the writer and supervised the thesis; Dr. Short spent much time supervising the maps, plates, microphotography and petrography; Professor McKee gave time and advice on special manuscript forms. Thanks to Dr. E.D. Wilson of the Arizona Bureau of Mines and Mr. A.F. Schride for offering many helpful suggestions. Mr. D.W. Black was of great assistance with the microphotography.

The writer is greatly indebted to Mr. H.O. Woods, formerly superintendent of the copper smelter at Hayden, Arizona, who was of great assistance during the field season with living accommodations, map reproduction and in supplying an airplane and equipment for the taking of aerial photographs.

Appreciative thanks to the Shattuck-Denn Mining Corporation and especially to Mr. J.E. McKay, superintendent of the Seventy Nine mine, Hayden, Arizona, for help and cooperation in so many varied ways with the field work. The company supplied the writer with a rodman for mapping Plate II, gave financial assistance to help make this work possible, and put all available company maps of the property at his disposal.

The writer is deeply indebted to his very helpful wife, Jane K. Kiersch, for her great effort in helping compile the manuscript and the addition of an artistic touch to the cartography.
CHAPTER II

GENERAL GEOLOGY

SUMMARY

The oldest known rock of central Arizona, the Pinal schist, is not exposed in the Seventy Nine mine area, but crops out in the Dripping Spring range to the north in the vicinity of Superior, Arizona.

The oldest rock in the Seventy Nine mine area is Mescal limestone, youngest member of the pre-Cambrian Apache group. The overlying basalt flow normally included with the Apache group was nowhere observed beyond doubt in the area. Three miles north of the northern limit of Plate I, the complete section of the Apache group, which overlies the basement Pinal schist of central Arizona, crops out. It includes Scanlan conglomerate, Pioneer shale, Barnes conglomerate, Dripping Spring quartzite, Mescal limestone and an overlying basalt flow. Beneath the lower limit of the Mescal outcrop is intrusive diabase.

Overlying the Mescal limestone are the Middle-Cambrian Troy quartzite, the undifferentiated beds, probably of the Middle Cambrian age, Upper Devonian
Martin limestone, the Lower Mississippian Escabrosa limestone and the Lower Pennsylvanian Naco limestone. This entire sedimentary series is locally conformable in dip and strike but is separated by at least three disconformities. East of the Keystone fault this series is little disturbed, except for gentle tilting. West of the fault the beds are much displaced and steeply dipping.

Intruded into the Mescal limestone and lower portion of the Troy quartzite are sills (?) and apophyses of diabase which crop out in the Seventy Nine mine area to some 400 feet in thickness. The total thickness is unknown, as the lower contact is not exposed. The age of the diabase was determined by Short and others⁹, to be post-


Middle Cambrian and pre-Upper Devonian at Superior, Arizona, where the maximum known sill thickness of 3,100 feet and excellent field relationships are present.
Carpenter suggests a Middle Cambrian or somewhat earlier age on the basis of field relationships in the Vekol Mountains.

The Apache group and Paleozoic rocks apparently remained horizontal and undisturbed until Upper Cretaceous time. No igneous bodies other than the diabase were intruded during the Paleozoic or Mesozoic eras and no Mesozoic sedimentary rocks are present.

During Upper Cretaceous time, large outpourings of basaltic and andesitic flows and ejections of pyroclastic material occurred a few miles to the southwest in the Christmas area. Associated intrusive rocks likewise were developed. This extensive development of basic material is expressed in the Seventy Nine mine area by local basalt porphyry sills (?) and plugs and andesitic and dacitic porphyry sills. The area was probably covered by basic flows and pyroclastics, since eroded, and now represented in gravels of the Gila conglomerate.

After this volcanic activity, the area was quiet until presumably the Cretaceous-Tertiary (Laramide) interval, when the region was subjected to stresses resulting in a major north-south fault system with associated shear zones which

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strike N. 60°-70° E. Some regional tilting accompanied this movement.

This period of deformation was accompanied in its later stages by the intrusion of acid igneous rocks in the form of dikes, sills, and plugs, probably apophyses of the deep seated Central Arizona batholith. Such bodies as the North and Main dikes of rhyolite porphyry, North Star and South dikes of monzonite porphyry and Seventy Nine dike of quartz diorite porphyry were all intruded at this time.

Intrusion of the earlier dikes along the shear zones in probably Early Tertiary time was followed shortly by a renewal of movement along this old north-south fault zone with the development of shear fractures striking N.70°-85°E and tension fractures at about N 55°E direction. The active north-south faulting is expressed by such breaks as O'Carroll, Keystone, Ore Body and Reagan Camp fault. Ore solutions apparently rose along the now favorable fault zone channelways and possibly the shear zones, and were deposited in adjacent shear and tension fractures where permeable. The shattered rhyolite porphyry, North Dike, or in some cases the fractured impure limestone and shale beds with deposition up dip, acted as the host. The mass of the limestone beds were unfavorable for penetration and subsequent deposition of the ore solutions, due to their
ability to heal up quickly upon fracturing and presented an impermeable barrier to the solutions. The ore was probably deposited in late Early to Middle Tertiary time.

The ore bodies of the Seventy Nine mine occur as discontinuous replacement veins and bodies in a shattered rhyolite porphyry dike, and as replacements in adjacent thin-bedded impure shaly limestone of Pennsylvanian age.

In the London-Arizona mine, the ore bodies are located where fractures intersected the favorable O'Carroll bed at the base of the Martin limestone. Bedding plane faulting probably contributed to the fracturing of these basal beds. This is likewise the ore control at the Apex mine, where a major fracture zone roughly paralleling the strike of the Seventy Nine dike-shear zone is mineralized at the base of the Martin limestone.

In probably Middle to Late Tertiary time, postore faulting was active with the formation of such breaks as Main, Mountain View and numerous other faults of a general N 35°-45° W strike. During this period of postore faulting, it appears likely that some renewed activity occurred along the N 70° E breaks, with some additional tilting of the beds. This direction has a strong control over the present drainage.

The Main fault has cut the Discovery ore body near the shaft collar and displaced the ore several hundred feet vertically.
This major postore faulting was prior to the covering of the area by the extensive Gila conglomerate.

Probably during the late Tertiary time, the Gila conglomerate, of extensive gravel deposits very irregular in thickness, was formed under subaerial or flu�atile conditions. The gravels include boulders and pebbles of all the rocks in the area, but are predominantly of basalt and andesite, the erosion remnants of the Upper Cretaceous outpourings. What is thought to be this formation includes fossils of Pliocene age outside of the Seventy Nine area a few miles to the south. It crops out just south of the Seventy Nine mine and extensively to the west of Reagan Camp fault in the outwash plain of the Gila River. It appears to have been deposited on the tilted erosion surface of the Naco limestone beds; this accounting for part to all of the Gila's tilt in some places.

Minor post-Gila faulting and adjustment has taken place. This is evidenced by faults present in the Gila and a dip of $28^\circ$ to the west, clearly seen in Seventy Nine Gulch.

Erosion has removed the Gila from large parts of the Seventy Nine mine area. The outcrop to the south of Seventy Nine Gulch in the vicinity of the mine appears to be an erosional remnant. This stripping of the area has exposed the oxidized Discovery ore body at the Seventy Nine mine and several other ore bodies in the district, as at the London-Arizona mine, in the lower Martin limestone.
Sedimentary Rocks

Mescal limestone

The Mescal limestone and overlying Apache basalt, where present, form the upper part of the pre-Cambrian Apache group. As first described by Ransome, in the Ray quadrangle, they are limited below by the Dripping Spring quartzite and above by the Troy quartzite.

The Mescal limestone is generally thin-bedded and parts of it contain much chert in bands parallel to the bedding (see Plate XXIII, Fig. 2). Siliceous material included within the limestone forms thin irregular layers which stand out on weathering and give the beds a gnarled, rough appearance.

The entire Mescal limestone section is not present within the Seventy Nine mine area. Nowhere are the lower beds, lower contact or underlying Dripping Spring quartzite visible. The Mescal occurs as small isolated limestone blocks up to 50 feet thick resting on the intrusive diabase (see Plate XXIII, Fig. 2); and as limestone beds

above the diabase which in turn are overlain by arenaceous strata. These arenaceous strata more than 90 feet thick consist of:

Troy quartzite

<table>
<thead>
<tr>
<th>Thickness (Approx.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(feet)</td>
</tr>
</tbody>
</table>

Disconformity

Mescal limestone*

1. Siliceous strata: Light gray, aphanitic...40

2. Sandstone: White to vitreous, grains 0.02-0.05 mm, in size: weathers iron stain..................30

3. Hornfels: Medium gray, sandy appearance; microscopically consists of orthoclase and hornblende; distinct parallelism to micro-texture;.........................20

Diabase

* Upper part of Mescal limestone

Overlying the siliceous strata is the basal conglomerate of the Troy quartzite. Nowhere was the presence of the overlying Apache basalt definitely established nor was this basalt found by Ross on Ash Creek a few miles to the south in the Dripping Spring range. Suggestions of basalt were seen in the highly altered igneous material under the Basal Troy and above the unquestionable diabase in Chocolate.

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Canyon. At Ash Creek the probable equivalent of the Mescal consists of thin-banded green shale and red quartzite 90 feet thick. In the Seventy Nine mine area as much as 90 feet of sandstone, hornfels and siliceous strata at the top of the Mescal are apparently the result of local deposition. This type of sediment was not described by Ransome in his Mescal section measured a few miles to the north of the Seventy Nine mine area. This local type of sediment overlying the limestone beds of the Mescal and underlying the Troy has been observed by Shride in the Salt River area east of Roosevelt Lake. It occurs as a discontinuous series of beds over a wide area. Hinds described strata of a very similar lithology in the Roosevelt Lake area, above the Mescal limestone and below the Troy quartzite, and gave the name of Roosevelt formation to them.

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13 Ransome, F.L., op. cit.


These overlying strata have been mapped as Mescal. It must be kept in mind that in the future some subdivision may be established between the Mescal and Troy, which would include these beds and be comparable to the Roosevelt subdivision.

Troy quartzite

Disconformably above the Mescal limestone is the Troy quartzite, of Middle Cambrian age. Nowhere in the Seventy Nine mine area is there a complete section of Troy. The Tornado Peak section has over 100 feet of the upper beds of the Troy quartzite exposed in the cliffs of Chocolate Canyon. To the north three quarters of a mile, the exposed Troy includes all units from the contact with the Mescal limestone to near the top of the formation. Here the gently dipping Troy caps the hill and forms the cliffs of the highest topographic feature in the Seventy Nine mine area.


The Troy was first described by Ransome in the Ray quadrangle. He noted that the beds differ greatly in their thickness, ranging from thin flaggy or shaly layers to cross-bedded pebbly beds 25 to 50 feet thick. In general, thick beds are characteristic of the lower and middle portions, whereas the upper part is thin-bedded, mostly yellowish or rusty colored and worm-marked.

A not quite complete section of the Troy quartzite measured by Ransome one half mile north along the continuation of the northernmost Troy of Plate I and recorded with approximate thickness is given below:

Recent erosion surface *

<table>
<thead>
<tr>
<th>Thickness (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. Yellowish, rusty, thin-bedded quartzites with olive-gray shale partings roughened by worm casts; at least .... 50</td>
</tr>
<tr>
<td>10. Fine-grained quartzite with very regular laminations from 2 to 6 inches thick......................... 1-1/2</td>
</tr>
<tr>
<td>9. Rather thin beds of white fine-pebbly quartzite........................................ 50</td>
</tr>
<tr>
<td>8. A single bed of massive cross-bedded fine-pebbly white quartzite, with layers of small quartz pebbles every few feet. Forms a cliff..................... 50</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>1.</td>
</tr>
<tr>
<td>2.</td>
</tr>
<tr>
<td>3.</td>
</tr>
<tr>
<td>4.</td>
</tr>
<tr>
<td>5.</td>
</tr>
<tr>
<td>6.</td>
</tr>
<tr>
<td>7.</td>
</tr>
</tbody>
</table>

Disconformity *

Lescal limestone *
Troy quartzite is light gray or white on fresh surface; generally buff, brown, rusty or maroon on weathered surface. It is commonly found weathered with diffusion rings of blue and light brown color one to two feet in diameter.

The Troy is broken by some faulting which has repeated the normal section and exaggerated its true thickness in this area. Such displacements are marked by fault breccia zones. Sharp angular pieces, up to six inches in length are cemented together in many places and show the presence of considerable manganese and copper stain.

In measuring the section of Troy (362½ feet) Ransome does not include all the upper beds. The top of his section is the recent erosion surface; with the normal expectancy of some upper beds thus having been eroded. It seems reasonable to believe that probably as much as 400 feet of Troy has been present in the northern part of the Seventy Nine mine area. The Troy, in the vicinity of the Hogvall prospect (Plate I) appears to have a thickness somewhat less than 300 feet, but its base is concealed.

The upper beds of the Troy are not fossiliferous, except for the so called worm casts, in the Seventy Nine mine area. However, the writer has collected brachiopods
from these strata at the crest of the Mescal Mountains, near highway 77.

Color, cross-bedding, grain size, composition and cliff-forming character easily distinguish the Troy quartzite.

Undifferentiated Cambrian beds

Conformably overlying the Troy quartzite is a series of shales and quartzites which have been mapped separately from the underlying Troy and designated as the undifferentiated Cambrian beds. They are of Middle Cambrian age and may be the northernmost known outcrop of the Santa Catalina formation observed in Deer Creek valley by Stoyanow19.


These beds are exposed in a complete series along the line of the Tornado Peak section, where they were measured by Peterson20. Their description recorded by the writer is as follows:

Martin limestone

Disconformity

Undifferentiated Cambrian beds

<table>
<thead>
<tr>
<th>Thickness (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Quartzite: Greenish, fine-grained, inclusions coarse white pebbles max. size 2 inches upper part; cliff forming. ................. 8</td>
</tr>
<tr>
<td>2. Shale: Brown, fine-grained, sandy, thin-bedded, partly micaceous and very platy; forms slope; weathers dark brown; poorly preserved trilobite fragments and many worm casts. ......................... 82</td>
</tr>
<tr>
<td>3. Quartzite: Greenish to rusty, fine-grained, partly shaly; cliff forming. ...... 15</td>
</tr>
<tr>
<td>4. Shale: Brown, fine-grained, sandy, thin-bedded, partly micaceous and platy; forms slope; weathers dark brown; many worm casts; many places partially concealed. ......................... 80</td>
</tr>
<tr>
<td>5. Quartzite: Light brown to tan, fine-grained, bedded, parts shaly. ............... 25</td>
</tr>
<tr>
<td>6. Concealed. .............................................. 15</td>
</tr>
</tbody>
</table>

225 feet

Troy quartzite

Near the top of Number 2 member, as it crops out in North Star Gulch (Plate II, the writer collected free cheeks of trilobite fragments. As this bed is definitely under the base of the Upper Devonian Martin limestone, as it is very similar to Bed Number 4 and as the lithology is
different from that of the Troy, the writer has grouped these beds together with the associated thin quartzites, as undifferentiated Cambrian.

Stoyanow\textsuperscript{21} at Pepper Sauce Canyon in the Santa Catalina Mountains has differentiated the Middle Cambrian beds overlying the Troy quartzite as follows:

\begin{tabular}{ll}
\textbf{Thickness} & \textbf{(feet)} \\
Southern Belle quartzite, cliff-forming, massive white quartzite & 26 \\
Middle Santa Catalina formation. Alternating, thin-bedded, rusty quartzite, yellow and red sandstone, and brown and green micaceous shale. Fauna throughout entire formation: \textit{Agraulos} sp., \textit{Inouyia} sp., \textit{Agnostidae} sp., \textit{Stenotheca} sp. & 350 \\
Troy quartzite & \\
\end{tabular}

It appears that possibly one of these Cambrian sub-

divisions of Stoyanow's is present in the Seventy Nine mine area. The trilobite fragments establish the beds as Cambrian, but they are too poorly preserved to show what part of the Cambrian is represented. Because these beds grade upward from the Troy quartzite, which is considered to be of Middle Cambrian age, the suggestion is made that these beds are probably of that age also. It appears likely that these are the equivalent of the Santa Catalina formation of Stoyanow 22 exposed in Peppersauce Canyon 45 miles to the south.

Stoyanow, A.A., op. cit.

Martin limestone

Disconformably above the undifferentiated Cambrian beds of Middle Cambrian age is Upper Devonian limestone. On the basis of lithology and fossil content this limestone is correlated with the Martin limestone of the Bisbee, Ray, Globe, and Miami districts 23.


Weathering of the Martin limestone tends to form debris-
covered slopes similar to those developed from the softer members of the underlying undifferentiated Cambrian beds. These are in contrast to the sharp cliffs of the Troy quartzite below and the Escabrosa limestone above. Viewed from a distance the Martin, above the commonly gossan stained basal members, usually appears a distinctly buff, in marked contrast to the prevailingly iron-stained Cambrian beds or the pinkish-gray, gray and white Escabrosa.

There is no apparent angular unconformity between the Martin limestone and the underlying Cambrian beds, though the hiatus is considerable.

In this region a full section of Martin is present only in the vicinity of Tornado Peak and in a small area shown in the northwest corner Plate I. At North Star Gulch only part of the section is present.

The thickness of the Martin limestone varies somewhat. At Tornado Peak where Peterson measured it, the thickness

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is 328 feet, but at its outcrop in the northwest corner of Plate I., it is estimated to be about 250 feet thick.

The following subdivisions of the Martin were measured by Peterson at Tornado Peak. Their description, recorded
by the writer is as follows:

**Escabrosa limestone**

**Martin limestone**

<table>
<thead>
<tr>
<th>Thickness</th>
<th>feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Limestone shaly: Medium gray, shaly, thin-bedded, cliff former; weathers to sharp rough surface.</td>
<td>30</td>
</tr>
<tr>
<td>2. Covered: (Light blue-gray to pinkish, fine-grained, shale at section A-A', Plate VI).</td>
<td>20</td>
</tr>
<tr>
<td>3. Shale: Dark green, fine-grained, arenaceous, very thin-bedded, forms slope; suggestive of being fossiliferous.</td>
<td>68</td>
</tr>
<tr>
<td>4. Limestone shaly: Light gray to white, shaly, thin-bedded, upper 10 feet a dark green.</td>
<td>55</td>
</tr>
<tr>
<td>5. Limestone: Blue gray to white, aphanitic, facies near center sandy; thick-bedded, cliff former; weathers rough, massive; top one foot greenish, medium-grained, sandstone bed with angular fragments of limestone.</td>
<td>120</td>
</tr>
<tr>
<td>6. Limestone alternating: Dark blue and green dolomitic, fine-grained, thin-bedded, top 8 inches shale bed; mineralized horizon London-Arizona and Apex mines.</td>
<td>25</td>
</tr>
<tr>
<td>7. Limestone: Yellowish to creamy, sandy, thin-bedded, mineralized horizon London-Arizona and Apex mines.</td>
<td>10</td>
</tr>
</tbody>
</table>

328 feet
Disconformity

Undifferentiated Cambrian beds

The Martin limestone as it crops out in the North Star Gulch area (Plates I and II) has a much more rusty to buff color on a weathered surface than at Tornado Peak. Bed Number 4 is very tan to buff color and on weathering forms small step cliffs two to three feet high. Bed Number 5 also weathers a tan color here.

Bed Number 2 is a pinkish thin, paper shale in North Star Gulch and grades upward into the shaly limestone of Bed Number 1.

The Upper Devonian section of this part of Arizona has been subdivided by Stoyanow on the basis of specimens found on Pinal Creek, north of Globe. Here *Camarotoechia endlichii* (Leek) was found in the impure limestone at the very top of the section. Stoyanow has correlated the impure limestone and paper shale with the lower part of the Ouray limestone of Colorado which is of Upper Devonian age. No fossils were found in the corresponding beds in the Seventy Nine mine area but they are probably of the same age.
Harshman has separated and described the lower member of the Upper Devonian sequence at Superior as the Crook formation, 252 feet thick. Stoyanow in the Picacho de Calera Hills, 25 miles northwest of Tucson, has described an Upper Devonian series of 73 feet underlying the Martin limestone which he has named the Picacho de Calera formation.

The Martin limestone in the Seventy Nine mine area no doubt includes some of these subdivisions of the Upper Devonian. Because of limited scale of mapping, no attempt has been made to differentiate these proposed subdivisions of the Upper Devonian, and they are not shown on Plates I and II.

Huddle and Dobrovolny have proposed the name, Martin...
formation, to cover the entire Upper Devonian sequence, in correlating across central and northwestern Arizona.

Escabrosa limestone

Overlying the Upper Devonian, Martin limestone, without break is the Escabrosa limestone, of Lower Mississippian age. This formation represents the lower portion of the Tornado limestone of Ransome, named after Tornado Peak.


