Geology and Ore Deposits of the Dives and Gold Ridge Groups Dos Cabezas, Arizona

by

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A Thesis
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INTRODUCTION

Field work

This report is the result of field work done during the school year 1939-40. During this time laboratory investigations of polished and thin sections were carried on at the University of Arizona.

No topographic maps of this area were available, and no bench marks for elevation. In preparing a map a baseline was laid out south of the area, and its azimuth determined by solar observation. A triangulation system was then extended into the area by the use of a transit. A bench mark, established during a survey of the Consolidated Gold Mines claims, was used in starting the contour map. This bench mark, 5750 feet above mean sea level, is under the track leading from the main adit where it passes the corner of the powerhouse building. In plane tabling with an alidade, the Beaman stadia arc was used, and distances determined by rod readings. The scale is 400 feet to the inch, and the contour interval 50 feet. Two maps, showing the claims of the Dives and Gold Ridge groups were reduced to the map's scale and may be superimposed on the areal map by lining up the adits of the Dives and Gold Ridge.
mines. The original map did not include the Philadelphia mining area so contours south of station VI are not accurate nor are plotted positions of quartz veins and basic dikes.

Acknowledgments

The writer wishes to acknowledge his indebtedness to the faculty of the Department of Geology of the University of Arizona for critical reading of the manuscript, and to Professor A. A. Stoyanow for his aid in the identification of fossils and suggestions in stratigraphy.

Baseline measurements were made with the kind assistance of Mr. Vard Johnson and others, and contouring done with the help of Mr. Manuel Mayuga and Mr. Albert Halley. Mrs. Alice Huntsman kindly furnished the records of her properties and granted permission to study the underground workings of the Gold Ridge Mine. Mr. C. B. McIntire, as representative of the Dives Mine, deserves especial thanks for making available all the records of that company as well as accompanying the writer underground on many occasions. A mine map made in 1937 by M. B. Mills was the basis of Plate No. 3.
The underground geology is the work of the writer except for the position of quartz veins on the 600 foot level and a few places on the 300 foot level. The diagram of the Huntsman mine is the result of combining a compass survey with mine workings shown on the claim map. The location map is from Darton's Guidebook of the Southern Pacific Railroad mentioned below. The roads have been added from a roadmap of Arizona.

Previous Investigations:

No comprehensive reports have been made on the Dos Cabezas Mountains or any large section of them. Reports have been made for the benefit of mining companies on the Central Copper, Gold Ridge, and Dives properties, and probably on other mines as well.

In 1875-1878, G. K. Gilbert of the Wheeler Geological Survey party west of the 100th Meridian described the geology from Ewell Spring to Camp Bowie in Volume 3 of Wheeler's report. In 1925, N. H. Darton of the U. S. Geological Survey made a reconnaissance survey of the area which was very briefly described and sectionized (2 miles south of Dos Cabezas) in his University of Arizona bulletin No. 119, "A Resume of Arizona Geology". In 1933, the same author described the Dos Cabezas Mountains and surrounding valleys in his "Guidebook of
Dos Cabezas and Vicinity

Approximate location of thesis area in red
Paleozoic ridge in green
GEOGRAPHY

Location

A rough map of the quadrangle is presented so the reader may easily locate the area which lies on the southwest slope of the Dos Cabezas mountain range in Cochise County, and is about 2 miles north of the town of Dos Cabezas in T. 14 S., R. 27 E., measured from the Gila and Salt River principal guide meridian and baseline. The area covers approximately two square miles and is elongated along a quartz vein which is the probable source of the gold bearing ores. The Consolidated Gold Mining Company, Ltd., and Mrs. Alice Huntsman own the majority of the claims in the area, while E. I. Tout owns the Central Copper Company claims just to the north. The Gold Prince and Le Roy mines lie to the southeast of the region to be discussed.