Plate I. Stoyanow has shown conclusively that the Tornado limestone is of two definite ages separated by a hiatus. The lower portion is correlated with the Lower Mississippian limestone of southeastern Arizona. The upper portion is of Lower Pennsylvanian age and in this paper the Naco limestone is employed. This conforms with the usage in mining districts to both the north and south of the Seventy Nine mine area, and with the U.S. Geological Survey name for the Lower
The Escabrosa limestone, with its prominent white cliffs is one of the most conspicuous formations in the Seventy Nine mine area. In the vicinity of Tornado Peak and especially along the fault scarp of the Keystone fault, Plate I., the prominent vertical cliffs are easily separated from the thinner beds of the Martin limestone below and the Naco limestone above. The Escabrosa is mostly a high-calcium limestone, but contains a small dolomitic member about 150 feet above the base. It includes some chert nodules throughout, which are especially abundant in the upper portions. Except for crinoid stems, fossils are not abundant in the formation.

The thickness of the Escabrosa varies considerably within the Seventy Nine mine area. At Tornado Peak it consists of 581 feet of limestone, intruded by a sill, 135 feet thick, of Cretaceous andesite porphyry. (see page 65) Less than 3 miles west on the south side of North Star Gulch,
Plate VI., it consists of 440 feet of limestone. At this locality no andesite porphyry sill is present. The difference in thickness appears to be primarily the result of the erosion interval represented between strata of the Escabrosa limestone and Naco limestone. No doubt, erosion was more effective in the immediate vicinity of the Seventy Nine mine than in the Tornado Peak area.

On the basis of color and cliff-forming tendency, the Escabrosa can be divided into six members. The lowest 115 feet is composed largely of massive gray limestone beds. The lower third of this basal member is composed of alternating light and dark bands, the central part a distinctive gray massive limestone and the upper portion a gray to white bed. This member is zone Number 14 of the section subsequently described. It forms the basal part of the characteristic Escabrosa bluff and in places is very precipitous.

The second member is a series of thin-beds 30 feet thick, which weather to small ledges. In the Tornado Peak area, this member is immediately under the 135 foot andesite porphyry sill of Cretaceous age. The iron stained, smooth, slope-forming sill, where present, is a conspicuous marker above the member.

The second member includes zones 11 to 13 of the section.
The third member is a series of limestone beds, 195 feet thick. Alternating light gray to dark blue beds are at the bottom, blue to dark blue beds are in the center and white to light gray beds are at the top. Throughout the area this member forms nearly vertical cliffs. It includes zones seven to ten of the section.

The fourth member is a series of thin-bedded limestones 62 feet thick which weather to a gentle slope. They are dark blue in the lower parts but light blue-gray above. This member includes zones four to six of the section.

The fifth member is a blue gray to buff dense limestone, 60 feet thick. It forms a small but prominent cliff above the two large, massive, cliff-forming members just described. This member is zone three in the section.

The sixth member is a light to blue gray, thin-bedded limestone 119 feet thick. It weathers to a gentle slope, similar to that formed by the overlying Naco limestone. The upper portion weathers to a distinct buff color. This member is represented by zones one and two in the section.

The Escabrosa limestone at Tornado Peak was measured by Peterson. Its description recorded by the writer is as follows:

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Naco limestone

Disconformity: Upper 100 feet removed by erosion across two and one-half miles to west

Escabrosa limestone

Thickness (feet)

1. Limestone: Blue to dark gray, aphanitic, thin-bedded; abundant chert lenses and nodules; weathers ledges, smooth surface, buff; lower portion darker color. ........ 69

2. Limestone marblized: Light gray, medium to coarse-grained, thin-bedded, weathers with differential hardness; Fossils, crinoid stems, Zaphrentidae (?), Spirifir centronatus (Winchell), replaced, good preservation, common; garlic odor on breaking. ............. 50

3. Limestone: Dark blue, aphanitic, arenaceous, thick-bedded, chert lenses and nodules common, irregular to podlike, dark in upper portion; weathers cliff, blue-gray to buff. ......................... 60

4. Limestone: Light gray, weathers soft slope, blue-gray. .................. 10

5. Limestone shaly: Light gray, shaly, thin-bedded, weathers soft slope; fossiliferous, zaphrentoid coral; replaced, potential ore horizon. ........ 20

6. Limestone: Dark blue, fine-grained thick-bedded, arenaceous, scattered chert lenses; weathers cliff, sandy smooth, blue-gray. ....................... 32

7. Limestone: Crinoidal, marblized; light gray, coarse-grained, thick-bedded, few chert lenses; weathers prominent cliff, smooth surface, much white secondary lime material present in
in fractures; fossiliferous, crinoid stems, replaced, abundant bottom and center, common upper part; garlic odor on breaking. .................. 60

8. Limestone: Dark-blue-gray, aphanitic, sandy, thin-bedded, chert lenses, few; weathers prominent cliff, sandy smooth, medium blue; top and bottom very sandy and cross-bedded, center lens; 3 white bands 6 inches wide within bed. .............................. 40

9. Limestone shaly: Light blue-gray, shaly, thin-bedded, weathers slope, sugary, normally concealed; potential ore horizon. ................................. 10

10. Limestone alternating: Dark blue, aphanitic, thick-bedded, weathers cliff, medium blue; fossiliferous, Syringopora aculeata (Girty), zaphrentoid coral, replaced, common; several alternating thin bands 1 foot thick, maple colored limestone; lower 8 feet blue, aphanitic, sandy, weathers gray; dolomite. ............ 85

Andesite porphyry (intrusive Cretaceous): Weathers slope, granular, light-brown, few irregular projecting outcrops; (see page 65 for description) a definite sill. ................................. 135 feet

11. Limestone: Dark gray, weathers ledge, medium blue; partially concealed. ........ 4

12. Garnet: Brown, coarsely crystalline, massive, in places large crystals, associated specularite, minor calcite as secondary mineral; weathers cliff, granular surface. ......................... 10

13. Limestone: Light blue-gray, aphanitic, thin-bedded, chert lenses, 1 to 2 inches thick, alternate similar sized bands limestone upper portion, buff to rusty. .. 16
14. Limestone: Gray, fine-grained, thick-bedded, weathers slope, smooth surface in Tornado Peak section, normally cliff former; fossiliferous, crinoid stems; upper third granular; weathers smooth, secondary lime deposited in fractures; center third aphanitic, weathers rough surface, light gray, conspicuous; lower third more than 4 alternating beds blue-gray, sandy and white to light gray limestone; few chert lenses bottom portion. .......................... 115

581 feet

Martin limestone

A complete section with description of the Escabrosa limestone near the Seventy Nine mine is shown by Plate VI. The thickness here is less due primarily to the pre-Naco erosion.

The Escabrosa limestone contains a rather meager invertebrate fauna of Lower Mississippian age in the Seventy Nine mine area. Bed Number 3 contains *Spirifer centronatus* (Winchell), an index fossil in the Madison limestone of this age. The abundance of *Syringopora* sp.?; crinoid stems and an unnamed zaphrentoid coral is characteristic of the Escabrosa limestone. On the basis of the fauna collected by Ransome

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the Escabrosa limestone at Bisbee was correlated with the Kinderhook and Osage and more recently has been shown to include strata of Burlington age.


Naco limestone

Disconformably overlying the Escabrosa limestone of Lower Mississippian age is the Naco limestone of Lower Pennsylvanian age. It is the upper part of the Tornado limestone of Ransome, but is only partially exposed at Tornado Peak, Plate I. Stoyanow in showing that the Tornado limestone includes strata of two different ages separated by a disconformity has suggested the name Galilio limestone for this upper portion or Pennsylvanian part of the Tornado in central Arizona. Elsewhere the Pennsylvanian
is called Naco limestone. In this paper, however, the name Naco limestone is employed to conform with usage in the Superior Mining area, 40 miles to the north, in the Biscbee mining district to the south, and with the U.S. Geological Survey name for this formation in central Arizona. The measured section at Tornado Peak used by the U.S. Geological Survey in their correlation of central and northeastern Arizona stratigraphy is included within Plate I. This is the closest published geologic section which includes the sequence exposed in the writer's area. Upper Mississippian strata are represented in southern Arizona by the Paradise formation. The upper part of

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40 Ransome, F.L., op. cit.


42 Hernon, R.M., the Paradise formation and fauna: Jour. of Paleont., vol. 9, No. 8, p.
Ransome's original Naco limestone at Bisbee was shown by Stoyanow to include Permian strata, and this term "Naco" is now restricted to the Pennsylvanian beds.

The Naco limestone consists of white, light gray, rusty or light pink thin-bedded limestone. Except for a few small cliff-forming members, the beds are generally two feet or less in thickness. Included within it are some iron-stained shales and a few very thin, greenish to gray, quartzite beds. These comprise a very small part of the total. Chert nodules, common in the Escabrosa, especially the upper portion, are also abundant in the Naco, especially the lower and upper beds. The lower beds of this formation contain even more chert nodules than the underlying Escabrosa, where in the lower 100 feet very abundant large massive bodies are present.

The total thickness of the Naco limestone is not exposed in the Seventy Nine mine area. At Tornado Peak, Peterson measured 388 feet to an erosion surface at the top.
greater thickness is present in the immediate vicinity of the Seventy Nine mine. Outcropping in North Star Gulch, the Naco is exposed to the south for about one mile, dipping from $20^\circ$ to $35^\circ$ south. This section is cut by a system of faulting which has repeated the beds. In places the eroded surface of the Naco is covered by Gila conglomerate as at the ridge south of the Seventy Nine mine (Plates I and II.). Although a complete unbroken section is not present, it seems logical to assume from the extensive outcrop of Naco west of the Keystone fault that possibly 1000 feet or more of Naco is present in the Seventy Nine mine area. At the Seventy Nine mine, the Naco includes stratigraphically higher beds than at the Tornado Peak section where it is 388 feet. Thus with more than 400 feet of Naco limestone cropping out at the Seventy Nine mine and with additional extensive Naco exposed to the south, this unmeasured section would not have to account for an unreasonable thickness to have 1000 feet of Pennsylvanian beds in the area. These Naco beds to the south of the Seventy Nine mine have a partially different lithology than the beds at the Tornado Peak and Seventy Nine mine section of North Star Gulch.

The base of the Naco in the Seventy Nine mine area is a chert conglomerate bed two to three feet thick. This conglomerate formed at the close of the hiatus between the Escabrosa and Naco formations is found everywhere at this horizon.
It is readily distinguished from the chert of the overlying limestone, by the red and brown colored angular pebbles. Abundant Lower Pennsylvanian fossils were collected in a one foot horizon which varied from one to twelve feet above the conglomerate throughout the Seventy Nine mine area. This horizon contains abundant *Squamularia perplexa* (McChesney) replaced by calcite.

Mississippian fossils of the species *Spirifer centro-natus* (Winchell) were collected 70 feet below the conglomerate.

It is difficult to separate the two limestones on lithologic evidence only, so the conglomerate, where present, is used as the boundary markers.

The section of Naco limestone at Tornado Peak measured by Peterson with description recorded by the writer is as follows:

<table>
<thead>
<tr>
<th>Recent erosion surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness (feet)</td>
</tr>
<tr>
<td>1. Limestone: Blue gray, medium-grained, thick-bedded, weathers slope, light gray; fossiliferous, Archaeocidaris sp. (?), <em>Spirifer rockymontanus</em> (Harcou), Fusulina (?), crinoid stems, replaced, abundant.</td>
</tr>
</tbody>
</table>

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45 Peterson, N.P. in Huddle, J.W. and Dobrovolny, E. op. cit.
2. Limestone: Blue-gray, aphanitic, thin-bedded, few chert lenses; weathers slope, smooth, mottled especially lower portion; fossiliferous lower portion, Syringopora sp. (?), Spirifer occidentalis (Girty), replaced, abundant. .......... 165

3. Shale: Dark maroon to black, weathers slope, smooth, iron stained to black; in places partially baked. ............... 25

4. Limestone: Light blue-gray, aphanitic, thick-bedded, weathers slope, knotty surface, rusty to buff. ................. 35

5. Concealed. ................................................ 5

6. Limestone marblized: Blue-gray, coarse-grained, thin-bedded, weathers slope, smooth surface, light gray; fossiliferous, crinoid stems, replaced, abundant. ...... 5

7. Limestone: Light gray, aphanitic, thin-bedded, weathers slope, smooth surface, light blue-gray. ....................... 10

   Dacite porphyry sill. .................... 5 feet

8. Limestone: Blue-gray, fine-grained, thin-bedded, few chert lenses; weathers ledges to smooth surface; light blue, mottled in lower part; several horizons of intraformational conglomerate in lighter colored thin beds. ................................. 25

9. Limestone: Maple, coarse-grained to aphanitic, thick-bedded, chert lenses and nodules, irregular massive bodies 2 to 5 feet thick, 10 to 15 feet above base, rusty; weathers cliffs and ledges, light gray; fossiliferous, Squamularia perplexa (McChesney), abundant, in 1 foot thick horizon 12 feet above base, elsewhere as little as 1 foot above base, replaced calcite. ......................... 60
10. Conglomerate: Covers erosion surface, matrix: light gray, silica, well cemented; gravel: \( \frac{3}{8} \) inch average, sharp angular brown and gray chert. .............................. 3

Disconformity: Upper 100 feet removed by erosion across two and one half miles to west.

Escabrosa limestone

The Naco limestone contains an abundant, well preserved fauna of Lower Pennsylvanian age in the Seventy Nine mine area. Some of the fossils which were collected are:

Bryozoa
Archaeocidaris sp. (?)
Archaeocidaris sp. (?)
Chonetes sp. (?)
Composita sp. (?)
Marginifera sp. (?)
Derbya sp. (?)
Spirifer cameratus (Morton)
Spirifer occidentalis (Girty)
Hustedia mormoni (Marcou)
Squamularia perplexa (McC Chesney)

Gila conglomerate

The poorly consolidated alluvial deposits that occupy the greater part of the Gila River Valley belong to the Gila conglomerate, parts of which are of Pliocene age. This for-
mation is widespread throughout adjacent parts of Arizona.

No complete thickness is exposed in the Seventy Nine mine area, but Ross reports several hundred feet present in the Christmas area, 3 miles east, with much of it obviously removed by erosion. The base of the Gila is exposed on the hill south of the Seventy Nine mine, Plate II, where it rests on the eroded surface of the Naco limestone and is more than 150 feet thick. It crops out over a considerable part of the area to the west of the Reagan Camp fault as shown in Plate I.

The formation consists of poorly sorted subangular to angular fragments of basalt, basalt-porphyry, andesite, andesite-porphyry, quartzite, granitic rocks and limestone. The fragments include large masses several feet in diameter but average four to six inches in length. The matrix of these blocks and imperfectly rounded fragments is a poorly sorted sand of granitic and basaltic origin. In places a poorly sorted sandstone is interbedded. Where well consolidated the formation forms cliffs several tens of feet high as in Seventy Nine Gulch (see Plate I.). Much caliche helps cement the fragments in the Seventy Nine mine area,
giving the conglomerate a decided white color where erosion has exposed the underlying beds in a steep slope.

The large outcrop of Gila conglomerate adjacent to and south of the Seventy Nine mine, Plate II, contains large boulders and smaller fragments of typical mineralized material such as vein silica, garnetized limestone with specularite and copper carbonates, and the rhyolite porphyry rock, mineralized at North Dike. Thus the conglomerate is younger than any of these features.

South of the Christmas area, fossils of Pliocene age

\[\text{Ross, C.P., op. cit. p. 17}\]

were found in rock supposedly of the Gila formation. On this basis it can be considered to be in part at least of Pliocene age.

The Gila conglomerate has apparently undergone subsequent tilting and in Seventy Nine Gulch, Plate I, dips 28° west. Part of this tilt may be a result of its deposition on a sloping surface. Gila commonly possesses a depositional tilt, but much of it is the result of crustal disturbance.

Quaternary alluvium
All the alluvial deposits younger than the Gila conglomerate have been grouped under the name Quaternary alluvium. Two subdivisions have been recognized. The older of these is a partly consolidated series of deposits represented by remnants found on slopes above the present flood plains. The deposits are well exposed along Chocolate Canyon near the Keystone fault.

The second division of the Quaternary alluvium has been termed Recent alluvium. It occupies channels and small flood plains of the present intermittent streams.

The older alluvium is a coarse, poorly sorted gravel of subangular to rounded fragments derived from the rocks outcropping locally. Much of it is partially cemented with caliche. In a stream cliff on Chocolate Canyon near Keystone fault, an exposure of westward-dipping Gila conglomerate has been truncated and is capped by several feet of this horizontal alluvium.

The youngest alluvium is unconsolidated sand, silt and gravel. This material is of local derivation.

Quaternary alluvium has been mapped, Plates I and II., only where it consists of appreciable thicknesses or has considerable areal extent. The fine sand and gravel present in the bottom of all intermittent streams throughout the Seventy Nine mine area was not mapped.
Igneous Rocks

Diabase

Intruded into the Mescal limestone and Troy quartzite, is a widespread diabase mass east of Keystone fault, Plate I. This controversial formation has been fully described by Ransome in the Globe and Ray-Miami reports\(^\text{48}\). It has invaded the Mescal limestone primarily but isolated occurrences of small dikes and sills in the Troy are present. Its highest position in the Troy is found in Chocolate Canyon above Chilito. Relationship to the underlying formations is unknown in the Seventy Nine mine area, but if comparable to similar areas in the Dripping Spring range, it is emplaced as a sill.

Diabase of similar character and geologic occurrence crops out in various places in the Santa Catalina, Galiuro, Dripping Spring, Mescal and Mazatzal ranges and the Sierra Ancha and upper Salt River. In this large area 130 miles long north-south and 50 miles wide the greatest known thickness of diabase is in the Magma mine\(^\text{49}\), Superior, Arizona.


Here two sills totaling 3,100 feet in thickness have been cut by mine workings.

The diabase is exposed for a thickness of more than 400 feet in Chocolate Canyon, Plate I, and as the canyon floor is diabase the total thickness in the Seventy Nine mine area is unknown.

The emplacement of the diabase apparently was accomplished by forcing apart the intruded limestone and quartzite, although locally assimilation may have been important. Ransome concluded that its intrusion took place at shallow depths.

A dark greenish soil is characteristic of all areas where diabase crops out. This combined with the low flat nature of weathering, assists in the recognition of this rock even where concealed by Troy debris.

Based on mineral composition, the diabase may be divided into two types; a: hornblende diabase; b: diabase.

Both types are believed to be derived by differentiation within the same magma chamber. A typical specimen of hornblende diabase is as follows:

Megascopically a fresh surface has the typical ophitic texture of diabase. Laths of medium to dark plagioclase, maximum 2.0 mm. in size, with parallel sides and good cleavage are surrounded by dark colored ferromagnesian. The laths and the ferromagnesian are about equal in proportions and compose 40% each or two, 80% of total rock. The hand lens reveals considerable green glassy mineral.

This rock is exceptionally heavy and suggests presence of magnetite.
Microscopically the hornblende diabase has the following composition (see Plate XII, Fig. 1.):

**Essential**

Plagioclase - 60% Andesine-labradorite, $\text{Ab}_{50}\text{An}_{50}$
max. grains 1.0 mm. in size

Hornblende - 25% (granulated)
max. grains 1.0 mm. in size

**Accessory**

Biotite - 15%
max. grains 0.5 mm. in size

Apatite - 5%

**Alteration**

Sericite
Magnetite - 2%
Chlorite

The plagioclase, andesine-labradorite, is intergrown in a typical ophitic structure of a diabase with the hornblende and biotite. Occurs as euhedral to subhedral outline. Moderate alteration to sericite. It has been iron stained. Hornblende as granulated euhedral to subhedral grains in outline is in close association with biotite and magnetite. Biotite in formless equidimensional grains forms aureoles around the magnetite. Apatite occurs in euhedral to subhedral grains of 1.0 mm. maximum length. Magnetite is abundant, and is associated with hornblende, biotite and the plagioclase. The interstitial material is badly crushed. (mylonitization).

A typical specimen of diabase is as follows:

Megascopically on a fresh surface, shows typical ophitic texture of a diabase. Laths of medium dull gray plagioclase feldspar with maximum of 4.0 mm. in size having parallel sides and good cleavage. These laths are surrounded by a dark colored mineral of indeterminate character. The laths of feldspar constitute 60% of the rock and the dark mineral 40%.

Microscopically the diabase has the following composition (see Plate XII, Fig. 2.):
Plagioclase - 60% andesine-labradorite, Ab$_{50}$An$_{50}$
max. grains 2.5 mm. in size

Augite (?) 36% partly altered to hornblende (uralite)
max. grains 2.0 mm. in size

Accessory Alteration

Apatite - 3%
max. grains 1.0 mm. in size
Sericite

Magnetite - 1%

Plagioclase, andesine-labradorite in euhedral to sub-
hedral outlines intergrown in a typical ophitic structure of
a diabase with augite (?). Moderate to intense alteration
of the feldspar has produced abundant sericite as an
alteration product.
The augite (?) has been altered to hornblende (uralite)
and the resulting material consists of small needle like
structures and very irregular matted masses.
Apatite is present in typical euhedral outline.
The interstitial material between the feldspar laths
contains much uralite as the result of alteration of augite
(?) The uralite is in the form of small needles and
radiating masses.

Several igneous bodies are intruded into the diabase,
especially at Schneider Hill, in Little Chocolate Canyon and
just east of upper Keystone Gulch, Plate I.

At Schneider Hill an irregular intrusive of quartz
latite porphyry has invaded a considerable area emplacing
itself as both a concordant and discordant mass with respect
to overlying sediments. The diabase, present as islands
within and on the periphery of the quartz latite porphyry
is altered and contains much primary and secondary magnetite. (Plate XII, Fig. 2.)

In Little Chocolate Canyon, eastward trending aplite
dikes extend east three quarters of a mile from the diabase
contact at Keystone fault to near the Schneider Hill quartz
latite porphyry and the headwaters of the canyon. These
dikes make sharp contacts with the diabase, both weathering to even slopes.

Many small irregular plugs (chonoliths) of granite porphyry intrude the diabase in the area east of upper Keystone Gulch and fault. These bodies weather in typical spheroidal manner as shown by Plate XXV, Fig. I, and stand out in relief from the surrounding even sloped diabase.

Age

The exact age of the diabase has been the source of much discussion, with new evidence in the spring of 1947, suggesting a possible partial revision of the present views. Ransome, after examination of the Ray and Miami districts,


assigned the diabase to the early Mesozoic or late Paleozoic. This was on the basis of dikes cutting Tornado (Escabrosa and Naco) limestone in the Tortilla Mountains and the Dripping Spring Range. Ransome thus concluded:

Intrusive relations show very clearly that the diabase is younger than the Troy quartzite. The Mescal (Martin ?) and Tornado limestones have been cut only here and there by small bodies of diabase, but these are supposed to represent parts of the same magma that solidified in the larger masses. The diabase is thus younger than the Pennsylvanian epoch of the Carboniferous.
Darton states: "I am sure that these (small bodies and dikes of diabase that cut the Martin and Tornado limestones) are not the same intrusions as the sills and dikes in the Apache group but feeders of some of the Tertiary or Quarternary basalts. In other portions of the region I have found that the diabase invades mainly the strata older than the Troy, but in some instances the lower part of the quartzite is invaded."


Short and Ettlinger found evidence in the Magma mine that the diabase engulfed the lower part of the Troy quartzite, but has not intruded the Martin limestone. They thus regarded the diabase as post-Middle Cambrian and pre-Upper Devonian. This same opinion was held by Short and others in 1943; they describe a sill of diabase, south of Superior, which intrudes Troy quartzite and shows distinct contact relationships. The diabase has intruded the Troy to within 50 feet of the underlying Martin limestone.


Short, M.N. and others, op. cit. p. 38.
Carpenter, 1946-47, in the Vekol Mountains, west of Casa Grande, Arizona, found the diabase intruded as dikes and sills in the lower Troy quartzite and cut by an erosion surface within the quartzite section. At places, the diabase crops out as a low ridge projecting above the ancient erosion surface in cross section. Fragments of the diabase were found in the sediments overlying the lower quartzite and below the top member of the thick quartzite section, both deposited overlapping the earlier diabase ridge. At the top of the quartzite series and above the diabase fragments is found the sandy uppermost member of the Troy which contains brachiopods elsewhere and thus dates the formation. Carpenter thinks this relationship suggests two periods of quartzite deposition, the diabase being intruded into the lower series prior to the intervening erosion interval which eroded sufficiently to expose diabase as a ridge. The later quartzite, dated by the brachiopods it contains, is of Middle Cambrian age. These field relations in the Vekol Mountains suggest a Middle Cambrian or earlier age for the invaded lower quartzite and the intrusive diabase.

As outlined, the exact age is still in doubt. The relationships of the diabase to the invaded rocks in the
Seventy Nine mine area add nothing to the previous knowledge. The diabase is confined to the lower parts of the quartzite series mapped as Troy.

Basic intrusives, flows (?)

Basalt porphyry (andesite, dacite)

Immediately east of Reagan Camp, Plate I., cropping out over an area of about one-fifth square mile is an intrusive basalt porphyry. This rock occurs in several small isolated masses on the weathered dip slope of the Naco limestone to the east and north of the main body. It is present as an intrusive body (sill?) in the Naco just west of stake Number 53, Plate II. Adjacent to the Reagan Camp fault west of A.H, Plate II., several small sills of basalt porphyry crop out.

Basalt porphyry and andesite porphyry of a very similar character crop out over a wide area east and south of Tornado Peak in the vicinity of Christmas, and Ash Creek. Ross has described this material as andesite, latitic and basaltic lava and pyroclastic rocks with interbedded conglomerate, sandstone and shale. Associated with these extrusives are dikes and sills, of varying sizes, with porphyritic texture.
and of andesite and basaltic composition. It seems apparent that present in the Seventy Nine mine area are intrusive sills, dikes and plugs (chonoliths) comparable to these porphyritic bodies.

The basalt porphyry is resistant to weathering and stands out in relief in contrast to the softer Naco limestone.

Along the borders of the main intrusive mass, facies are present of a little less basic composition. This material can be traced along bedding planes and fractures as small apophyses of the main basaltic mass.

In a few cases, moderately sized sills have been emplaced laterally into the adjacent Naco. A typical sill of this nature 15 feet thick, is intruded east of the main mass and near the Chilito road. It is a dacite porphyry. Adjacent to Reagan Camp fault, just west of ΔH, Plate II, a small outcrop of dacite porphyry shows excellent flow structure.

The main mass is not of uniform composition, but appears to show several facies of differentiation. One very prominent facies is immediately east of Reagan Camp and is an andesite porphyry.

As previously mentioned, the large intrusive plug is of varying composition, probably the result of local differentiation from the main magma. Based on mineral composition, it
may divide into: a. the main mass of basalt porphyry  
b. andesite porphyry, a local differentiation within main mass.  c. dacite porphyry, the marginal facies, apophyses, and sills.

A typical specimen of basalt porphyry is as follows:

Megascopically a dark gray rock on fresh surface, weathers to a medium blue. A porphyritic texture with an aphanitic groundmass. Laths of plagioclase, feldspar maximum of 2.0 mm. in size. Small amount of ferromagnesian in about equal sized grains with the feldspar.

In weathering areas 1 to 5 inches in size, have a distinctively darker color, suggesting a large or porphyritic texture, not present on fresh surfaces.

Microscopically the basalt porphyry has the following composition (see Plate XIII, Fig. 1.):

<table>
<thead>
<tr>
<th>Phenocrysts</th>
<th>Groundmass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plagioclase-65% labradorite $\text{Ab}<em>{40}\text{An}</em>{60}$</td>
<td>Plagioclase-Labradorite 50%</td>
</tr>
<tr>
<td>max. grains 2.0 mm. in size</td>
<td>Hornblende</td>
</tr>
<tr>
<td>50% Hornblende - 34%</td>
<td></td>
</tr>
<tr>
<td>max. grains 1.5 mm. in size</td>
<td>Alteration</td>
</tr>
<tr>
<td>Quartz - 1%</td>
<td>Sericite</td>
</tr>
<tr>
<td>max. grains 0.5 mm. in size</td>
<td>Limonite</td>
</tr>
<tr>
<td></td>
<td>Magnetite</td>
</tr>
<tr>
<td></td>
<td>Chlorite</td>
</tr>
</tbody>
</table>

Plagioclase, labradorite, present as unoriented laths. The laths are in a glassy to felted groundmass. Alteration to sericite with moderate amount of limonite. Some laths well zoned.

Hornblende is present in anhedral to subhedral outline and is probably the result of augite alteration. Chlorite and magnetite associated. Quartz in few scattered anhedral grains.

The groundmass consists of fine grained labradorite and hornblende with parts completely glassy. All altered to a dark iron stained color.
A typical specimen of andesite porphyry is as follows:

Megascopically a medium gray porphyritic rock with an aphanitic groundmass. Phenocrysts of a light plagioclase feldspar, prominent with a few scattered grains of biotite. Small amount of alteration present.

Microscopically the andesite porphyry has the following composition:

<table>
<thead>
<tr>
<th>Phenocrysts</th>
<th>Groundmass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plagioclase- 85%</td>
<td>Plagioclase-</td>
</tr>
<tr>
<td>Andesine-labradorite Ab An 60%</td>
<td>Andesine-</td>
</tr>
<tr>
<td>max. grains 2.5 mm. in size</td>
<td>labradorite</td>
</tr>
<tr>
<td>Biotite- 15%</td>
<td>Alteration</td>
</tr>
<tr>
<td>max. grains 1.5 mm. in size</td>
<td>Sericite</td>
</tr>
<tr>
<td>Quartz</td>
<td>Chlorite</td>
</tr>
<tr>
<td>max. grains 0.7 mm. in size</td>
<td>Kaolin</td>
</tr>
</tbody>
</table>

Accessory

Magnetite

Plagioclase, andesine-labradorite, in euhedral to subhedral outline, and in megascopic examination of slide, show good rectangular to square outline. Most grains have gone to sericite. No twinning striations apparent on most feldspars, due to intense alteration.

Biotite in subhedral to anhedral outline. Most grains fresh, with few grains slightly chloritized. Some grains in altered radiating needle structure.


A typical specimen of dacite porphyry is as follows:

Megascopically on a fresh surface, medium to light gray porphyritic rock with aphanitic groundmass. The feldspar phenocrysts are very fresh and show albite twinning when observed with the hand lens. A dark green to brown ferromagnesian mineral with a few scattered grains of quartz composes the remainder of the phenocrysts.

On a weathered surface, a light gray rock. Feldspar phenocrysts have been weathered out, leaving former outlines.
Microscopically the dacite porphyry has the following composition:

<table>
<thead>
<tr>
<th>Phenocrysts</th>
<th>Groundmass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plagioclase- 75% andesine, Ab An</td>
<td>Feldspar (orthoclase ?)</td>
</tr>
<tr>
<td>max. grains 2.5 mm. in size 60 40</td>
<td></td>
</tr>
<tr>
<td>Quartz - 5%</td>
<td>Quartz</td>
</tr>
<tr>
<td>max. grains 1.5 mm. in size</td>
<td></td>
</tr>
<tr>
<td>Hornblende (altered)- 20%</td>
<td>Accessory</td>
</tr>
<tr>
<td>max. grains 2.0 mm. in size</td>
<td>Apatite Iron stain Sericite Epidote</td>
</tr>
<tr>
<td></td>
<td>Chlorite Sphene Muscovite</td>
</tr>
</tbody>
</table>

Plagioclase, andesine, in euhedral to subhedral outline. Some grains well zoned. Most grains moderate to intensely sericitized, a few fresh. Quartz in euhedral to subhedral grains, with a few scattered inclusions.

Hornblende (?) has been altered to chlorite and epidote. Groundmass is glassy to fine-grained with a few of the feldspars very fresh. Composed of feldspar (orthoclase ?) and quartz. Much iron staining at surface. Little muscovite in radiating needle shaped crystals.

The field evidence as to the relative ages of the associated intrusives is as follows:

(1) Within the main mass a dike of dacite porphyry, 50 feet wide, crops out for several hundred feet, Plate I.

(2) The sill (?) outcropping west of stake No. 53, Plate II, is cut by a rhyolite porphyry dike, a granite porphyry plug and contacts a granodiorite porphyry plug (?).
Andesite porphyry

A large sill 135 feet in thickness occurs in the lower part of the Escabrosa limestone where measured along the line of the Tornado Peak section. This is between members Number 10 and 11 of the Escabrosa section.

The andesite porphyry sill is found everywhere intruded at the same horizon east of Keystone fault. Following the sill west from the 135 foot thickness at Tornado Peak, it thins to about 75 feet where exposed along the Keystone fault scarp. This sill is not present west of Keystone fault where the Escabrosa limestone is exposed and has been measured (Plate VI) in the North Star Gulch area. The 10-foot bed of garnet and specularite member Number 12 of the Tornado Peak Escabrosa section is also missing west of Keystone fault.

The sill weathers to an even slope, with a few irregular massive projections, two to four feet high, of andesite porphyry.

A typical specimen of andesite porphyry is as follows:

Megascopically a light gray porphyritic rock with an aphanitic groundmass. Phenocrysts of feldspar up to 4.0 mm. in size, some showing good albite twinning. Small amount of biotite and epidote.

Weathers to a dull greenish-gray color, and is moderately iron stained. The phenocrysts of feldspar are leached out leaving ghost outlines.

On the lower contact, a facies with a large amount of epidote and hornblende is darker. The feldspars are darker and stained, with a smaller percentage of plagioclase phenocrysts than in the center and mass of the sill.
Microscopically the andesite porphyry has the following composition (see Plate XIII, Fig. 2):

<table>
<thead>
<tr>
<th>Phenocrysts</th>
<th>Groundmass</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Plagioclase - 90% andesine, Ab$<em>{60}$An$</em>{40}$</td>
<td>50% Plagioclase-andesine</td>
</tr>
<tr>
<td>max. grains 2.0 mm. in size</td>
<td>Glass</td>
</tr>
<tr>
<td>50%</td>
<td>Alteration</td>
</tr>
<tr>
<td>Quartz - 1%</td>
<td>Chlorite-kaolin</td>
</tr>
<tr>
<td>max. grains 0.1 mm. in size</td>
<td>Sericite</td>
</tr>
<tr>
<td>Biotite - 9%</td>
<td>Epidote</td>
</tr>
<tr>
<td>max. grains 1.0 mm. in size</td>
<td></td>
</tr>
</tbody>
</table>

Plagioclase, andesine, in euhedral to subhedral outline. Some grains well zoned. Most of the grains are partially to totally covered by a dark to black stain which obliterates the albite twinning. Biotite in ragged subhedral to anhedral outline. Most of the grains are chloritized. Some formation of epidote as alteration of the biotite. Groundmass is fine-grained to glassy. Consists of plagioclase and glass ($n>1.54$). Some kaolinization and sericitization.

Age of basic rocks

The widespread similar andesitic and basaltic porphyries of the Christmas and Ash Creek area were determined to be of Cretaceous age by Ross. This was due

---

to their petrographic similarity, to the extensive lavas of this area and those further to the south. At Deer Creek to the south, Campbell determined the extensive lavas to be of Cretaceous age, on the basis of fossil leaves found imbedded in the interstratified sediments.

On this correlation basis, and the field evidence of known younger dike rocks cutting the basalt porphyry, the basalt, andesite and dacite porphyry are therefore thought to be of Upper Cretaceous age.

Acid intrusives

Rhyolite porphyry

One of the most widespread intrusive dike rocks throughout the Seventy Nine mine area is a rhyolite porphyry. Such bodies as North, Main and Long Fellow dikes and those dikes north of the Apex mine, Plate I, are of rhyolite porphyry.

Dikes of rhyolite porphyry are present cutting the Troy quartzite and all intervening formations up to and including the Naco limestone. Most of them are found outcropping in the Naco.
The rhyolite porphyry weathers to a very distinctive light tan color in comparison to the other dikes and sills of normally darker color. It is somewhat more resistant to erosion than the limestones and crops out in most localities slightly above them. Generally the rhyolite porphyry weathers in blocks due to associated fractures, six to twelve inches apart. It is characterized by the presence of large quartz phenocrysts, the only dike rock in the Seventy Nine mine area with same.

A typical specimen of rhyolite porphyry is as follows:

Megascopically on a fresh surface a greenish-tan porphyritic rock, with an aphanitic groundmass. The phenocrysts consist of quartz and feldspar grains, with a max. of 5.0 mm. in size. The feldspar is more abundant than the quartz phenocrysts.

Microscopically the rhyolite porphyry has the following composition (see Plate XIV, Fig. 1.):

<table>
<thead>
<tr>
<th>Phenocrysts</th>
<th>Groundmass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plagioclase- 50% (Albite Ab An)</td>
<td>Essential 70%</td>
</tr>
<tr>
<td>max. grains 2.0 mm. in size</td>
<td>Orthoclase- 85%</td>
</tr>
<tr>
<td>Quartz-30%</td>
<td>Quartz- 15%</td>
</tr>
<tr>
<td>max. grains 3.0 mm. in size</td>
<td>Variletal Biotite</td>
</tr>
<tr>
<td>Orthoclase- 20%</td>
<td>Alteration</td>
</tr>
<tr>
<td>max. grains 2.0 mm. in size</td>
<td>Sericite Kaolin Muscovite</td>
</tr>
</tbody>
</table>

Plagioclase, albite, in euhedral to subhedral outline and has under-gone moderate alteration to sericite and kaolin. A few phenocrysts have been completely sericitized.
Quartz as subhedral to anhedral outline. Ghosts of biotite completely bleached and replaced by muscovite. Groundmass consists of equidimensional grains in the order of magnitude of 0.01 mm. in size of orthoclase with minor amounts of quartz. The groundmass has been strongly sericitized and moderately kaolinized.

The age relationship of the rhyolite porphyry to the numerous acid intrusives within the area is not evident in most cases. A few field relationships are present as follows:

(1) Rhyolite porphyry is cut by a granite porphyry dike near the intersection of Keystone Gulch and Little Chocolate Canyon, Plates I and II.

(2) A rhyolite porphyry dike contacts the mass of granodiorite porphyry just west of A E, Plate II.

(3) A rhyolite porphyry dike cuts the basalt porphyry mass near stake Number 53, Plate II.

Granite porphyry

A very prominent dike in the Keystone Gulch area, a large sill (?) just north of North dike in the Blue Copper claim, Plate II, and irregular plugs and masses east of upper Keystone Gulch are of granite porphyry.

These bodies are intruded in the diabase and Naco limestone.

A characteristic of the dike south of stake Number 53,
Plate II, has been noted in other dikes of the area. The contact of the discordant intrusive granite porphyry with the adjacent Naco limestone is sharp and about vertical as exposed in the walls of Keystone Gulch. Fifty feet above the floor of the gulch, the porphyry ends abruptly with apparently undisturbed thin beds of limestone capping the intrusive porphyry. No porphyry is present above this stratigraphic position as a result of this local condition.

The granite porphyry weathers from being slightly more resistant than limestone, to a little less resistant. The dike in Keystone Gulch tends to weather to a soft, granular body, forming a topographic low in comparison to the intruded Naco. Yucca cacti grow selectively along this soft, weathered outcrop.

The granite porphyry masses intruded in the diabase weather to a creamy colored, granular textured outcrops which stand slightly above the intruded even sloped diabase. In places the granite porphyry exhibits a decided spheroidal weathering effect. (see plate XXV, Fig. 1).

A typical specimen of granite porphyry is as follows:

Megascopically in a dark greenish gray granitic rock, of distinctly porphyritic texture, with aphanitic groundmass. The phenocrysts of feldspar having maximum size of 5.0 mm. are very striking to the eye in hand specimen, and constitute 50% of the rock. Small amounts of quartz in irregular outline and ferromagnesian minerals are present. The groundmass is composed of equidimensional grains of feldspar quartz and ferromagnesian minerals.
Microscopically the granite porphyry has the following composition (see Plate XIV, Fig. 2):

**Phenocrysts**

- **Orthoclase** - 70% max. grains 3.0 mm. in size
- **Quartz** - 15% max. grains 2.5 mm. in size
- **Plagioclase** - 10% Oligoclase, Ab 0.85 An 0.15 max. grains 1.0 mm. in size
- **Biotite** - 5% max. grains 1.0 mm. in size

**Groundmass**

- 50% Essential:
  - Orthoclase
  - Quartz
- 50% Varietal:
  - Oligoclase
- 50% Alteration:
  - Kaolin
  - Sericite
  - Chlorite
- 50% Accessory:
  - Apatite
  - Calcite

The phenocrysts of orthoclase are euhedral crystals in outline, and have been moderately altered to sericite and kaolin. Quartz occurs in euhedral to subhedral outline and has a few scattered inclusions within. The plagioclase is oligoclase and shows considerable sericitization. Biotite occurs in euhedral to subhedral outlines. Some of the grains have been completely chloritized, while others are comparatively fresh.

The groundmass, 50% of the rock, is composed roughly of equidimensional grains of the order of magnitude of 0.01 mm. and consists of orthoclase, with smaller amounts of quartz. The groundmass has been slightly kaolinized.

The age relationship of the granite porphyry to the numerous acid intrusives within the area is not evident in most cases.

A few field relationships are present as follows:

1. Granodiorite porphyry as small dikes cut the granite porphyry, Keystone Gulch area.

2. Granite porphyry as a sill (?) contacts the
rhyolite porphyry of North dike, Blue Copper claim.

(3) Granodiorite porphyry contacts the granite porphyry south of stake Number 53, Keystone Gulch (Plate II).

Quartz monzonite porphyry

Quartz monzonite porphyry outcrops as discontinuous masses in lower North Star Gulch, Plate II.

It is present cutting the Martin and the Escabrosa limestone. The masses have been observed both as concordant and discordant intrusives.

On weathering, it stands out in relief from the shale members of the Martin, but is an even slope when adjacent to the limestones. Often it weathers in large blocks up to one foot in size.

A typical specimen of quartz monzonite porphyry is as follows:

Megascopically on fresh surface a medium dark, greenish gray porphyritic rock with an aphanitic groundmass of 50%, phenocrysts 50%. Feldspar phenocrysts, maximum grains 2.5 mm. in size, are most abundant with lesser amounts of ferromagnesian. A greenish indeterminate mineral scattered throughout.

On weathering, the rock acquires a decided greenish appearance.