Dos Cabezas may be reached by a 13 mile drive over a good gravel road from Willcox. This road leads to the "Wonderland of Rocks" to the south in the Chiricahua Mountains on the east side of Sulphur Spring Valley.
Climate and Water Supply

This area lies on the desert side of the mountainous belt of Arizona and annual rainfall is between the extremes of the desert and higher mountain ranges. The town of Dos Cabezas has an elevation of 5250 feet and a yearly rainfall ranging from 8.6 inches in 1891 to 15.1 inches in 1909 (these figures are not extremes as only five years are given). Somewhat more than this falls in the Dos Cabezas Mountains, possibly 20 inches at the summit, which rainfall is the lower limit of yellow pine timber.

The principal rainy season covers a period of about 2 months, extending from July to September. A few heavy showers at this time contribute about one half the total rainfall.

The driest part of the year is the spring. Occasional rain or snow falls during the winter. Snow may reach a depth of half a foot or more on the mountain slopes.

The average temperature at Willcox during a 25 year period was 61.7° F. Nearby mountainous areas are relatively cooler.

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Many facts and figures from:
The Dos Cabezas range is flanked on the southwest by hard Paleozoic strata dipping steeply away from the range and forming a conspicuous ridge (shown in green on location map). Behind this ridge is a wide, low basin (called Ewell Spring Valley herein) in which water is impounded because of the Paleozoic "dam". Cross canyons have formed to carry off excess water, but extremely weathered Pre-Cambrian granite and quaternary fill, which blankets the basin, catch and contain much water. Dos Cabezas is the site of Ewell Spring used as early as 1885 by exploring parties.

The Dives Mine obtains about 16,000 gallons of water per day from 5 drill holes that tap a limestone bed in the face of their main adit. More water is obtainable at higher elevations, as at the Tout properties. Enough water can be drained from mine workings to supply small mills provided some water is recovered and returned to the circuit.

Flora and fauna

Much of the area consists of rocky talus-covered slopes with prickly pear, rainbow cactus, yucca, catclaw, and mesquite as the principal vegetation. Sycamore and cottonwood trees are scantily represented in the larger
draws, and in one canyon uncontrolled withdrawal of water has killed many trees. On many of the slopes live oaks are numerous. Grass appeared rather scanty but there are many head of cattle in this area. Small pine and juniper appear around the Dos Cabezas but do not extend much below 7000 feet.

Game is not abundant but Gambel’s quail, rabbit, and deer were noted. Wild cats inhabit old adits, and one rattlesnake was seen. Burros are present in large numbers having been formerly used to transport ore from the Gold Ridge Mine.
PHYSIOGRAPHY

The Dos Cabezas Mountains consist of a narrow range with steep slopes and extend somewhat east of southeast for about 20 miles. The Chiricahua Mountains, in contrast, are four townships wide and more gently inclined. Viewed from the west, the northern part of the Dos Cabezas range appears barren and relatively low. Southward the range culminates in two volcanic peaks that rise over 8200 feet above sea level. These peaks are the most conspicuous landmark in the whole Sulphur Spring Valley. North of the range is Stein's Pass through which the highway and railroad extend, and at the southern end is Apache Pass, the location of old Fort Bowie. To the west of the range is Sulphur Spring Valley which has no drainage outlet, but contains a central playa or alkali flat at an elevation of 4134 feet. The name bolson is applied to this type of valley.

As far back as 1875, G. K. Gilbert\(^1\) stated concerning the origin of the Basin and Range Structure:

"the ridges of the system occupy loci of upheaval and are not mere residua of denudation; the valleys of the system are not valleys of erosion

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but mere intervals between lines of maximum uplift. The movements of the strata by which ridges have been produced have been in chief part vertical along planes of fracture and have not involved great horizontal compression."

Concerning the Dos Cabezas Range Gilbert said "the structure is monoclinal, demonstrably due to vertical faulting". Further he says:

"Within the ranges there are indeed eroded valleys, and the details of relief show the inequality of erosion due to unequal resistance, but there is not on a grand scale that close dependence of form on durability that must maintain were the great features of the country carved by denuding agents."

Steep normal faults striking east-west have influenced the physiography of this area. Outpourings of lava have determined the character of the higher parts of the range.
11.

REGIONAL GEOLGY

The southern slopes of the Dos Cabezas Mountains, north and east of the town by that name, are composed of late Paleozoic limestone, Upper Cretaceous sandstone and slate, and Late Cretaceous and Tertiary intrusive and extrusive igneous rocks.