Microscopically the quartz monzonite porphyry has the following composition (see Plate XV, Fig. I.):
Phenocrysts

<table>
<thead>
<tr>
<th>Phenocryst</th>
<th>Groundmass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plagioclase-75% oligoclase, Ab\textsubscript{85}An\textsubscript{15}</td>
<td>Essential Plagioclase-oligoclase</td>
</tr>
<tr>
<td>max. grains 2.0 mm. in size</td>
<td>quartz</td>
</tr>
<tr>
<td>Biotite - 15%</td>
<td>Biotite</td>
</tr>
<tr>
<td>50%</td>
<td>Orthoclase</td>
</tr>
<tr>
<td>max. grains 1.0 mm. in size</td>
<td>Accessory Apatite</td>
</tr>
<tr>
<td>Quartz - 10%</td>
<td>Alteration</td>
</tr>
<tr>
<td>max. grains 0.6 mm. in size</td>
<td>Kaolin</td>
</tr>
<tr>
<td></td>
<td>Sericite</td>
</tr>
<tr>
<td></td>
<td>Chlorite</td>
</tr>
<tr>
<td></td>
<td>Epidote</td>
</tr>
<tr>
<td></td>
<td>Magnetite</td>
</tr>
</tbody>
</table>

Plagioclase, oligoclase, is in euhedral to subhedral outline, shows moderate alteration to kaolin with minor amounts of sericite. The oligoclase shows some effect of iron staining.

Biotite in subhedral to anhedral outline and has been moderately altered to form magnetite, chlorite, and epidote. The groundmass is roughly equidimensional grains in the order of magnitude of 0.02 mm. in size, and consists of oligoclase, orthoclase and quartz. Some of the groundmass has been sericitized, with the oligoclase the most highly altered as is the rule.

This rock has no field relationships with the other igneous bodies.

Monzonite porphyry

Several monzonite porphyry dikes and sills (?) are present in the immediate vicinity of the Seventy Nine mine. Such bodies as the South dike, Seventy Nine sill (?), North Star dike, and the irregular mass south and east of ΔE, Plate II, as well as numerous small sills.
Dikes, sills and irregular masses intrude both the Escabrosa and Naco limestone.

The monzonite porphyry is slightly more resistant to weathering than the surrounding limestone.

The South dike appears to spread out as sills in the thin-bedded Naco at several places along its outcrop. East of the Main fault, the South dike does not cut the surface. The post-dike normal displacement of the Main fault adds several hundred feet to the Naco section on the east side. Thus it seems apparent that within this section the South dike becomes a sill or low angle discordant body which does not crop out, or at least not in its expected position. Possibly, it cuts the pre-Gila surface to the south, but is now concealed by this conglomerate.

A typical specimen of the South dike, representative of the monzonite porphyry, is as follows:

Megascopically on fresh surface, a greenish brown aphanitic rock, with abundant phenocrysts of feldspar and ferromagnesian. The rock has been moderately altered and iron stained. On surface not stained, rock a medium light gray with darker ferromagnesian phenocrysts.

Microscopically the monzonite porphyry has the following composition (see Plate XV, Fig. 2):

<table>
<thead>
<tr>
<th>Phenocrysts</th>
<th>Groundmass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plagioclase-85%</td>
<td>Essential Orthoclase</td>
</tr>
<tr>
<td>Andesine, Ab. An. 35</td>
<td>Quartz</td>
</tr>
<tr>
<td>max. grains 3.0 mm. in size</td>
<td>Alteration</td>
</tr>
<tr>
<td>65%</td>
<td>Sericite</td>
</tr>
<tr>
<td>55%</td>
<td>Chlorite</td>
</tr>
<tr>
<td>Hornblende - 12%</td>
<td>Magnetite</td>
</tr>
<tr>
<td>max. grains 2.5 mm. in size</td>
<td>Accessory</td>
</tr>
<tr>
<td>45%</td>
<td>Apatite</td>
</tr>
<tr>
<td>Quartz - 3%</td>
<td></td>
</tr>
<tr>
<td>max. grains 0.5 mm. in size</td>
<td></td>
</tr>
</tbody>
</table>

Quartz in subhedral outline, very scattered. Groundmass roughly equidimensional grains in order of magnitude of 0.02 mm. in size. A small amount of quartz in groundmass. Iron stained throughout.

The monzonite porphyry dikes and sills (?) show the following field relationships with the other acid intrusives:

1. An irregular mass (sill?) of monzonite porphyry contacts rhyolite porphyry south and east of Δ E, Plate II.

2. A small dike (?) of monzonite porphyry apparently intersects a body of granite porphyry east of Δ C.

A border facies of the main monzonite porphyry intrusives is an irregular outlined sill of hornblende monzonite porphyry present in Keystone claim, Plate II. This sill is exposed in the center of an intermittent stream channel and is cut off to the west by a prominent fault. It is intruded in the lower Naco limestone beds. This facies is slightly more resistant to erosion than the intruded Naco beds.

A typical specimen of the hornblende monzonite porphyry is as follows:

Megascopically a light gray porphyritic rock with an aphanitic groundmass. Phenocrysts of ferromagnesian are very abundant and give the specimen a spotted appearance. Weathers to a greenish, iron stained surface.

Microscopically the hornblende monzonite porphyry has the following composition (see Plate XVI, Fig. 1):
Phenocrysts

Plagioclase-35% Oligoclase, Ab An 15
max. grains 2.5 mm. in size
Orthoclase - 15%
max. grains 2.0 mm. in size
Hornblende - 50%
max. grains 2.0 mm. in size

Groundmass

Orthoclase
max. grains 0.02 to 0.01 mm. in size
Orthoclase is the principal constituent. Parts are wholly a glass. Some of the mass is dark, iron stained in color (characteristic of glasses).

Granodiorite porphyry

Near stake Number 53, Plate II, in the Keystone Gulch area are several disconnected bodies of granodiorite porphyry. In Keystone Gulch west of AF, Plate II, are several large sills and numerous small bodies of granodiorite porphyry. Near stake Number 53, a plug of granodiorite porphyry has invaded basalt porphyry; to the west the main granite porphyry dike has been cut by a small granodiorite porphyry dike; elsewhere small dikes are present. In the vicinity of AF, the granodiorite porphyry has been intruded as sizable sills in the Naco limestone. Several of the sill outcrops are terminated by faults.
Most of the outcrops weather at about the same rate as the surrounding Naco limestone, an exception being the sills which outcrop in the floor of Keystone Gulch; they weather to a soft granular textured mass, and are topographic lows. Except where iron stained and bleached, the granodiorite porphyry is a very fresh looking rock.

South of ΔE, Plate II, there is an outcropping of granodiorite porphyry on either side of the nose of the ridge, but on the ridge it has not been intruded to surface. Here is found the same capping as described under granite porphyry.

A typical specimen of granodiorite porphyry is as follows:

Legascopically a very fresh unaltered rock, light gray, phaneritic groundmass, with near equal proportions of phenocrysts, maximum size 5.0 mm. consisting of feldspar and biotite. The phaneritic groundmass consists of feldspar, quartz and ferromagnesian minerals averaging 0.15 mm. in size.

Microscopically the granodiorite porphyry has the following composition (see Plate XVI, Fig. 2):

<table>
<thead>
<tr>
<th>Phenocrysts</th>
<th>Groundmass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plagioclase-80%</td>
<td>Essential</td>
</tr>
<tr>
<td>Andesine, Ab, An</td>
<td>Plagioclase-10%</td>
</tr>
<tr>
<td>max. grains 3.0 mm. in size</td>
<td>Andesine</td>
</tr>
<tr>
<td></td>
<td>Quartz - 40%</td>
</tr>
<tr>
<td></td>
<td>Orthoclase-50%</td>
</tr>
<tr>
<td>Biotite - 5%</td>
<td>Accessory</td>
</tr>
<tr>
<td>max. grains 1.5 mm. in size</td>
<td>Apatite</td>
</tr>
<tr>
<td>Hornblende - 15%</td>
<td>Garnet</td>
</tr>
<tr>
<td>max. grains 1.0 in size</td>
<td>Iron Ore</td>
</tr>
<tr>
<td></td>
<td>Alteration</td>
</tr>
<tr>
<td></td>
<td>Sericite</td>
</tr>
<tr>
<td></td>
<td>Chlorite</td>
</tr>
<tr>
<td></td>
<td>Magnetite</td>
</tr>
</tbody>
</table>
Plagioclase, andesine, is in euhedral to subhedral outline. Some specimens are well zoned. A very slight alteration to sericite.

Biotite is in subhedral to anhedral outline and is comparatively fresh.

Hornblende in euhedral to subhedral outlines shows good cleavage and some alteration to biotite and magnetite.

Groundmass is of roughly equidimensional grains of about 0.15 mm. size. Groundmass slightly altered to sericite.

The age relationship of the granodiorite porphyry to the numerous acid intrusives though not evident in most places is as follows:

(1) Granodiorite porphyry dikes cut a granite porphyry dike.

(2) Granodiorite porphyry plugs and dikes cut the Upper Cretaceous basalt porphyry.

Quartz diorite porphyry

The Seventy Nine dike and a few isolated irregular bodies are of quartz diorite porphyry.

These discordant bodies are present cutting the Naco limestone.

The quartz diorite porphyry on weathered surface presents a darker color than most of the other Cretaceous-Tertiary intrusive bodies. The presence of biotite and hornblende is readily seen in the rock. Parts of the Seventy Nine dike weather to a soft smooth, granular textured outcrop of low relief. This is especially true where it crops out
in Seventy Nine Gulch.

A typical specimen of quartz diorite porphyry is as follows:

Megascopically a light greenish gray granitic rock, of distinctly porphyritic texture. Phenocrysts of plagioclase showing some twinning striations are up to 2.0 mm. in size. The ferromagnesians are biotite and amphibole. Both show good euhedral outline.

The groundmass consists of fine equidimensional grains of feldspar and quartz.

Microscopically the quartz diorite porphyry has the following composition (see Plate XVII, Fig. 1):

<table>
<thead>
<tr>
<th>Phenocrysts</th>
<th>Groundmass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andesine - 85%, Ab, An</td>
<td>Essential</td>
</tr>
<tr>
<td>max. grains 2.0 mm, An 35</td>
<td>Andesine - 40%, Ab, An</td>
</tr>
<tr>
<td>50%</td>
<td>Orthoclase - 30%</td>
</tr>
<tr>
<td>Biotite - 5%</td>
<td>Quartz - 30%</td>
</tr>
<tr>
<td>max. grains 1.5 mm. in size</td>
<td>Alteration</td>
</tr>
<tr>
<td>Hornblende - 10%</td>
<td>Epidote</td>
</tr>
<tr>
<td>max. grains 1.0 mm. in size</td>
<td>Sericite</td>
</tr>
<tr>
<td></td>
<td>Chlorite</td>
</tr>
</tbody>
</table>

The phenocrysts of andesine are euhedral to subhedral in outline, with a large proportion showing poor to good zoning. The andesine has been moderately altered to large amounts of sericite with less chlorite.

Biotite is present as shreds in euhedral to subhedral outline. Most of the biotite shows some alteration.

The fresh phenocrysts of hornblende show good cleavage and are in euhedral to subhedral outline. Some alteration to chlorite shown.

The groundmass, 50% of the rock, is composed of roughly equidimensional grains in order of magnitude of 0.05 mm; andesine 40%, quartz 30%, orthoclase 30% with minor amounts of opaque iron mineral.

The quartz diorite porphyry has no field relationships with the other numerous acid intrusives, to show a relative age of emplacement.
Diorite porphyry.

In the immediate vicinity of A C, Plate II, several dikes and sills are present of diorite porphyry.

These dikes and sills all crop out in the Naco limestone.

The diorite porphyry weathers to a light gray to tan colored surface, and is of a lighter color than such nearby intrusives as the North Star and North dikes. The diorite porphyry weathers to a smooth slope similar to the intruded Naco limestone.

A typical specimen of diorite porphyry is as follows:

Megascopically a medium dark gray, holocrystalline porphyritic rock with phaneritic groundmass. Major portion of phenocrysts consist of feldspar, with lesser amounts of biotite.

The rock is slightly iron stained.

Microscopically the diorite porphyry has the following composition (see Plate XVII, Fig. 2):

<table>
<thead>
<tr>
<th>Phenocrysts</th>
<th>Groundmass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plagioclase-83% Andesine, Ab$<em>{60}$An$</em>{40}$ max. grains 2.0 mm. in size</td>
<td>Essential Plagioclase-65%</td>
</tr>
<tr>
<td>Quartz - 8% max. grains 1.0 mm. in size</td>
<td>Andesine Orthoclase-35%</td>
</tr>
<tr>
<td>50% Biotite - 5% max. grains 1.5 mm. in size</td>
<td>Quartz Biotite</td>
</tr>
<tr>
<td>Hornblende - 4% max. grains 0.8 mm. in size</td>
<td>Alteration Sericite Chlorite</td>
</tr>
</tbody>
</table>

Plagioclase, andesine in euhedral to subhedral outline. Some grains well zoned. Most moderately sericitized.
Biotite in euhedral to anhedral outlines. Some alteration to chlorite. Hornblende in subhedral grains and bleached. Quartz in euhedral to anhedral outline; moderate amount of inclusions. Groundmass is roughly equidimensional grains about 0.03 mm in size. Consists primarily of plagioclase, andesine, with minor orthoclase. Few scattered grains quartz and biotite. Plagioclase in groundmass undergone moderate sericitization. Some iron staining of the groundmass and phenocrysts.

The age relationship to the numerous acid intrusives is not evident. The only field evidence is as follows:

(1) Diorite porphyry was intruded contemporaneously (?) with faulting, 400 feet west of AC, Plate II., this fault also forms the southwest fault wall of the monzonite porphyry, North Star dike.

Schneider Hill, quartz latite porphyry

A quartz latite porphyry plug is intruded into the diabase and overlying sediments just east of Schneider Hill, Plate I., and is named after same. In some of the contact relationships with the overlying strata of Lescal limestone, it appears to be emplaced concordantly.

The quartz latite porphyry weathers to a smooth, granular surface on most of its outcrop, but in a few places it is moderately resistant to erosion and stands above the surrounding diabase and overlying strata in relief.

The overlying strata have been metamorphosed to hornfels.
A few isolated islands of hornblende diabase are present within the Schneider Hill, quartz latite porphyry.

A typical specimen of Schneider Hill quartz latite porphyry is as follows:

Megascopically a light gray, porphyritic rock with a phaneritic groundmass.
Phenocrysts of quartz, feldspar and biotite constitute less than 50% of rock.
The groundmass composed of equidimensional grains of feldspar and quartz.

Microscopically the Schneider Hill quartz latite porphyry has the following composition (see Plate XVIII, Fig. I):

<table>
<thead>
<tr>
<th>Phenocrysts</th>
<th>Groundmass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plagioclase - 60% Oligoclase, Ab$<em>{65}$An$</em>{15}$</td>
<td>Essential</td>
</tr>
<tr>
<td>max. grains 3.0 mm. in size</td>
<td>Orthoclase - 50%</td>
</tr>
<tr>
<td>Quartz - 20%</td>
<td>quartz - 50%</td>
</tr>
<tr>
<td>max. grains 2.0 mm. in size</td>
<td>Accessory</td>
</tr>
<tr>
<td>Orthoclase - 8%</td>
<td>Apatite</td>
</tr>
<tr>
<td>max. grains 1.5 mm. in size</td>
<td>Alteration</td>
</tr>
<tr>
<td>Biotite - 2%</td>
<td>Sericite</td>
</tr>
<tr>
<td>max. grains 1.5 mm. in size</td>
<td>Chlorite</td>
</tr>
</tbody>
</table>

A comparatively little altered rock. Phenocrysts of oligoclase in euhedral to subhedral in outline; some show good zoning. Oligoclase has been moderately altered to sericite.

Orthoclase phenocrysts in euhedral to subhedral outline and show very minor amounts of sericitization.
Quartz is present in subhedral to anhedral grains.
Biotite present as scattered subhedral to anhedral grains; has undergone slight alteration to chlorite.
The groundmass consists roughly of equidimensional grains in the order of magnitude of 0.1 mm. to 0.2 mm. in size. Orthoclase and quartz are present 50% each.
Orthoclase slightly altered to sericite. A few inclusions present in the quartz grains. A very few scattered grains of apatite throughout.
The field evidence as to age relationships are as follows:

(1) Intruded into diabase

Aplite

Within the Little Chocolate Canyon area, three aplite dikes of extensive outcropping intrude the diabase and Troy quartzite. All three contact the Keystone fault and extend east.

The creamy colored aplite dikes in places weather to a soft granular smooth slope, similar to the diabase; other places they are more resistant to weathering and stand out in relief above the surrounding diabase. Where intruded into the Troy quartzite, the aplite dikes are topographic lows in contrast to the resistant cliff-forming Troy.

The aplite dikes make sharp, clear cut contacts with the intruded diabase.

A typical specimen of the aplite dikes is as follows:

Megascopically a light greenish gray to creamy gray colored sugary textured, acid rock. The grains of feldspar and quartz are equidimensional. Minor and smaller grains of biotite. Some of the quartz grains are much larger than the mass and have a maximum size of 3.0 mm., while the average is 0.6 mm. in length.

A few of the feldspars in euhedral to subhedral outlines with maximum of 3.0 mm. in size. The very insignificant amount of mafic, gives this rock a very light and even color.

Microscopically the aplite dikes have the following composition (see Plate XVIII, Fig. 2):
Essential Varietal

Quartz - 39%
max. grains 0.5 mm. in size

Orthoclase - 30%
max. grains 0.5 mm. in size

Plagioclase - 30% albite, Ab$_{95}$An$_{05}$

Biotite - 1%

Alteration

Kaolin
Sericite

A comparatively unaltered rock of anhedral texture. It is essentially a holocrystalline, near equidimensional rock, with no euhedral outlines. The feldspars are anti-perthitic, with the orthoclase exceeding the plagioclase (albite). Quartz occurs as subhedral grains with a small amount of inclusions.

The orthoclase is slightly altered to sericite. The plagioclase feldspar, albite, is a microperthite. It is the most altered mineral in the rock, with slight development of sericite and kaolin.

The field evidence as to age relations of the intrusive bodies is as follows:

(1) Aplite dikes are intruded into diabase and Troy quartzite.

Source and age, acid rocks

59 Ettlinger has termed the source of the acid intrusives


of Globe, Miami, Ray, Pioneer, Troy, Silver King and the Banner mining districts as the Central Arizona batholith. The rocks range in composition from diorite to porphyritic granite.
Ettlinger has put the time of intrusion as post-Pennsylvanian (probably Laramide). This period of acid intrusives will be referred to as Cretaceous-Tertiary in age.

This age of acid intrusion corresponds to most of the other mining districts of central and southern Arizona. Quartz monzonite intrusion at Ajo, granite porphyry at Bisbee, monzonite porphyry at Morenci, granite and quartz monzonite in the Tucson Mountains and a granite batholith in central Sonora, Mexico, are all postulated to have been emplaced during the Cretaceous-Tertiary interval.

Metamorphism

Regional metamorphism

Little widespread regional metamorphism is present in the Seventy Nine mine area.

The Troy quartzite, metamorphosed from sandstone, is the principal occurrence of a regional feature. Parts of the Troy have not been completely metamorphosed, and still remain a sandstone.

A few quartzite beds are scattered through the geologic section above the Troy, with two in the overlying undifferentiated Cambrian beds.
The Paleozoic limestones and shales show little or no regional metamorphism.

Contact metamorphism

Diabase

The contact action of the diabase on the Mescal limestone is appreciable. In some places a baked shale type of material is the result. In the Schneider Hill area, Plate I, a bed of hornfels about 20 feet thick was the result of intrusion. The hornfels consists of orthoclase and hornblende. Microscopically the rock shows a strong parallelism.

The contact action of the diabase on Troy quartzite is slight. Slight alteration of the Troy to a stained siliceous zone where the diabase has intruded as sills and dikes was evident. Only a very few diabase-Troy contacts are present in the Seventy Nine mine area.

Schneider Hill quartz latite porphyry

The same type of hornfels as present at diabase contacts is formed where the quartz latite porphyry contacts the Mescal. It shows a practically negligible amount of metamorphism on contacting the invaded diabase. Excessive iron staining is about the only effect.
Garnetization

The base of the large andesite porphyry sill of 135 feet thickness exposed in the Tornado Peak section is separated by 4 feet of limestone from 10 feet of massive coarsely crystalline garnet with specularite. Apparently this garnet bed is connected in origin with the contact metamorphic effects of the sill. This bed is not present where the sill is missing in the section.

The dip slope of the ridge immediately east of the large basalt porphyry outcrop, Plate I., is composed of a garnet bed up to 10 feet in thickness. This is undoubtedly the result of contact metamorphism by the adjacent basalt porphyry and its apophyses and sills of dacite porphyry intruded in the Naco beds.

A considerable sized garnet zone occurs in Seventy Nine Gulch, Seventy Nine Number Two claim, and appears to be associated with the N 66° E fault zone as plotted, Plate II.

Several beds in the mine workings have been garnetized. This is most apparent in workings near the dikes.

Marbleization

Several limestone beds, both surface outcrops and in the
mine workings show the result of contact metamorphism, and have been recrystallized to coarse textured marble.

Baked shale

Devonian shales are baked where cut by the quartz monzonite intrusive in North Star Gulch. Pennsylvanian shales are baked and iron stained where cut by the North dike near ΔΒ, Plate II.

Siderite

Some siderite zones have been noted in the mine workings within beds that are also garnetized.

Structure

Summary

The Dripping Spring range has a general northwest trend and is apparently bounded on both sides by faults of a similar irregular strike. Cutting across the uplifted Dripping Spring range block, large faults of a general north-south direction have dissected the range into several physiographic belts. Tilting of the beds has accompanied this crustal movement.
Most of the north-south faults appear to be steeply
dipping and of a normal displacement. A few reverse faults
are present. The faults of the Seventy Nine mine area are
split into those of preore and postore ages. The preore
faults are of primary economic importance, as they have con­
trolled the subsequent mineralization.

A few postore faults are present, some displace known
ore bodies; one direction N 70° E, has had a strong influence
on the topography.

The preore faults are large and strike slightly west
of north. Associated with this movement, major shear
zones were formed having a general N 60° - 70° E strike.
The large faults appear to dip steeply west, the shear
zones steeply north. Two periods of preore faulting
occurred; predike faulting and postdike faulting. Along
their strike, some of the preore faults have a few silica
outcrops with associated copper mineralization. The pre­
ore faults are probably of Early to Middle Tertiary age.

The postore faults consist of some renewed activity
along the preore north-south faults and their resulting
shear zones. A strong N 70° E fault direction with steep
to vertical dip is prominent everywhere. This old preore
direction displaced the sedimentary beds with the south
block generally moving up with respect to the north block
down. Renewal of this faulting has strongly influenced
the drainage. The Main fault of N 35°-45° W strike is another postore fault direction. Several smaller faults of this general strike are present such as the Mountain View fault. The main fault displaces known ore. The major postore period of faulting is considered to be prior to the formation of the Gila conglomerate and probably of Middle to Late Tertiary in age. Some minor faulting was formed in post-Gila time as evidenced by the tilt to the beds and the faults found in the Gila conglomerate.

The preore or postore nature of some of the faulting is uncertain.

The two systems of faulting were related to one period of igneous activity. The preore faults were both prior to and related with the emplacement of the Central Arizona batholith and its reflection in the Seventy Nine mine area as acidic dikes and associated intrusive bodies. All postore faults are dated after the batholithic emplacement and the related ore deposition.

Folding and tilting

Very little folding of the beds is in evidence throughout the Seventy Nine mine area. One of the few places where folding was noted was in Keystone Gulch just south of the North dike. Here two parallel easterly trending faults have arched the Naco beds (Plate II).
The sedimentary formations of the Seventy Nine mine area, apparently are quite competent which has resulted in faulting and fracturing when subjected to stress.

The earliest preore faulting resulted in large normal displacements along such north-south breaks as Keystone and O'Carroll faults. This produced a comparatively even tilt of about 15° to the south for the whole Dripping Spring range throughout this area. Subsequent preore and later postore faulting has modified the original tilt of the beds. The area west of Keystone fault has undergone much additional tilting as evidenced by the numerous fault blocks which have a dip of 30° to 40° to the south.

Bedding plane faults

Some bedding plane faulting was apparently associated with the tilting. This is suggested by the fault gouge found along bedding planes of the thin beds which comprise the Discovery ore body. Bedding plane faulting may have contributed to the fracturing of the basal Martin limestone, thus assisting in its preparation as a favorable host for ore solutions. Bedding plane faulting may be a partial reason for the favorable structure and subsequent location of such ore bodies as those at the London-Arizona mine.
Faulting

Preore faults

The main preore faults of a north to northwesterly strike consist of O'Carroll, Keystone, Ore Body and Reagan Camp faults. Associated with these faults are strong shear zones of a general N 60°-70° E strike.

These major faults are of normal displacement and dip steeply west. The major displacements of the area took place along these faults striking from due north to north 31° west. The largest, Keystone fault, has a normal displacement of over 2000 feet. As a result of this vertical movement, major shear zones were formed having a general N 60°-70° E strike. For unknown reasons, a greater number of shear zones was formed between the Keystone and Camp Reagan faults. Within this large fault block, the greatest number of shear zones was formed near the Camp Reagan fault, with fewer forming to the east in the vicinity of the Keystone fault (Plate II). A small number of these shear zones was formed between the O'Carroll and Keystone faults (Plate I).

Field evidence shows a negligible to small amount of vertical movement along the shear zones.

Probably closely following the earliest preore faulting, the granitic rocks from the parent Central Arizona batholith were intruded. These acid magmas invaded the weak shear zones, and formed the numerous dikes, sills and irregular
granitic masses of the Seventy-Nine mine area.

A second period of preore faulting followed the emplacement of the dikes. This postdike and preore faulting consisted of a recurrence of movement along the major north-south faults with the resulting shear zone movement and stresses fracturing the numerous dikes of the area. This second period of movement shattered the dikes with a general N 70°-85°E shear direction and a tension fracture direction of about N 55°E.

At this time or slightly later such faults as the Gulch fault zone, having a near N 70°E strike, were formed. Numerous faults having this strike are present throughout the Seventy-Nine mine area, and are invariably mineralized. The N 70°E faults invariably show vertical displacement of the beds; south block generally moving up with respect to the north block. Some of this displacement is probably post-ore.

This second period of preore faulting shattered and made permeable the dikes and adjacent limestone beds. Ore solutions closely followed the faulting, with the initial invasion possibly before faulting ceased.

The preore faulting is postulated to be Early to Middle Tertiary in age.

Postore faults
The major postore faulting is represented by the Main and Mountain View faults having a general N 35°-45° W strike. Associated with this period was apparently additional movement along some of the preore N 70° E faults.

The Main fault, largest of the postore faults, dips 60° east and has a steep normal displacement. This fault displaces the Discovery and Massive Pyrite ore bodies and the North dike. The Mountain View fault has a similar strike and displaces the North dike. Faults such as the one cutting the North dike in Seventy Nine Gulch and intersecting the Ore Body Fault may be postore (Plate II). Those faults to the east along the strike of the North dike and which displace it, probably have a similar postore origin.

The prominence of N 70° E faults and their control over recent erosion suggests some possible renewed activity along a limited number of these preore breaks. This would account for only a small part of their total displacement.

The main period of postore faulting was prior to the deposition of the Gila conglomerate.

This is postulated by the movement along the Main fault. No displacement of Gila conglomerate is apparent to the south of Seventy Nine Gulch along the strike of the Main fault (Plate II). The faulting is postulated to have occurred in Middle to Late Tertiary time.

Minor faulting and probably some tilting has occurred
since the deposition of the Gila conglomerate. This is evidenced by small faults within and a dip of 28° to the west of the Gila conglomerate beds in Seventy Nine Gulch (Plate II).
CHAPTER III

ORE DEPOSITS

History of Mining Seventy Nine Mine-Tornado Peak Area

Some prospecting and small development work was done in the Seventy Nine Mine-Tornado Peak Area (see Plate I) prior to World War I, but this amounted to very little. The high prices prevailing for the base metals as a result of the war and for a period thereafter stimulated much prospecting, development and production. As a result, several previously located, plus a few new properties were brought into production. The short haul, six miles, to the Hayden copper smelter, allowed several otherwise sub-marginal copper deposits to operate, namely the London-Arizona mine and the Gila Canyon Copper Company on Schneider Hill.

The Seventy Nine mine is the only property within the area covered by the scope of this investigation which has continued on an active basis since the slump in base metal prices of 1920. The individual properties within this area will be covered separately.
Seventy Nine mine

Location

The Seventy Nine mine is located four miles due north of Hayden Junction, which is on the Hayden-Kelvin-Ray-Superior highway two and one half miles northwest of Hayden, Arizona. It is at an elevation of about 3500 feet, on the western slope of the Dripping Spring Mountains. Prominent landmarks of the region are Tam O'Shanter Peak, one and one-half miles due north and Tornado Peak, one and three-quarter miles southeast of the mine.

History and production

The deposit was located in 1879 by Mike O'Brien and his brother Pat who were attracted to a large iron-stained silica outcrop which stands 20 feet above the surrounding limestone. Little work was done until Lee Reagan and associates of the Continental Commission Company leased the prospect in November 1919 from the heirs of O'Brien in Ireland. Ore from the grass roots paid for the development,

roads, lease, and other necessary improvement of the property.

The early ore was hauled by burro, using kyacks, to the railroad at Hayden Junction, 4 miles away. Reagan realized the need for a road, which was completed in October 1920. This improvement in their marketing methods did not compensate for the then declining price of lead, and operations were suspended in December 1920. In January 1921, the property was purchased by Hugh H. Hanger of the Continental Commission Company, which was capitalized at $1,000,000. Work was resumed in January 1922 by the Continental Commission Company and continued until the property was purchased by the Seventy Nine Mining Company on May 12, 1922. At that time the production was 50 tons per day using hand methods of mining. The 3,000 tons of ore shipped by the Continental Commission Company averaged 24 percent of lead, 1.75 percent of copper, 4 ounces of silver, and 80 cents in gold to the ton. The 121 cars of ore shipped by them averaged a net return of $1,000 per car after freight and refining charges were deducted.

The Seventy Nine Mining Company continued to produce at the same rate as the previous owners. In 1923 the mine was

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reconveyed to the Continental Commission Company as a result of a long series of litigation.

In April 1926, the Seventy Nine mine was sold for a judgement of $16,000, the result of prolonged litigation, at a public sale in Globe, Arizona. A group of Los Angeles people purchased the property and reopened the Seventy Nine mine in 1928 after a shutdown of about six years. D.C. Peacock and J. Jamison directed the operations of the new company under the name of Seventy Nine Lead-Copper Company.

In 1930, the mine averaged about 125 tons daily capacity. Ore values ran 20 percent lead, 6 ounces of silver and about 80 percent in gold per ton.

In 1936, under the direction of the Southwestern Engineering Company, a gravity and flotation concentration plant was constructed. At this time production was averaging 1000 tons per month.

In 1937, the company averaged 500 tons of ore per month through the new lead-zinc concentrator on the property. This milling operation was not successful, however, and operations were suspended in February 1938.

During the period of operation by Jamison and Peacock, the mine became a true shaft operation, instead of a series of inclined workings. They drove the inclined shaft to the 6th level and modernized the property to its present status.

In 1940, the Shattuck-Denn Mining Corporation, Bisbee,
Arizona as holder of 60 percent of the stock reopened the property. An extensive exploration program was immediately initiated on the 5th and 6th levels under the direction of George Warner, superintendent.

In 1942, the output averaged 500 tons monthly of sulfide lead-zinc-copper ore to the Shattuck-Denn mill, Bisbee, Arizona. The mine output has approximated this figure in recent years.

The mine has produced a combined total of some 110,000 tons of oxide and sulfide ore. The total production has had a gross value between three and four million dollars.

John E. McKay is the present superintendent of the Seventy Nine mine. He is supervising an active exploration program in connection with present operations.

Property

The property comprises 26 claims, embracing an area of 460 acres, with the original Seventy Nine mine claim near the center of the group. The original workings of the mine were developed by two adits one above the other; the lower or 2nd tunnel level being the main haulage way (see Plate VII). The early stoping in the mineralized thin-bedded limestone started at the surface and followed the replaced beds downward. The 2nd level was used as a
haulage way to the surface, and the ore was dropped down chutes to this adit. In many places the replaced beds were mined below this 2nd tunnel level and which led to the eventual driving of a 60° inclined shaft. The 2nd, 3rd, 4th, 470, 5th and 6th levels all connect with this shaft. A normal fault cuts the replacement ore body a short distance east of the shaft collar displacing the ore several hundred feet downward to the east and thus the reason for driving the incline to levels 5 and 6 where faulted segments of ore were mined (see faulting, postore).

The 1st level is inaccessible. The 2nd level has 2,500 feet of accessible working. Levels 3, 4 and 470 have only small partially caved workings near their connection with the inclined shaft. The 5th level has about 4000 feet of workings, most of them open. On the 5th level the first ore in the North dike of rhyolite porphyry was discovered, 800 feet east of the shaft. The 6th level covers about the same ground as the 5th and has had production from the ore bodies in the North dike below those on the 5th level. Production has also come from replaced limestone beds situated between the 5th and 6th levels. This ore body is up dip from the massive pyrite body located 150 feet east of the shaft on the 6th level and is between the South and North dikes. On the 6th level a winze on the south side of North dike 1100 feet east of shaft connects.
with the 7th level. On this level 500 feet of workings serves two ore bodies within the North dike which were followed downward from the 6th level.

Near the shaft and within the Seventy Nine Gulch, the office, change house, blacksmith shop, compressor house, abandoned mill and numerous other buildings are located. Up the gulch 1,000 feet from the office are located an inclined prospect shaft and horizontal adit. Other prospect workings are scattered over the group, namely in the West Point, Long Fellow and Lizzie Claims.

Classification ore deposits

The ore bodies are of the replacement vein and bed replacement type. The ore was deposited in shear zones and fractures at a moderate depth. The Seventy Nine mine ore deposits would fall within the range of the mesothermal type according to Lindgren's classification.\(^{61}\)

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Mineralization

Summary

The ore bodies of the Seventy Nine mine occur as replacements in the thin-bedded Naco limestone and as small discontinuous vein replacement bodies in the North dike, a rhyolite porphyry rock. The Discovery ore body is located essentially between the North and South dikes near the present shaft. Here thin-bedded impure limestone separated by siliceous strata are mineralized. The Main fault, displaces this ore body 150 feet east of the inclined shaft, and mining of faulted ore, the Massive Pyrite ore body, was continued on the 5th and 6th levels. The Massive Pyrite ore body is very similar in origin and type to the Discovery ore body. The tonnage extracted from these bedded replacement deposits constituted the major production of the Seventy Nine mine prior to the discovery of ore associated with the North dike.

Production since 1940 has been confined to ore bodies on the 5th, 6th and 7th levels, 800 to 1,100 feet east of the shaft and closely associated with the North dike. Within this part of the dike are located several discontinuous vein replacements of massive sulfide ore. The Number 17 raise ore body of 6th level is one of the largest in this group and extends from above the 5th to below the 7th levels.
The adjacent Number 30 and 31 stope ore bodies of the 6th level (see Plate V) are not connected at depth. They appear to have a connection at depth with the underlying ore bodies of Number 4 stope, 7th level but this has not been observed. The Ore Body fault zone separates the Number 17 raise ore body from the Number 30 and 31 stope ore bodies.

The faulted Discovery and Massive Pyrite ore bodies of oxidized ore are similar mineralogically. The ore bodies associated with the porphyry such as Number 17 Raise the Number 30 and 31 stope of the 6th level are similar mineralogically. These porphyry host ore bodies are of primary sulfide, with oxidation having reached its lower limit in the Number 17 Raise ore a short distance below the 6th level. All Seventy Nine mine ore bodies are similar in that lead is the principal ore metal. In the oxidized zone, lead occurs as cerussite (sand carbonate) with minor amounts of anglesite and galena. The sulfide ore consists of about equal proportions lead and zinc. Small amounts of copper and silver are recovered from both ores.

The principal ore minerals are galena, sphalerite and cerussite (sand carbonate) with minor amounts of anglesite, chalcopyrite, chalcocite and covellite. The galena is argentiferous.

The oxidized ore mineral cerussite is predominant in
the Discovery, Massive Pyrite and upper parts of the ore bodies in the North dike. The sulfide ore minerals galena and sphalerite are predominant in the lower levels of the North dike ore bodies, the 7th level having only primary ore.

Supergene enrichment has been important in the Discovery, Massive Pyrite and upper parts of the North dike ore bodies.

Relation ore to sedimentary rocks

**Discovery ore body:** This ore body, surrounded by a strong gossan, crops out just north of the collar of the present incline shaft in beds striking N 75° E and dipping 25° - 35° to the south. It is mineralized for about 300 feet along the strike of the beds, in a series of two to three foot members separated by thin siliceous shale and siliceous strata. The mineralized and interbedded material is more than 50 feet thick and apparently extends down dip to its intersection with the South Dike. (Plate VII). These lower workings were inaccessible to the writer. The Discovery ore body is cut by the post-ore Main fault on the east. It appears to die out to the west where the beds are less shattered and broken. This ore body has a slight pitch to the east, which is not a
function of the dip and strike of the beds.

Mineralization has been selective in a series of fine fractured and broken thin, calcareous shale beds interbedded with siliceous strata and is confined to a vertical range of about 50 feet. The relationship of ore with shaly material suggests (see ore deposition, page 115) a possible cause of deposition. This same relation is the rule throughout the Seventy Nine mine area. Nowhere was pure massive limestone replaced.

**Massive Pyrite ore body:** The second largest single ore body of the Seventy Nine mine within the thin-beded limestone is that termed the Massive Pyrite in this report. It is located immediately east of the Main fault, which displaces it on the west, between the 5th and 6th levels. On the 6th level, alternating thin-beds of shaly and calcareous material have been replaced by massive pyrite with much associated silification. The pyrite body extends south to the Seventy Nine dike and north to the South dike. It is faulted to the west and dies out within 175 feet to the east in the limestone. It extends from about 50 feet below the 6th level to 15 feet above. The replaced beds dip approximately 40° to the south.

Up dip from the Massive pyrite body across the South dike and between the South and North dikes (see Plate VIII), the alternating thin beds have been mineralized for a distance of 200 feet along their strike, through a
vertical distance of about 50 feet. The mineralization is strongest up dip from the north contact of the South dike. High grade ore was not mined up dip to the contact of North dike, but was stopped at an economic cut-off (Plate VIII).

There are only slight surface indications of gossan above this ore body. A large circular mass of silica 15 feet high crops out on the surface vertically above the Massive Pyrite body and is termed locally a "Blow Out".

Mineralization has been selective in fractured and shattered alternating, thin-bedded, calcareous shaly material.

Other limestone bed deposits: In the vicinity of Number 17 raise, 6th level, the adjacent Naco limestone beds to the north of North dike have been mineralized in a manner similar to that found within the dike at this locality. Mineralization roughly parallels the dike contact, and nowhere extends a great distance from the porphyry.

On the south contact of North dike Number 20 raise, 6th level, strong mineralization occurs along the porphyry-limestone boundary with abundant silicification. Nowhere did the mineralization extend more than a few feet into the limestone beds.

Relation ore to igneous rocks
Mining operations since 1940 have been largely restricted to discontinuous ore bodies associated with the North dike, a rhyolite porphyry. These vein replacement bodies are on the north and south contact as well as confined to the dike. In the vicinity of Number 17 raise, 6th level, the mineralization occurs along the north contact of the rhyolite porphyry-limestone boundary. Here the igneous rock has been extensively shattered and altered. Mineralization in this area along the north contact of the dike extends from above the 5th to below the 7th levels.

These discontinuous ore bodies within the porphyry include such bodies as those of Number two, Number three and Number four stopes 5th level; Number 17 and Number 20 raises, and Number 30 and Number 31 stopes of the 6th level; Number one and Number four stopes of the 7th level.

These disconnected sulfide ore bodies are in the extensively fractured rhyolite porphyry with an abundance of a clay-like mineral of unknown composition associated as stringers throughout the mineralized portions. This clay-like mineral is less common in portions of the dike separating the ore bodies, where mineralization is scanty. This is to be expected, as the unknown clay-like mineral is thought to be of hydrothermal origin. Pyrite is present in the sulfide ore as stringers, but is most prominent as massive bands bordering the highly fractured and mineralized porphyry, consisting of the unknown clay-
like mineral. Silicification is present in varying amounts. The hypogene ore bodies consist of closely spaced sulfide stringers separated by seams of the unknown clay-like mineral. The host rock, rhyolite porphyry, shows much kaolinization of its feldspar.

The hypogene ore of these ore bodies associated with the porphyry is very similar mineralogically. Galena and sphalerite are the main minerals with associated pyrite and minor amounts of chalcopyrite. The zinc content of the ore is slightly higher on the 7th level than above on the 6th level. Silver is present as "argentiferous galena".

Most of the ore bodies associated with the porphyry are not connected vertically. The mineralization is largely confined to an area in the North dike 800 to 1100 feet east of the shaft with separate ore bodies at different elevations. This confinement of the ore bodies to a section of the dike laterally and vertically suggests that the dip of the mineralized fractures stopped the solutions from moving vertically and forming continuous ore bodies.

Relation ore to structure

**Preore:** The major ore structure of the Seventy Nine mine area is preore faulting (see faulting for discussion). The ore solutions apparently penetrated and
possibly the shear zones, roughly paralleling the strike of the dike system (see Plate II). Near the surface the sulfide rich solutions penetrated the more permeable shear zone breaks and tension fractures of the favorable host rock. Thus faulting has been the major controlling factor in localizing the ore solutions combined with the physical character of the wall rock.