To the southwest of the town of Dos Cabezas is a section of Paleozoic sedimentary rocks dipping westward and making up a long ridge, one half mile across, extending 4 miles north and about 5 miles south of the town. Near the highway 2 miles north of the town is the section shown by Darton who, in 1919-1922, here rediscovered the Ordovician beds originally found by Gilbert in 1875. Darton regarded them as an upper member of the Abrigo formation. Darton's section includes Pinal schist, Bolsa quartzite, and Abrigo, Ordovician, Martin, and Escabrosa limestones. A study by the writer of this section further reveals the presence of the Naco lime-


2 Gilbert, G. K., - op. cit.

stone as indicated by Chaetetes milleporaceous and Lophophyllum. Innumerable specimens of Composita mexicana reveal the presence of the Snyder Hill limestone. No Cretaceous beds overlie the last named formation, having been eroded off at this spot or covered by valley fill down the dip. The Paradise Formation of Upper Mississippian Age, present in the Chiricahua Mountains was not found, nor was there any evidence of Permian Manzano beds.

The basal Bolsa conglomerate in this section overlies the Pinal Schist. The latter is a dark colored, purplish, sericitic schist which grades downward into a light colored, green, sericitic schist. The schist is largely composed of fine quartz grains. It strikes N 15° E and dips 45° to the west whereas the quartzite strikes N 45° W and dips 55° S. The schist extends into the valley towards the range proper where alluvium covers it. It reportedly outcrops on the other side of the range. The basal Bolsa conglomerate was probably derived from this sandy Pinal schist. This conglomerate outcrops as an erosion pillar one half mile northwest of the highway facing Ewell Spring Valley and consists of 30 feet of dense quartzite with conglomeratic bands. These bands contain angular, dark red and white quartz pebbles reaching 1 inch across in a dark red matrix.
Three and one half miles southeast of the town the highway crosses the continuation of the Bolsa conglomerate. Here it is 25 feet in thickness and rests on a granite (?) porphyry. The quartz pebbles of the conglomerate are well rounded and become larger toward the base. At the extreme base the pebbles exceed 1 foot in diameter. That portion of the conglomerate that lies between 1\(\frac{1}{2}\) and 5 feet from the top is composed of 1 inch granite fragments exclusively, evidently derived from the underlying granite which is therefore Pre-Cambrian. This granite porphyry is deeply weathered and very similar in appearance to the Tertiary quartz monzonite porphyry. As a result the contact between these two intrusives might prove difficult to determine. The Pre-Cambrian intrusive mass extends southward and westward, possibly being a batholith and comprising the basement of much of Sulphur Spring Valley. No intrusive was observed in the Courtland-Gleeson area which does not cut the Cambrian formations.¹ There is a marked contrast, therefore, between the Bolsa conglomerate north and south of the town of Dos Cabezas. This can be understood by the presence of Pinal schist in the former area and its lack in the latter. The southern edge of the Pre-Cambrian schist in this area is near the town of Dos Cabezas.

STRATIGRAPHY

Summary

The area mapped contains Pennsylvanian (?) and Upper Cretaceous (?) sediments.

On the northeast side of the Ewell Spring Valley, Upper Cretaceous (?) quartzite makes up the first three or four ridges of the Dos Cabezas range. This may be due to great thickness but is probably the result of step faulting. Interbedded with this quartzite is an altered slate which has been termed a quartz hornfels. The hornfels and quartzite have been formed by an intrusive quartz monzonite porphyry stock, and the great east-west Twin Peaks normal fault has downthrown this altered material to the north so that less altered sandstone and slate appear. The position of this fault is occupied by a quartz erosion pillar which locally reaches 200 feet in width. Above the slate and sandstone is a limestone formation of variable thickness which is locally interbedded with quartz latite lava flows. A limestone block occurring on Gold Ridge is believed to be Pennsylvanian in age. The entire top of the range is made up of Tertiary lava flows and dikes. The older lavas have been intruded by monzonite outliers. Associated with the monzonite intrusive are basic dikes, quartz latite porphyry, quartz veins, and a few small pegmatite veins.
SEDIMENTARY ROCKS

Pennsylvanian (?)