The original period of preore faulting produced the structural weak shear zones, of a general N 60°-70° E strike. These zones were subsequently invaded by acid magmas, with the resulting formation of granitic porphyry rocks as numerous dikes and sills. The second period of preore faulting consisted of renewed activity along the major north-south faults. This movement coming after emplacement of the granitic dike system, faulted, fractured and sheared the limestone and dikes. The North dike, a rhyolite porphyry, for some unknown reason appears to have been more intensely broken than many of the other dikes. This may possibly be connected with the fact that the North dike is the only dike essentially continuous in outcrop between the Keystone and Reagan Camp faults (Plate II).

The second period of preore faulting, with its accompanying shear along the old structurally weak zones occupied by the dike system, produced extensive fracturing and shattering of the dikes. The porphyry dikes, especially North dike, fractured in a manner which produced a permeable host
FIG 2. DIAGRAM SHOWING STRIKES AND DIPS OF FAULTS, SHEAR ZONES AND FRACTURES SEVENTY NINE MINE AREA. MAJOR WITHIN OUTER CIRCLE; MODERATE WITHIN INTERMEDIATE CIRCLE; MINOR WITHIN INNER CIRCLE. (DESIGN SUGGESTED BY B.S. BUTLER)
rock to invading ore solutions. A few horizons in the Naco limestone also fractured in a favorable manner. Most of the Naco limestone did not fracture favorably, but healed up, presenting an impermeable channel to ore solutions.

This second period of preore faulting produced a general N $70^\circ$-$85^\circ$ E shear direction and a tension direction of about N $55^\circ$ E. It is within these shear and tension fractures that the mineralization was deposited. This is clearly shown by Fig. 2 (page 111). The major faults strike due north to north $31^\circ$ west. The theoretical shear and tension fractures resulting from this major northwesterly faulting are the prominent mineralized breaks in the Seventy Nine mine area.

The relationship of mineralized fractures to the major faulting is clearly seen in the mine workings, 6th level, in the vicinity Number 31 stope. The Ore Body fault, of north-south strike, cuts the workings a short distance to the west. The resulting tension and shear fractures, from this fault movement, are here mineralized as sulfide stringers. Following mineralized N $55^\circ$ E fractures along their strike to the east, they are found to swing into weakly mineralized N $35^\circ$ E fractures, which soon change to near north-south striking fractures, completely barren of any mineralization.
It is believed that ore solutions penetrated upward along the major north-south faults. In the case of this relation to known ore, it is postulated that ore solutions permeated upward along the Ore Body fault. It probably tapped the deep seated Central Arizona batholith source in the vicinity of the North dike. As the ore solutions penetrated upward, the permeable tension and shear fractures of the North dike were encountered; the ores were deposited in this favorable host and rarely in the adjacent limestone. These breaks are closely spaced, thus the mineralization has been concentrated, and areas of several square-sets high with a floor area of a dozen or so square-sets are now mined as a massive ore body.

The Keystone fault shows much silicification and mineralized stain along its outcrop near ΔF, Plate II. The Ore Body fault shows some mineral stain along its outcrop near ΔC, Plate II. Underground the Ore Body fault zone was not mineralized along its strike where seen, but mineable ore bodies are located very close by.

The limestone replacement deposits as the Discovery and Massive Pyrite orebodies have an apparent similar origin to the ore bodies in the porphyry. A strong suggestion of associated north-south faulting and shearing within this area is the alignment of the bending along the strike of the outcrop of North, South and Office dikes near the Discovery ore body (Plate II). The
echelon off-setting may indicate north-south faulting and a possible channelway for the ore solutions. Mineralization may have penetrated upward along this north-south zone, and on encountering the shattered and permeable Naco limestone beds, migrated laterally where they were deposited as the Discovery and Massive Pyrite ore bodies. This zone if extended south aligns itself with the north-south fracture zone of the Long Fellow dike, where a large mineral stained area is exposed.

The Discovery and Massive Pyrite ore bodies also appear to be connected with the dike system, especially the South dike and to a lesser degree the Seventy Nine dike. The north contact and shear zones of the South and Seventy Nine dikes may have acted as a partial ore channel for the mineralization of the Discovery and Massive Pyrite ore bodies.

The main shear zones of North dike may also have been a partial channelway for the ore solutions. It is possible that these solutions penetrated upward from the Central Arizona batholith source and were deposited within the shear zone channelways at a moderate depth.

Postore: Some postore faulting is present; the Main fault being the largest. It displaces the Discovery and Massive Pyrite ore bodies.

The Massive Pyrite ore body has been referred to as the faulted segment of the Discovery ore body. The writer
cannot fully agree with that reasoning. Plate X shows the displacement and direction of fault movement along the Main fault. By reconstructing the pre-faulting position of the mineralized beds, it places the Massive Pyrite ore body higher in the geologic section than the Discovery ore body. From this solution, it appears that the Naco limestone has two favorable replacement zones within its lower portion.

No faulted bits of the silicified massive pyrite body of the 6th level were found in the lower levels of the Discovery ore body, the normal expectancy if they were faulted blocks of each other.

Several stopes, as in the Number four, 7th level, show postore movement along the seams of the unknown clay-like mineral. This evidence consists of the "mullions" formed on the fault planes so abundant in the clay-like material.

Hypogene Ore

Ore deposition

Replacement was the dominant process in deposition of the Seventy Nine mine ore. The ore solutions selectively replaced the impure calcareous shale beds and formed the Discovery ore body and similar bedded deposits. This was a molecular substitution, leaving no open spaces.
Bain has shown that replacement deposits are associated with moderately tight fissures rather than sizable open fractures. This allows capillary action to function aiding circulation of the ore solutions within the host rock.

Bedding plane faulting, present in the thin-bedded replacement deposits, has undoubtedly aided the circulation of the ore solutions. The presence of an abundance of the unknown clay-like mineral, probably of hydrothermal origin, suggests circulation along these bedding plane channelways. Not all of this material is of hydrothermal origin, as similar material is produced by faulting.

Within the shattered rhyolite porphyry, ore was deposited along preexisting fractures, with some replacement of the host. In the intensely faulted and sheared parts of the rhyolite porphyry, permeable channelways for the circulation and deposition of the ore solutions were present. These fractures were spaced so closely together that the ore was concentrated into mineable ore bodies. Between the closely spaced ore stringers are bands of altered wall rock, showing some replacement and much of the unknown clay-like mineral. This replacement is clearly shown by microscopic examination of the ore (see Plate XXI, Fig. 2).
The adjacent limestone beds do not fracture or shatter to the same degree as the porphyry. Except in the thin favorable zones, it tends to heal up on fracturing and become impermeable.

The association of some of the ore deposits with impure and shaly limestone suggests a possibility that carbonaceous material aided in the process of ore deposition.

Age of mineralization

Ore deposition closely followed the pre-mineral faulting and may have begun before it entirely ceased. Pre-mineral faulting of at least two separate periods took place prior to the ore deposition. The mineralization is postulated to be of Early to Middle Tertiary age.

Wall-rock alteration

A detailed study was not made of the wall-rock alteration. The Seventy Nine mine ore bodies, especially those in the rhyolite porphyry, are associated with large amounts of wall-rock alteration which should be studied in detail. Such study would most certainly add to the known information concerning reasons for ore deposition, thus aiding future prospecting.

Microscopic examination of the rhyolite porphyry from
the 6th level reveals much sericitization and kaolinization of the feldspar; the original biotite is bleached and replaced by muscovite. This is the result of alteration by the ore solutions. The porphyry appears white to creamy colored throughout the mine workings due to this alteration. It is characterized by large phenocrysts of quartz, smaller and more abundant phenocrysts of altered feldspar and a very fine-grained groundmass.

In the rhyolite porphyry especially, and less abundantly within the limestone beds is a clay-like mineral of unknown composition. It is hard to believe that all this material was formed only by alteration of the igneous rocks in the mine workings. It seems more likely that much of this clay-like mineral is of hydrothermal origin. This mineral is most abundant in the rhyolite porphyry where it has been excessively fractured, shattered and invaded by ore solutions. In the vicinity of the Number 17 raise, 6th level, angular blocks of porphyry up to two feet in length are separated by seams of this clay-like mineral several inches wide, which completely encloses the porphyry. On examining the contact of the clay-like mineral and the porphyry, a gradation from almost completely kaolinized outer material to a core of fresh porphyry with only the feldspar phenocrysts moderately altered was observed.

Solutions which followed the main period of mineralization silicified some portions of the rhyolite porphyry
dike and certain limestone beds. Several ore bodies in the porphyry are characterized by abundant silicified host rock. This degree of silification is shown by Plate XIX, Fig. 1. The silification of limestone is widespread as seen in the workings, but little ore is associated with these beds. Associated with the Discovery ore body, are large amounts of silica in the form of lenses and replacement bodies. This is best seen on the surface in the open stopes.

A large circular siliceous mass 15 feet high (Plate II) crops out vertically above the Massive Pyrite ore body of the 6th level. A large silica lense is present on the 7th level, Number three cross-cut and shows the result of post-mineral faulting. This is shown by microscopic examination Plate XIX, Fig. 2.

Underground in the limestone beds, are what appear to be solution channels of the circulating water. The limestone is a soft, coarse-textured mass and is dissolved for several feet along the strike of the channel. A box-work of a dark brown secondary mineral (siderite?) is deposited within the channelway.

Paragenesis

Samples of ore were collected from all levels of the
Seventy Nine mine. Hypogene ores were collected from the lower levels and mixed ores in the intermediate levels. Fifteen polished sections were made of the hypogene samples from the 5th, 6th and 7th levels to determine the paragenesis of the mineralization in the Seventy Nine ore bodies. The following discussion is based on the microscopic examination of the polished sections of hypogene ore. The age relation of the mineralization is shown by Fig. 3, page 121. Stages one, two and three are of hypogene origin, the fourth and fifth stages are of supergene origin.

Pyrite (FeS$_2$): The most abundant sulfide in the Seventy Nine Mine is pyrite. This is most plentiful in the lower workings, especially the 6th level. Here a massive pyrite body cut-off to the west by the Main fault extends to the east and has been shown to be too low grade in values for milling. Invariably massive pyrite bands are located along the margins of the hypogene ore bodies within the North dike; small pyrite stringers are throughout the hypogene ore. The amount of pyrite decreases appreciably on the upper levels. The massive pyrite was probably formed by precipitation around closely spaced nuclei. Many pyrite grains show embayments or veinlets filled with sphalerite, galena, quartz, or supergene cerussite and anglesite, but no evidence of pyrite replacing these minerals was observed. Pyrite in the "exploded
### STAGES

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**Fig. 3.** General paragenetic relation of mineralization Seventy Nine Mine.
"bomb structure" similar to that depicted by Graton and Murdoch is common in Seventy Nine ores, (Plate XX, Fig. 1).


Pyrite is clearly the earliest mineral of the Seventy Nine ores, and deposition of the iron sulfide ceased before that of the other minerals began. This is a common sequence, with deposition of the excess iron and sulfur prior to the base metal compounds. Previous to the base metal deposition, some movement was apparent, it giving rise to shattered pyrite, later invaded by the second stage of mineralization.

**Sphalerite (ZnS):** Sphalerite is about equal in abundance to galena in the sulfide zone. It occurs in varying sized grains, indicating its replacement by later minerals. It is clearly later than pyrite but earlier than the other minerals (Plate XX, Fig. 1.). Throughout the sphalerite grains are small blebs of chalcopyrite.

Sphalerite is abundant in the lower levels of the mine, the highest grade zinc ore being on the 7th level. It is non-existent in the upper oxidized zone. This relation suggests the soluble zinc was leached by acid waters and removed. Insoluble lead sulfide remained. Invariably associated with galena, this association
suggests a contemporaneous origin, but the polished sections reveal embayments and veinlets of galena in sphalerite. Some of these replacements are parallel to cleavage directions of sphalerite, (Plate XX, Fig. 2), indicating that sphalerite is earlier than the replacing galena. This association of sphalerite and galena in many ore deposits suggests similar conditions of solution and deposition.

The solutions rich in zinc and lead carried small amounts of copper. Zinc precipitated out first, was followed essentially contemporaneously by lead and the lesser abundant copper.

Galena (PbS): Galena and its oxidization products are found throughout the mine. It is the most important ore-forming mineral of the Seventy Nine mine. In the oxidized zone all stages of alteration from unaltered galena to supergene anglesite and cerussite are found. This change is shown by Plate XXI, Fig. 1; galena is surrounded by a zone of anglesite, this in turn is surrounded by a margin of cerussite.

In the sulfide zone, galena is invariably associated with sphalerite. This association might suggest that the two minerals are contemporaneous, but detailed microscopic examination shows that sphalerite is the earlier mineral, as evidenced by embayments and veinlets of galena (Plate XXII, Fig. 1).
Sphalerite precipitated first from the solutions which later precipitated galena and small amounts of chalcopyrite. Probably no hiatus existed; the lead followed the zinc out of the solution which carried them both together with a minor amount of copper.

The microscope reveals the common warped or curved cleavage of much of the Seventy Nine mine galena.

Chalcopyrite is present as irregular grains along the cleavage contacts of sphalerite and galena. This has been interpreted as showing contemporaneity of precipitation with galena (see Plate XX, Fig. 2). It forms mutual boundaries with galena.

**Chalcopyrite** ($\text{CuFeS}_2$): Chalcopyrite is a minor ore mineral in the sulfide zone. Invariably it is associated with galena and sphalerite. It is seldom recognizable in a hand specimen of the sulfide ore. Microscopic examination shows small blebs and grains scattered through most specimens of sphalerite. In places a grain of chalcopyrite is along the cleavage contact of galena and sphalerite, forming mutual boundaries with galena.

Chalcopyrite on the strength of its mutual boundary relations with galena is thought to be essentially contemporaneous with it and after the earlier sphalerite, (Plate XX, Fig. 2.).

**Silver:** The Seventy Nine mine has carried silver values both in the oxide and sulfide ore from the surface
to the lowest level. In some ore bodies this value has greatly exceeded the average, the richest silver enrichment having been in the Number two stope on the 5th level.

Microscopic examination revealed no identifiable silver mineral in the sulfide ore. The silver content is apparently in the galena, forming "argentiferous" galena. Guild has shown that galena will absorb up to 5 percent silver before the silver will form as a separate mineral argentite or stromeyerite. From the observations, it appears that this is the case with the Seventy Nine mine ore. Silver is present as less than 5 percent of the total lead content and has not precipitated out as a silver sulfide, but has enriched the galena.

Quartz: Throughout both the oxidized and sulfide ore zones quartz is an abundant gangue. It occurs as crystals filling druses and cavities, stringers, silicifications of the limestone and rhyolite porphyry, and as massive silica bodies.

Microscopic examination of the sulfide ores reveals quartz stringers cutting and replacing all hypogene minerals. This establishes quartz as definitely later than all hypogene mineralization.
Much silica is present in the form of lenses and replacement bodies. This is best seen as a surface expression where weathering has removed the enclosing beds, leaving the resistant silica as bold outcrops. Some of these small bodies are on the surface at the Discovery ore body. A large circular mass 15 feet high is a surface expression above the Massive Pyrite ore body on the 6th level as already mentioned (page 119). It stands out just east of the Main fault, and is locally termed a "Blow Out". Microscopic examination shows two stages of silicification (see Plate XXIII, Fig. I). Similar siliceous bodies are found elsewhere in the Seventy Nine mine area. A large "Blow Out" surrounds AF adjacent to Keystone fault, Plate II. Much of this material is also west of Keystone fault in the area south of the Chilito road Plate I. Here the silica is in lenses parallel to the bedding of the Naco limestone, erosion having exposed it on the present weathered surface.

**Unknown clay-like mineral:** A white to light gray clay-like mineral of undetermined composition, is closely associated with the mineralization. It is the most abundant gangue in the porphyry ore bodies; lesser amounts are present within the adjacent limestone and bed replacement deposits. It is probably of hydrothermal origin.

**Minor minerals:** Hematite throughout the workings is normally associated with garnet and some siderite. It is commonly in a micaceous platy form, specularite.
Supergene ore

Oxidation and supergene enrichment

The Discovery ore body is characterized by an iron stain in the mineralized beds, the surrounding limestone and the adjacent porphyry on the surface. This strong gossan is not evident on the surface above the oxidized Massive Pyrite and other ore bodies of the 5th and 6th levels, located east of the Main fault.

In the Discovery ore body, oxidation of the pyrite, a constituent of the hypogene ore has been fairly complete. Only minor amounts of pyrite are found associated with the supergene ore. Limonite is common throughout the oxidized ore bodies of the Seventy Nine mine area. Following Blanchard and Boswell, limonite is used as a field name for fine-grained yellowish or brownish deposits derived by decomposition of iron-bearing minerals. Presumably it is mostly ferric oxide monohydrate (goethite), but it may be partly ferric oxide (hematite), lepidocrocite, jarosite, or certain basic ferric sulfates.

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Similar conditions apparently prevailed in the bed
replacement deposits and the ore bodies associated with the North dike of the 5th and 6th levels. On these lower levels the completely oxidized zone grades downward into the hypogene sulfide zone. The demarkation of these zones is not sharp but grades both horizontally and vertically. In cross section, the supergene zone penetrates deep into the hypogene ore in places, showing the effect of increased permeability for circulating ground waters. This is seen very strikingly in the vicinity of Number 17 raise, 6th level, where sulfide and oxide ore zones alternate along the wall of the cross cut.

Supergene ore constituted the major production prior to 1940. Subtraction of iron and zinc, and the alteration of galena with little migration of lead, has produced supergene ore at the Seventy Nine mine.

The top of the non-saturated zone of circulating waters as estimated by the present water table, was in the vicinity of the 7th level. This is about 500 feet below the present surface.

The hypogene ore runs about equal proportions of sphalerite and galena, with abundant pyrite and minor amounts of chalcopyrite seen only in polished sections viewed under the microscope. Emmons has listed the

---

order of oxidation for such a deposit as first, sphalerite, followed by chalcopyrite, pyrite and galena in the order named. The reactions in the oxidation of these minerals follow:

\[
\begin{align*}
ZnS + 4Fe_2(SO_4)_3 + 4H_2O & \rightarrow ZnSO_4 + 8 FeSO_4 + 4 H_2SO_4 \\
ZnS + O_2 & \rightarrow ZnSO_4 \\
CuFeS_2 + 4O_2 & \rightarrow FeSO_4 + CuSO_4 \\
14CuSO_4 + 5FeS + 12H_2O & \rightarrow 7CuS + 5FeSO_4 + 12H_2SO_4 \\
CuSO_4 + ZnS & \rightarrow CuS + ZnSO_4 \\
FeS_2 + 7O_2 + 2H_2O & \rightarrow FeSO_4 + H_2SO_4 \\
PbS + 2O_2 & \rightarrow PbSO_4 \\
PbS + CO_2 + H_2O & \rightarrow PbCO_3 + H_2S
\end{align*}
\]

Following the order suggested by Emmons, the sphalerite was converted to the soluble zinc sulfate by the oxidizing solutions. The resulting soluble sulfate removed zinc from the oxidized zone and presumably transported it downward. The following reaction normally takes place in limestone but no evidence to date has confirmed this for the Seventy Nine mine:

\[
ZnSO_4 + CaCO_3 \rightarrow ZnCO_3 + CaSO_4
\]
There has been little exploration for zinc carbonate ore in the limestone beds.

Chalcopyrite, the second mineral to be attacked, is converted to copper sulfate and soluble ferrous sulfate as shown on page 129. Copper sulfate in turn may be converted to covellite by reacting with sphalerite. This supergene copper mineral is present in the oxidized ore, conclusively shown by microscopic examination (Plate XXII, Fig. 1).

Pyrite, the third mineral attacked, forms soluble ferrous sulfate which can be oxidized to form ferric sulfate, ferric hydroxide or ferric oxide under the required conditions for the formation of each. The ferrous sulfate may react with limestone as follows:

\[ \text{FeSO}_4 + \text{CaCO}_3 \rightarrow \text{FeCO}_3 + \text{CaSO}_4 \]

Galena, the last mineral to be attacked by the oxidizing solutions, normally produces the initial sulfate anglesite, which is immediately followed by the formation of the carbonate, cerussite. This is the most abundant supergene mineral of the Seventy Nine mine. Secondary lead products are relatively insoluble, and have undergone little transportation from their original position. Minor amounts of hypogene galena are associated with the carbonate and sulfate of lead.

Oxidation has been active since the ores were deposited or soon after in Early to Middle Tertiary. In a country of
arid climate this process is slow, as it depends on a supply of oxygen dissolved in the circulating waters. During the earlier Tertiary, oxidation was probably restricted by the Cretaceous volcanics covering the area. Erosion of the volcanics in later Tertiary, with formation of the Gila conglomerate in the fault troughs speeded oxidation of the ore bodies.

As previously mentioned, permeability of the ore varied, with a resulting varying depth of oxidation. Lowest point of oxidation is about 500 feet below the present surfaces.

Water table

The water table was encountered about 20 feet below the 7th level during mining operations in the fall of 1946. As the mine was not equipped to pump this water, driving of this winze was stopped. No measurements have been taken of the underground flow.

Paragenesis

Oxidized minerals are abundant throughout the Seventy Nine mine. Supergene minerals are predominant in the Discovery, Massive Pyrite and the upper parts of the ore
bodies in North dike. Mixed supergene and hypogene ores are on the intermediate levels. A minor amount of oxidized material is on the lowest levels. Most of the oxidized minerals are above the 6th level. Those recognized at the Seventy Nine mine are:

- **Anglesite** $\text{PbSO}_4$
- **Azurite** $2\text{Cu}_3\text{O}_5\cdot\text{Cu(OH)}_2$
- **Brochantite** $\text{CuSO}_4\cdot\text{Cu(OH)}_2$
- **Cerussite** $\text{PbCO}_3$
- **Chalcanthite** $\text{CuSO}_4\cdot5\text{H}_2\text{O}$
- **Limonite** Mixture of oxidized iron minerals
- **Malachite** $\text{CuCO}_3\cdot\text{Cu(OH)}_2$
- **Manganite** $\text{Mn}_2\text{O}_3\cdot\text{H}_2\text{O}$
- **Melanterite** $\text{FeSO}_4\cdot7\text{H}_2\text{O}$
- **Psilomelane** $\text{In}_2\text{O}_3$
- **Wulfenite** $\text{Pb InO}_4$

The oxidized copper minerals are nowhere abundant enough to constitute copper ore. Some copper has been recovered from the oxidized ore as a by-product of the lead smelting. Azurite and malachite are the most abundant of the oxidized copper minerals and are found throughout the oxidized zone. Chalcanthite and brochantite were found sparingly associated with pyrite in Number 26 cross cut area of the 6th level.

Melanterite was found associated with pyrite along
Number 11 and 21 cross cuts of the 6th level, as a spotty massive lining along the drift.

Manganese oxides, probably psilomelane and manganite are common in the oxidized zone. Much manganese stain and some irregular masses are associated with oxidized ore, especially on the 2nd and 5th levels.

Wulfenite is sparingly present irregularly throughout the oxidized zone. It was found most abundant on the 4th level in old workings within a few feet of the Main fault. It does not occur in large enough quantities or consistently enough to be ore. Wulfenite may form from the oxidation of galena and molybdenite. No molybdenite was found in the sulfide zone.

Limonite occurs as a brown stain on the limestone and gangue minerals, as small stringers in the soft gougy fault material, and as pseudomorphs after pyrite.

Pyrite throughout the workings has been attacked by acid solutions forming iron sulfate. Subsequent transportation and hydrolysis of the iron sulfate solution has produced the first two modes of occurrence just mentioned for limonite. Pseudomorphs formed when the oxidized iron remained within the boundaries of the present mineral.

Anglesite is very common throughout the oxidized zone. The dark anglesite occurs as concentric rings around the primary galena where replacement is not complete. In
Plates XXI, Fig. 1 the result of primary galena having been attacked by dilute sulfuric acid and ferric sulphate is shown. First anglesite, which in turn is surrounded by later cerussite, formed as follows:

$$\text{PbS} + H_2SO_4 \rightarrow \text{PbSO}_4 + H_2S$$

The dark color of the anglesite is due to finely divided galena.

Cerussite is the most abundant oxidized mineral and constitutes rich ore throughout the oxide zone. It occurs in colorless crystal groups, but more commonly as earthy, white or yellowish masses, in places with a sandy texture (sand carbonate).

Lead in contrast to zinc shows only slight mobility in the oxidized zone. The carbonate is difficultly soluble.

Cerussite appears to replace anglesite very easily by the action of carbonic acid as follows:

$$\text{PbSO}_4 + H_2CO_3 \rightarrow \text{PbCO}_3 + H_2SO_4$$

$$\text{PbSO}_4 + \text{CaCO}_3 \rightarrow \text{PbCO}_3 + \text{CaSO}_4$$

Some cerussite is found in the lowest 7th level, but primarily it is above the 6th level. Gypsum is not found in the workings. Being fairly soluble, the gypsum may
have been later attacked by circulating waters.

**Covellite** (CuS): Minor amounts of covellite are associated with the oxidation products of galena. Microscopic examination reveals covellite grains along cleavage cracks in the galena with feathery edges, as replacements within anglesite, and along the anglesite-galena contacts. (Plate XXII, Fig. I.).

**Chalcocite** (Cu$_2$S): Minor amounts of chalcocite are associated with the sulfide ore. Microscopic examination reveals small chalcocite grains within the sphalerite, associated with fractures and as small supergene veinlets (Plate XXII, Fig. 2). This is best viewed with a high powered lens. Supergene chalcocite is a common result of chalcopyrite alteration.

**Mining methods**

Two types of mining methods have been used in developing the Seventy Nine ore bodies; open stoping method in the near surface bed replacement deposits, and square-sets with fill method in the porphyry and deep level bed replacement ore bodies. In spite of the high cost of square-set methods, the high grade ore bodies of the Seventy Nine mine have warranted their use.
Early mining in the 1920's was cheap and under good conditions. In the Discovery ore body, extraction of ore down a 25°-35° dip in thin-bed replacement bodies was continuous from the surface to about the 4th level. Originally open stoping underhand methods along the strike from the surface outcrop downward were used. This was later replaced by driving of the 1st and later the 2nd or tunnel haulage level. Overhand methods of mining were then initiated with ore chutes to the 2nd level. This ore body was mined for about 300 feet along the strike of the beds. The several ore horizons two to three feet thick were mined with only an occasional pillar of ore or "stull" required to support the back.

As mining progressed below the 2nd level, it became necessary to drive the present, completely timbered, 60° incline shaft and manway. All levels below the 2nd connect with the incline, with the exception of the recent 7th level. The ore mined below the 2nd level was trammed to the inclined shaft and hoisted to the surface.

At places on the 3rd and 4th levels, the ground immediate to the ore body became "heavy" and a change over to square-set with fill methods for extraction were required. Many of the 1st and 2nd level stopes are standing open with little support; the majority of the workings on the 3rd, 4th, and 470 levels are caved.

The main fault displaced the replaced beds, and the
incline was driven to the 6th level in order to mine faulted segments. A large oxidized limestone replacement ore body between the 5th and 6th levels just east of the Main fault was mined using mostly a standard square-set with fill method. The "heavy" ground necessitated this timbering, evidenced by its present caved condition. A part of this ore was handled on the 5th level, but most of it was dropped by chute to the 6th level and hoisted to the surface.

Most of the main drifts and cross-cuts on the 5th and 6th levels are within limestone beds which stand open without timbering. Wherever the drifts or cross-cuts intersect the dikes, timbering with lagging is usually needed to prevent caving.

Ore bodies mined on the 5th, 6th and 7th levels in the rhyolite porphyry, have required a standard square-set with fill method of extraction. The porphyry is excessively shattered and the fractures are filled with an abundant unknown clay-like mineral. This dike rock will stand open without support little longer than the time required to mine out a square-set block of ore and set the timber. Caving is undoubtedly accelerated by slippage along the clay-like mineral filled fractures of the shattered dike rock. Waste from the mining is usually present in large enough quantity to supply adequate backfill material. If not, backfill material is taken from the nearest available
locality in the mine, using a gravity feed for emplace-
ment. Many parts of the porphyry where not mineralized
will stand as open drifts and cross-cuts without timber-
ing. Some of the sulfide ore requires hand sorting in the
stopes. The ore is hand trammed along the main drift to
the incline and hoisted to the surface by skip.

All timbers in the square-sets are 8 inches by 8
inches Oregon pine. The sets measure 6 feet 8 inches high
and the caps and girts are each 5 feet long. As mining pro-
gresses above the sill floor chutes are usually vertical
most of the distance. No standard pattern of spacing for
chutes and manways has been followed, as all the stopes are
very irregular; rarely do adjoining tiers of sets cover the
same horizontal area.

The 7th level is connected with the 6th by a vertical
winze about 1100 feet east of the inclined shaft. The ore
mined between the two levels is dropped to the 7th by chute,
trammed to the winze, hoisted to the 6th where it is
trammed to the incline and hoisted to the surface.

Drilling is done by Ingersol-Rand-DA-30 drifters,
Sullivan S-91 stopers and Sullivan 1-57 jackhammers.
Timken detachable bits are used with 2\(\frac{1}{2}\) inch starters,
with 1/8 inch change down to 1-3/4 inch size. Most of
the ground is soft and a minimum of drilling is necessary;
however a 40 percent Apache gelatine powder is used. The
rounds are fired by fuse.
Metallurgy of the ore

Mining operations in 1947 produce both oxide and sulfide ore. The sulfide ore, containing values in lead, zinc, copper and silver, constitutes the present major output of the Seventy Nine mine. The sulfide ore is trucked to Hayden Junction and shipped by railroad car to the custom mill of the Shattuck-Denn Mining Corporation, at Bisbee, Arizona.

After crushing and grinding, the lead and zinc concentrates are produced in a differential flotation circuit. The sphalerite and pyrite are depressed by use of a "depressant" in the conditioning solution. The "argentiferous" galena and chalcopyrite are recovered from the solution as a lead concentrate in the first flotation circuit. The lead tailing is then reconditioned to activate the surface of the included sphalerite. The reconditioned tailing is run through the second flotation circuit, and sphalerite is recovered as a zinc concentrate. The pyrite and gangue remain in the zinc tailing, which is rejected.

The lead concentrate is shipped direct to the lead smelter at El Paso, Texas. The zinc concentrate is shipped direct to the zinc smelter at Amarillo, Texas.

The oxide ore of lead (cerussite) with minor amounts of copper and silver produced at the Seventy Nine mine is trucked to Hayden Junction and shipped by railroad car directly
to the lead smelter at El Paso, Texas.

The cut-off limit used in mining for shipping ore is an estimated 18 percent of combined lead and zinc.

London-Arizona mine

Location

The property of the London-Arizona Consolidated Copper company covers a broad area, but that part included within the area of this report is immediately to the south and east of the ghost settlement of Chilito. The workings referred to are designated on Plate I as the London-Arizona mine. The old settlement of Chilito is about six miles by road from Hayden, and in an amphitheater at the headwaters of Chocolate Canyon. Chilito is connected with Hayden Junction, 4 miles to the south by an unimproved road.

History and production

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The deposits of the present London-Arizona mine were located about 1880 by Watson. The claims were later
acquired by D.W. O'Carroll and about 1906 sold to the Dripping Springs Mining, Smelting and Reduction Company, which was reorganized about 1908 as the London-Arizona Copper Company. In 1913, the London-Arizona Consolidated Copper Company was formed as a merger of the London-Arizona, London-Range, London-Shamrock and Ball Copper Companies. Work was carried on intermittently until 1920, when high metal prices encouraged mining. Since the drop in price of base metals at the end of 1920, no large scale work has been attempted. The buildings and area in the vicinity of Chilito were used to operate a goat ranch during the 1945-46 season. A good water well is located at Chilito on the company property.

During the period of intense operation in 1920, 15,443 tons of ore, ranging in tenor from 2.75 to 18 percent copper, was shipped by wagon team to the Hayden smelter. The average grade of this ore, estimated by Harry Scott of Chilito, was 4.5 percent copper.

No appreciable amount of ore has since been mined.

Geology and ore deposits

The main workings of the London-Arizona mine, within
the area covered by this investigation, are immediately to the south and east of Chilito. These workings consist of about 60 adits and tunnels at irregular intervals along the outcrop of a mineralized horizon at the base of the Martin limestone.

At the Tornado Peak section, the top member of the undifferentiated Cambrian beds consists of a fine-grained greenish quartzite, eight feet thick. Disconformably above, the basal Martin strata consists of a thin-bedded, shaly limestone ten feet thick, which is overlain by alternating thick-bedded, gray limestone and green dolomitic limestone 25 feet thick. The upper contact of the bed is marked by an eight inch shale stratum. This basal Martin 35 feet thick is known locally as the O'Carroll bed. It is the horizon in the geologic section mineralized at the London-Arizona mine. Scattered mine workings extend for 2,000 feet along the outcrop of the O'Carroll bed near Chilito. A few of the adits having been driven to the south side of the hill down the dip of the beds and form tunnel levels.

These sporadic, discontinuous ore bodies in the O'Carroll bed, consisted primarily of oxidized ore. Copper carbonates were the principal ore minerals, with small amounts of supergene chalcocite.

contained malachite, chalcocite, andradite garnet, specularite and quartz.

The writer noted on visiting the workings that the upper part of the lower ten foot member contained a large amount of manganese and limonite stain and was a creamy to yellow color in the more intensely mineralized areas. Some silicification of the beds was evident as exposed in the workings, with moderate amounts of azurite and malachite showing on the walls. The areas of more intense mineralization showed a likewise greater amount of fracturing and breaking of the ore bed. There is a suggestion that bedding plane faulting may have contributed to the fracturing of these basal Devonian beds.

The ore solutions penetrated the more highly fractured and broken parts of the O'Carroll bed and selectively replaced the shaly and thin-bedded limestone. Replacement of impure limestone is common in this region, as at the Seventy Nine mine, Discovery ore body and the Christmas mine.

The age of the ore deposition for the London-Arizona
mine, closely follows the same pattern as elsewhere in this area for the Tertiary Period. (see page 117). The hypogene ore, apparently dominant in copper, has undergone the normal supergene processes of enrichment so common to the southwest (see page 127).

Lining methods

The sixty-odd separate workings of the London-Arizona mine have been developed in essentially the same manner. The underlying ten foot, thin-bedded shaly limestone of the O'Carroll bed carried the highest values. The conditions were ideal for open stoping of this mineralized bed, using adits and tunnels for both the stope and the haulage way. In a few more persistently mineralized areas, the ore was mined down dip to the south, and the workings eventually emerged on the north slope of the canyon immediately south of Chilito. The thick-bedded limestone overlying the main mineralized horizon is strong enough to support the back of the open stope workings with a minimum of "stulls" and pillars.

The mineralized beds were rather soft and lent themselves to hand methods of extraction easily. The hand method of mining was done by contract; the company officials buying the ore on the grade of individual dump samples, from where the company shipped to the Hayden smelter.
Metallurgy of the ore

The copper carbonate ore was suitable for direct smelting at the Hayden smelter, six miles away. The proximity of the smelter and the then high copper price, permitted an otherwise sub-marginal deposit to be mined.

Schneider Group

Location

The property of the Gila Canyon Copper Company is located on the north and east side of Schneider Hill (see Plate I) 2,000 feet northwest of Chilito. The workings are connected by an unimproved road with Hayden Junction and Chilito.

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History and production


The claims were held by Jake Schneider from the early 1880's to about 1907, when he sold them to the Hotchkiss Syndicate. The Gila Canyon Copper Company was formed
about 1912 to work the deposit. In 1916 and 1917, the Gila Canyon Consolidated Copper Company had an option on the property, but later it appears to have reverted to the Gila Canyon Copper Company. The principal production was from August 1916 to January 1919 with G.B. Chittenden in charge. Small spotty operations continued through 1920, but these ceased in early 1921.

The principal production period of August 1916 to January 1919, yielded 225 cars of copper ore of a net value of $125,384.

Geology and ore deposits

The main workings of the Gila Canyon Copper Company located on Schneider Hill are in the siliceous strata mapped as a part of the Heseal limestone with a few in the overlying Troy quartzite.

Schneider Hill is capped by more than 100 feet of Troy quartzite. Underlying this, the Heseal limestone consists of siliceous strata, sandstone and hornfels about 90 feet thick. The diabase in the Schneider Hill area is intruded into the hornfels. To the north and east the Schneider Hill quartz latite porphyry body (see Plate XXIII, Fig. I.) has been intruded into the diabase and in places apophyses were intruded a short distance into the overlying sediments (see Plate I.). As exposed, the quartz latite porphyry is
practically continuous from Little Chocolate Canyon south to the north side of Chocolate Canyon.

Along the outcrop of the strata mapped as Neskal limestone on the north and east sides of Schneider Hill, replacement and small fissure vein deposits have been mined. Some places the quartz latite porphyry contacts were mineralized and in a few localities the ore solutions permeated upwards into the overlying fractured Troy quartzite. The general fracture pattern of the Troy as observed showed an east-west direction of fracturing with strong postore fracturing and faulting of N 55°W strike.

Some of the ore bodies were of very limited extent near the weathered surface and lent themselves to an open-cut method of extraction, while a few were more continuous. Development of considerable underground workings was necessary to mine these more persistent vein replacement deposits.

The ore as collected on the dump by the writer was essentially copper carbonates with some chalcocite. A typical Troy quartzite host specimen of ore showed azurite filling the fracture system and imparting a striking blue pattern to the rock. At the intersection of the two largest fractures was deposited chalcocite. The fracture intersection showed a decided widening with enrichment by the chalcocite.
Ross reports pyritic material enriched by supergene chalcocite as part of the ore mined.

The associated hornblende diabase (see Plate XII, Fig. I.) contains considerable disseminated pyrite and magnetite and is moderately altered. The Schneider Hill quartz latite porphyry body is comparatively unaltered.

The ore deposition was apparently connected with the quartz latite porphyry intrusive and its deeper source. The intrusive on emplacing itself and the associated movement, fractured the overlying strata. In the later stages of cooling and solidifying, the ore solutions high in copper content were given off by the source magma; which penetrating upward into the favorably fractured overlying Mescal and Troy beds.

Subsequent erosion followed by supergene enrichment, so common to the southwest, has reworked the hypogene mineralization to its present state.

The age of the ore deposition for the Schneider Group, closely follows the same pattern as elsewhere in this area for the Tertiary Period (see page 117).
The 17 unpatented claims of the Gila Canyon Copper Company were developed by both adit with underground stopping and open-cut mining. A few of the small restricted oxidized ore bodies lent themselves to open-cut extraction. This was the common method employed on the north side of Schneider Hill where the relief is steep. Several adits on the east flank of the hill serve several hundred feet of underground drifting and cross-cutting. It is reported that one adit is about 1800 feet long. Hand methods were used in extracting the ore.

Metallurgy of the ore

The oxidized ore of copper carbonates and chalcocite were smelted directly at the Hayden smelter, six miles away.

Apex mine

Location

The Apex mine is on the southwest side of the crest
of the Dripping Spring range (see Plate I.) It is three-fourths of a mile straight north of Chilito, at an altitude of about 4,300 feet. An unimproved road south-eastward down O'Carroll Canyon extends five miles to Finney on the Globe-Winkleman highway 77.

History and production

Ross, Clyde P., Ore deposits of the Saddle Mountain and Banner mining districts: U.S. Geol. Survey Bull. 771, p. 63-64, 1925.

The deposit was located by Joe Lavell, who was grub-staked by S.O. Stuart about 1914. It was worked by lessees for a short time. Then Mrs. K.B. Muller bought a half interest, and she and Lavell worked it at irregular intervals for a couple of years. In 1917 and 1918 it was worked under lease by some New York people. Lavell died in 1918 leaving Mrs. Muller the sole owner. From October 1922 until his death in 1923, the mine was under lease to Dr. O.M. Roberts. Since then, several parties have tried to open up the Apex mine, but little actual output has been accomplished. In June 1945 the writer talked with Globe, Arizona people who were then sampling the mine. They expected to operate the Apex, but have not done so to date.
The property includes a small mill, now out of repair, built about 1901, what was once a nice dwelling house, now run-down, and several small mine buildings.

From $15,000 to $20,000 worth of gold ore has been shipped to the smelter. An unknown quantity of high grade, free milling ore was treated on the property. Some of the ore was reported to have been very high grade.

Geology and ore deposits

The ore bodies of the Apex mine are in the lower part of the Martin limestone, which includes the O'Carroll bed, and the underlying undifferentiated Cambrian beds. The main workings were along a fracture zone in the basal Martin limestone, trending about N 70° E (see Plate I). This highly fractured zone was mineralized through a vertical range of 15 feet and persisted for over 300 feet along the strike. It varied from a few inches to several feet in width. The fracture zone continues east along the strike beyond the limit of the present workings, but the ore values are reported to be very low. The ore solutions penetrated the adjacent bedding in the limestone, and low grade ore is present in the stope walls. Some low grade mineralization is present in the underlying Cambrian beds, which show some effect of alteration due to the circulating ore solutions.
Besides the major strong fracture zone, several minor discontinuous mineralized areas along the outcrop of the basal Martin beds have been mined. These all occur in highly fractured areas of the replaced bed and outcrop within a short distance of the main mineralized zone. These spotty ore bodies were also confined to a very short vertical range.

Open trenching and shallow shafts in the underlying Cambrian beds of shale and quartzite, below the main workings, show some mineralization.

The ore consisted largely of quartz, limonite, cerussite, and probably other oxidized lead minerals and some white alunite.

The high grade ore is stated to have contained much coarse wire gold.

A slightly altered, rhyolite porphyry dike (see Plate I.) about 50 feet wide cuts the Martin limestone and underlying Cambrian beds just north of the shaft collar.

Mining methods

The deposit has been developed by a horizontal adit.
within the main mineralized fractured zone for 300 feet along its strike. This level is connected with a vertical shaft, the collar of which is near the crest of the Dripping Spring range. Below the main haulage level, a winze has followed the mineralization a short distance into the underlying Cambrian beds. Open stoping, with hand methods, was used to extract the ore.

A vertical shaft was driven just north of the rhyolite porphyry dike and in the Cambrian beds, but little could be learned of the mining intentions or the ore body.

Metallurgy of the ore

The lower grade ore was shipped directly to the smelter for reduction. The high-grade gold ore was treated on the property in the small mill and the bullion sold directly.

Hogvall prospect

Location

Several claims comprising the Hogvall prospect are located, about three quarters of a mile west of Tornado Peak on the south side of the canyon (see Plate I).
History and production

The property was located by Anton Hogvall about 1916. It has had a very sporatic mining history, with the scattered ore bodies having been worked by several parties for short periods. During early 1946, a Mr. Crews of Globe and a Mr. Young of Hayden were operating the property on a limited basis with two men employed. During the summer of 1946, Crews withdrew from the partnership and Young was operating alone. During the late summer of 1946 a small mill was erected at the Upshaw Ranch, one and one-half miles due west of the property, to treat the gold ore produced.

No information was available on the production from this gold property. The amount of workings and activity suggest but a small total production.

Geology and ore deposits

The gold bearing ore bodies are located in the undifferentiated Cambrian beds. The best ore appears to have been in the upper part of the Cambrian and directly below the overlying Martin limestone. In two localities
as plotted on Plate I., the altered shaly beds have been mineralized in stringers within a narrow broken zone. The writer noted much oxidized iron material and considerable manganese stain, associated with the carbonaceous looking gold ore. The mineralization was confined to a narrow zone along the strike of the shattered zone which did not persist too definitely in vertical range. Only in a few places was this zone followed vertically for a depth of several square-sets. Mineralization did not penetrate upwards into the Martin limestone. The grade of mineralization apparently declines as the ore zone is followed downward in the Cambrian beds.

Mining methods

Adits were driven to follow the mineralized zones from favorable levels in the Cambrian beds. In the more intensely mineralized areas, some square-sets were used to follow the ore vertically within its narrow width along the strike of the fracture zone. Hand methods are used exclusively for extracting the ore.

Metallurgy of the ore

Little is known of the past or present ore treatment.
Young shipped several tons of his high-grade ore one half mile by burro to the Hayden Junction-Chilito road. He expected to truck this ore to the Upshaw ranch, two miles away, site of his treatment mill, for recovery in late 1946. Nothing has been learned of his recovery success.

Reagan Camp prospects

Location

The Reagan Camp property is located adjoining the Seventy Lead-Copper Companies' claims on the south. The claims extend from Reagan Camp on the west (Plate I) up Keystone Gulch and Little Chocolate Canyon to the Schneider Group on the east. They are bounded on the north by the Seventy Nine Lead-Copper Company claims and approximately on the south by Chocolate Canyon.

History and production

The early history of the claims is not known. Lee Reagan acquired the original property soon after losing

Mr. Kullum, Oral communication June 1946.
control of the Seventy Nine mine in 1923, as a result of litigation. Mr. Reagan still maintains an active interest in the property.

Mr. Kullum has been caretaker of the property since 1935. He has located several new claims adjoining the original ones, especially on the east and north sides.

Production has been small and very irregular from several scattered prospects and small workings. The best prospect is one-half mile east of the camp in Keystone Gulch (see Plate I). It has produced a few carloads of oxidized lead ore which was shipped directly to the smelter at El Paso, Texas.

Geology and ore deposits

Naco limestone and the large plug of basalt porphyry crop out over most of the claims. Part of the property is east of Keystone fault, where diabase crops out.

The best mineral showing is along the north contact of the basalt porphyry intrusive and the Naco limestone. The basalt porphyry contact dips steeply to the north where exposed in Keystone Gulch. One-half mile east of Reagan Camp on the south side of Keystone Gulch, several adits and cross-cuts have been driven at different elevations thru Naco limestone to prospect the contact of the porphyry plug.
Within the workings the thin-bedded Naco limestone has been mineralized up dip from the porphyry in a few favorable horizons. The ore of lead carbonate (cerussite) was not persistent along the strike or dip of the contact, nor was it continuous many feet laterally into the limestone.

Directly east one-fourth mile along this same contact is located a large siliceous outcrop with associated mineral stain in the Naco limestone from the above prospect. This large mass is very similar to the showing on the surface above the Massive Pyrite ore body at the Seventy Nine mine. Mineral indications are present as iron and copper stain in the underlying thin-bedded limestone.

Prospecting in the diabase east of Keystone fault in Little Chocolate Canyon, has located several small veins of lead and copper. None are large enough to be of commercial value.
CHAPTER IV

SUMMARY

This report covers an area of eight square miles, four miles due north of Hayden, Gila County, Arizona. It is divided into two physiographic subdivisions by the Keystone fault; a western belt that consists of much faulted and dissected steeply southern dipping limestone beds; and a central belt that consists of little faulted and gentle southern dipping beds of limestone, quartzite and shale with a large part consisting of diabase weathered to a gentle slope.

The sedimentary sequence begins with the upper part of the pre-Cambrian Mescal limestone. The Paleozoic rocks consist of Troy quartzite, undifferentiated Cambrian beds, Martin limestone, Escabrosa limestone and Naco limestone. This section is nowhere exposed at one locality in its entirety, about 2500 feet.

Sediments of Mesozoic age are not present in the area.

The Late Tertiary, Gila conglomerate is widespread. A large erosion remnant crops out immediately south of the Seventy Nine mine and has aided in dating the postore faulting. Two ages of Quaternary alluvium are present.

Intruded into the Mescal limestone with small apophyses cutting lower Troy quartzite is diabase, apparently emplaced
as a sill and correlated with the widespread central Arizona diabase. It is of post-Middle Cambrian age.

Cretaceous igneous activity is represented by a large plug of basalt porphyry east of Reagan Camp and minor bodies of dacite, andesite and basalt porphyries.

Probably in Early to Middle Tertiary, the area was intruded by an extensive acidic dike system, apophyses of the Central Arizona batholith. This dike system is most numerous in the block between Reagan Camp and Keystone faults; a small number are located throughout the remainder of the area.

Faulting is of two general periods, preore and postore. Preore faulting consisted of major displacement along north-south breaks with resulting shear zones forming which strike N 60°-70° E. The acidic dike system was intruded into these shear zones. A rejuvenation of movement along the major north-south faults produced a shearing and shattering of the dike system and certain favorable beds in the Naco limestone. This second period of movement produced tension fractures striking about N 55° E and shear fractures of N 70°-85° E strike.

Postore faulting striking N 35°-45° W has displaced known ore bodies. It is probably of Middle to Late Tertiary age.

Mineralization closely followed the second period of
preore faulting and is postulated to be of Early to Middle Tertiary age. The mineralization is of the replacement vein and bed replacement type; and falls within the isothermal range of moderate depth ore bodies. At the Seventy Nine mine, the ore solutions probably penetrated upward along the north-south faults. On encountering the shattered and permeable tension and shear fractures of the North dike, and the favorable horizons in the Naco limestone, the solutions migrated laterally and were deposited. It is possible that part of the ore solutions penetrated upward along the shear zones and were deposited at moderate depth. Elsewhere in the area, the basal part of the Martin limestone has been mineralized, as at the London-Arizona and Apex mines. Mineralization is of Early to Middle Tertiary age.

Hypogene mineralization was deposited in three separate states: first stage pyrite, second stage sphalerite, "argentiferous" galena, and chalcopyrite, third stage quartz. An abundant unknown clay-like mineral is associated with all the ore deposits.

Supergene mineralization was deposited in two stages: the fourth stage chalcocite, covellite and wulfenite, fifth stage azurite, malachite, anglesite and cerussite.

The Discovery and Massive Pyrite ore bodies consisted primarily of supergene ore (cerussite). The hypogene ore bodies located in North dike near the Ore Body fault consist
of about equal proportions of sphalerite and "argentiferous" galena. The hypogene ore bodies above the 6th level are generally oxidized. They consist primarily of lead carbonate.

Only the lower part of the Naco limestone has been prospected at the Seventy Nine mine. Nowhere has the underlying Escabrosa limestone been cut by workings or correlated drilling.

Potential ore horizons are located in the underlying Escabrosa limestone, Martin limestone and undifferentiated Cambrian beds (see Plate VI). Movement along the Main fault suggests a possible potential ore horizon within the Naco limestone in beds below the Massive Pyrite ore body (see Plate X).

The possibility of favorable ore horizons in the upper part of the Naco limestone cropping out to the south of the Seventy Nine mine should not be disregarded. The favorable beds mineralized at the Christmas mine a few miles to the east are probably included in the more than 1000 feet of Naco limestone cropping out within the area. No attempt was made to locate this horizon, as the position of the ore beds at the Christmas mine within the geologic section has been reported to be unknown.
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MICROPHOTOGRAPHS OF SEVENTY NINE MINE- TORNADO PEAK AREA IGNEOUS ROCK THIN-SECTIONS
PLATE XII

Fig. 1.

Hornblende diabase with dark mineral, magnetite. Laths are of labradorite. Polarized light X 21.5

Fig. 2.

Diabase, laths of labradorite. Polarized light X 21.5
Fig. 1.

Basalt porphyry. Phenocrysts of labradorite.  
Polarized light X 21.5

Fig. 2.

Andesite porphyry. Andesine and biotite phenocrysts.  
Ordinary light X 13
Plate XIII

Fig. 1.

Fig. 2.
PLATE XIV

Fig. 1.

Rhyolite porphyry, North dike.
Sericitized albite phenocrysts.
Polarized light X 13

Fig. 2.

Granite porphyry. Carlsbad
twinning in orthoclase, with
biotite.
Polarized light X 13
PLATE XV

Fig. 1.

Quartz monzonite porphyry.
Phenocrysts of oligoclase.
Polarized light X 13

Fig. 2.

Monzonite porphyry, South dike.
Phenocrysts of andesine.
Polarized light X 13
Fig. 1.

Hornblende monzonite porphyry, a facies of the monzonite porphyry. Oligoclase and hornblende phenocrysts. Polarized light X 21.5

Fig. 2.

Granodiorite porphyry. Zoning of andesine phenocrysts. Polarized light X 13
Fig. 1.

Quartz diorite porphyry, Seventy Nine dike. Sericitized andesine phenocrysts. Polarized light X 13

Fig. 2.

Fig. 1.

Fig. 2.
Fig. 1.

Schneider Hill, quartz latite porphyry. Oligoclase phenocrysts. Polarized light X 13

Fig. 2.

Aplite. Quartz, orthoclase and albite grains. Polarized light X 13
Fig. 1.

Rhyolite porphyry, North dike, silicified on 7th level of Seventy Nine mine.  
Polarized light X 21.5

Fig. 2.

Massive silica body, 7th level, Number 3 cross-cut.  
Polarized light X 13
Fig. 1.

Pyrite in exploded bomb structure. Sphalerite has replaced pyrite which in turn was replaced by galena and chalcopyrite. Latest mineral quartz in veinlets cutting pyrite. X 82

Fig. 2.

Sphalerite showing good cleavage outline invaded by later galena and chalcopyrite. Chalcopyrite principally as blebs in the sphalerite. X 82
Plate IX

Fig. 1.

Fig. 2.
Fig. 1.

Pyrite in exploded bomb structure, cut by anglesite and cerussite. X 51

Fig. 2.

Host rhyolite porphyry replaced by sphalerite which in turn is replaced by galena and chalcopyrite. Later quartz as small veinlets cutting all minerals. X 82.
PLATE XXII

Fig. 1.

galena with dark covellite as secondary product formed along cleavage planes. X 82

Fig. 2.

Sphalerite replaced by galena and chalcopyrite. Secondary chalcocite formed along galena-sphalerite boundary. X 82
Fig. 1.

Fig. 2.
PHOTOGRAPHS OF SEVENTY NINE MINE-

TORNADO PEAK AREA
Fig. 1.

Large siliceous outcrop ("Blow Out") 150 feet east collar shaft Seventy Nine mine. Clearly shows two stages of silicification. Polarized light X 21.5

Fig. 2.

Thin-bedded, cherty Mescal limestone block resting on weathered diabase. Area immediately east of Keystone fault and gulch. A typical diabase weathering slope.
Seventy Nine mine headframe and buildings taken from along Main fault. Discovery ore body begins on right side of photograph and extends to right, seen in Fig. 2.

Discovery ore body surface workings in the thin-bedded Naco limestone. Taken from along Main fault. Fig. 1. to the left of photograph.
Fig. 1.

Spheroidal weathering in granite porphyry intruded into diabase east of Keystone fault.

Fig. 2.

Looking west down Chocolate Canyon from Troy quartzite cliffs exposed along the Tornado Peak section. The ghost town of Chilito in the foreground.
Fig. 1.

Fig. 2.
Tornado Peak section, exposed in Chocolate Canyon, measured by N. P. Peterson. Tornado Peak highest point. Lower cliffs Troy quartzite, massive light gray cliffs Escabrosa limestone. Workings of London-Arizona mine seen along the outcrop of the O'Carroll bed, base of Martin limestone. Ghost town of Chilite in foreground
Fig. 1.

Schneider Hill and the workings of the Gila Canyon Copper Company as viewed from the Troy quartzite cliffs, Tornado Peak section. Schneider Hill, quartz latite porphyry exposed in foreground and in saddle to right of hill.

Fig. 2.

Panoramic view Dripping Spring range from Gila conglomerate outwash plain two miles to the west. Keystone fault scarp shown by massive Escabrosa limestone cliffs and overlain by the thin-bedded Naco limestone.
Fig. 1.

Looking east up Chocolate Canyon at the center of the Urupping Spring range from 500 feet west of Keystone fault. Troy quartzite cliff on right, underlain by a few feet of Mescal limestone and a long slope of weathered diabase.

Fig. 2.

Road to Seventy Nine mine taken from one-fourth mile east of Reagan Camp prospect. Steeply dipping Naco limestone beds, cut-off by Reagan Camp fault on left, with Gila conglomerate exposed. H, Plate II, located top hill in center.
Fig. 1.

Looking north along Keystone fault. F, Plate II located top hill in center. Naco limestone on left, weathered diabase slope with Troy quartzite cliffs on right.

Fig. 2.

Looking south along Keystone fault from Chilito road, Cholocate Canyon. Troy quartzite cliffs overlain by undifferentiated cambrian beds and Martin limestone on left, steeply dipping Naco limestone on right.
Thin-bedded Naco limestone distorted by movement along Keystone fault. Left side (cliffs) up, and are massive Escabrosa limestone. Right side down. Taken from north side of Chocolate Canyon looking south.

More distorted Naco limestone beds, the result of movement along keystone fault. These beds are located directly west or to the immediate right of Fig. 1. above.
in packet:
11 maps
GEOLOGIC MAP OF THE TORNADO PEAK-79 MINE AREA
GILA COUNTY, ARIZONA

SCALE 1:2000

GEOLOGY BY G.A. KIERSCH 1946

CONTOUR INTERVAL 100 FEET
DATUM IS MEAN SEA LEVEL
EXPLANATION

ALTERED PORPHYRY & LIMESTONE
MINERALIZED: Ox. = OXIDE, Sul. = SULFIDE, Mx. = MIXED
ALTERED PORPHYRY & LIMESTONE
NON-MINERALIZED
MASSIVE PYRITE WITH SILICA
MINERALIZED STRINGERS
FAULT
FAULT INFERRED
CONTACT INFERRED
CONTACT APPROXIMATE LIMESTONE BEDS
CAVED
LAGGED

GEOLOGY BY
G. A. KIERCH 1946-47
LEVEL WORKING AFTER
79 LEAD-COPPER CO. MAPS

79 MINE
GEOLOGIC MAP 5th LEVEL
SCALE 1" = 50 ft

GEOLLOGY BY
G. A. KIERCH 1946-47
IN CAVED AREAS AFTER
J. B. TENNEY 1942
PLATE X

IN 44°W
STRIKE MAIN LOOKING EAST

MAIN FAULT
DIRECTION MOVEMENT, DISPLACEMENT
79-MINE

SCALE
HOR. 1"=50 FT. VERE. 1"=50 FT.
G.A. KIERSCH 1947

SOLID LINES WEST BLOCK (UP)
DASHED LINES EAST BLOCK (DN.)

INTERPRETATION BASED ON PROJECTION OF DATA
OBTAINED OUTCROPS AND UNDERGROUND WORKINGS
The United States Geological Survey is making a series of standard topographic maps to cover the United States. This work has been in progress since 1892, and the published maps cover more than 47 percent of the country, exclusive of outlying possessions.

The maps are published on sheets that measure about 14 by 20 inches. Under the general plan adopted the country is divided into quadrangles bounded by parallel of latitude and meridians of longitude. These quadrangles are mapped on different scales, since each map is of a scale that is best adapted to general use in the development of the country, and consequently, though the standard maps are of nearly uniform size, the areas they represent are of different sizes.

On the lower margin of each map is printed a graphic scale showing distances in feet, meters, miles, and kilometers. In addition, the scale of the map is shown by a fraction expressing a fixed ratio between linear measurements on the map and corresponding distances on the ground. For example, the scale \( \frac{1}{100000} \) means that 1 unit on the map (such as 1 inch, 1 foot, or 1 meter) represents 100,000 units of the same unit on the earth's surface.

Although some areas are surveyed and some maps are compiled and published on special scales for special purposes, the standard topographic surveys and the resulting maps have for many years been of three types, differentiated as follows:

1. Surveys of areas in which there are problems of great public importance—relating, for example, to mineral development, irrigation, or reclamation of swamp areas. Maps made for these purposes are of sufficient detail to be used for the planning and construction of projects. The standard maps are of nearly uniform size, and their size is determined by the size of the folio. A circular describing the folios will be sent on request.

2. Surveys of areas in which there are problems of average public importance, such as much of the basin of the Mississippian and its tributaries, or parts of the northwest, are made with sufficient detail to be used in the planning and construction of projects. The standard maps are published on a scale of \( \frac{1}{100000} \), (1 inch = nearly 1 mile), with a contour interval of 10 to 100 feet.

3. Surveys of areas in which the problems are of minor public importance, such as much of the mountain or desert region of Arizona or New Mexico, and the high mountain areas of the northwest, are made with sufficient detail to be used in the publication of maps on a scale of \( \frac{1}{250000} \), (1 inch = nearly 2 miles), or \( \frac{1}{500000} \), (1 inch = nearly 4 miles), with a contour interval of 20 to 250 feet.

The aerial camera is now being used in mapping. From the information recorded on the photographs, planimetric maps, contours, and maps of the area surveyed the maps are compiled and published on special scales for special purposes, the standard topographic maps being accompanied by figures showing altitude. The heights of many prominent features is represented, directly beneath its position in the sketch, by contour lines.

A survey of Puerto Rico is now in progress. The scale of the published maps is \( \frac{1}{100000} \).

The features shown on topographic maps may be arranged in three groups—(1) water, including seas, lakes, rivers, canals, streams, and other bodies of water; (2) relief, including mountains, hills, valleys, and other features of the land surface; and (3) culture (works of man), such as towns, cities, roads, railroads, and boundaries. The symbols used to represent these features are shown and explained below. Variations appear on some earlier maps, and additional features are represented on some special maps.

All the water features are represented in blue, the smaller streams and canals by single blue lines and the larger streams by double lines. The larger streams, lakes, and the sea are accentuated by blue water lines or blue tint. Intermediate streams—those whose beds are dry for a large part of the year—are shown by lines of blue dots and dashes.

Relief is shown by contour lines in brown, which on a few maps are supplemented by shading showing the effect of light thrown from the northwest across the area represented, for the purpose of giving the appearance of relief and thus aiding in the interpretation of the contour lines. A contour line represents an imaginary line on the ground (a contour) every part of which is at the same altitude above sea level. Such a line could be drawn at any altitude, but in practice only the contours at certain regular intervals of altitude are shown. The dot or dots of altitude of the Geodetic Survey maps is shown on sea level. The 100-foot contour would be the shore line if the sea should rise 20 feet above mean sea level. Contour lines show the shape of the hills, mountains, and valleys, as well as their altitude. Successive contour lines that are far apart on the map indicate a gentle slope, lines that are close together indicate a steep slope, and lines that run together indicate a cliff.

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

The sketch represents a river valley that lies between two hills. In the foreground is the sea, with a bay that is partly enclosed by a hooked sand bar. On each side of the valley is a terrace into which small streams have cut narrow gullies. The hill on the right has a rounded summit and gently sloping sides separated by ravines. The spur are traversed at their lower scale by a sea cliff. The hill at the left terminates abruptly at the valley in a step near, from which it slopes gradually away and forms an inclined tableland that is traversed by a few shallow gullies. On the map each of these features is represented by lines drawn beneath its position in the sketch, by contour lines.

The contour interval, or the vertical distance in feet between one contour and the next, is stated at the bottom of each map.

This sketch, which on a few maps is supplemented by shading showing the effect of light thrown from the northwest across the area represented, is repeated on the map. The interval of altitude for the particular area mapped is stated at the bottom of each map.

A survey of Alaska has been in progress since 1892. The aerial camera is now being used in mapping. From the information recorded on the photographs, planimetric maps, contours, and maps of the area surveyed the maps are compiled and published on special scales for special purposes, the standard topographic maps being accompanied by figures showing altitude. The heights of many prominent features is represented, directly beneath its position in the sketch, by contour lines.

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