This limestone occurs as a block on Gold Ridge, resting on slates and covered by lava flows. Along the lava contact the limestone is sandy, thin-bedded, and brown to light grayish-white in color. It weathers white or brown. In general, the top is a dark brown sandy limestone becoming purer and lighter in color farther down. About 50 feet from the top the limestone is somewhat cherty and light gray to blue when freshly broken. Chert becomes quite prominent from here to the underlying slate contact. Some of the chert is reddish, and 100 feet down there is a 1 foot seam of green shale interbedded with the limestone. Near the bottom of this formation the limestone is again sandy. Brown sandstone and gray limestone are interbedded although limestone greatly predominates. There are hard seams of limonite and some calcite seams. The slate is dark green to black near the contact. A thrust zone of about 6 feet separates the two formations so that the contact cannot be seen. The limestone formation is approximately 200 to 250 feet in thickness, but apparently is thicker farther east where it extends several miles until lost to sight over a far peak.

The beds are filled with small crinoid stems and
innumerable shell fragments all too small and fragmental to identify. A large coral *Campophyllum*?and several doubtful specimens of *Fusulina* were collected. Brachiopods were found but were not identifiable. Lausen describes in the Whetstone Mountains 1600 feet of Naco proper as "thin-bedded, dark-gray to black (often weathering white) limestone, in places with chert, partly dense and granular, interbedded with calcareous shale that weathers buff." He collected *Campophyllum torquium*.\(^1\) This limestone has been placed in the Pennsylvanian for convenience in mapping; its age is uncertain. It is not so thin-bedded as the Upper Cretaceous, is fossiliferous, and is apparently faulted over the Cretaceous.

**Upper Cretaceous (?)**

Deposited during this time were sandstone, shale, and limestone with local sedimentary breccia beds. The lower sandstones have been metamorphosed to quartzites, but the upper beds are essentially unaltered. Shales have altered to quartz hornfels and slates. Limestone is somewhat silicified but otherwise little changed.

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\(^1\) Stoyanow, A. A., op. cit., p. 522.
Quartzite

The basal beds of this series consist of perhaps 100 feet of quartzite. Its thickness is not measurable because of a well developed jointing. The beds apparently dip steeply northward under the hornfels with an average strike of N 30° W. These beds are well expressed in the south-western part of the area. Two ridges are shown, and there are two more similar ridges to the south where the quartzite finally disappears in Ewell Spring Valley. Between these quartzite ridges are hornfels areas which are softer and form the washes. These ridges are believed the result of step faulting roughly paralleling the Twin Peaks fault.

The formation is white, locally somewhat buff or reddish. Originally thin-bedded, recrystallization has obscured the bedding. Where apparently massive in some places very thin seams of black sand indicate the bedding. Sericite has been abundantly developed. Jointing planes vary, but 800 feet east of Station I they are:

- N 80° W; dip 43° S.
- N 10° E; dip about 90°.
- N 80° W; dip 43° N.

Near this same spot a 1 foot bed of hornfels was observed in the quartzite having the appearance of a dike. There seems to be no doubt but that the quartzite is the same age as the hornfels and therefore the same as the shale and sandstone above.
Underlying the limestone and in the upper slate beds are beds of quartzite having the appearance of quartz veins. Limestone beds near these lenses of quartzite are very sandy. The irregularity of the quartzite along the strike indicates that these beds are similar to the sandstone and differ only in having been cemented.

**Hornfels**

The slates near the monzonite intrusive have been altered to a dark, dense quartz-sericite rock. Near Station IV a schist has developed. These metamorphic rocks are discussed under that heading.

**Shale and Sandstone**

Away from the intrusive, the shales have developed a cleavage, and are now black slates. Interbedded with the slates are sandstone beds apparently little altered. Since the formation strikes northwest the youngest beds are in the eastern part of the area. The lower and extreme upper parts of this formation are predominantly slate, but sandstone predominates in the central portion.

A thin section of the sandstone from near the quartz "dike" south of the Gold Ridge mine proved to be arkosic with the following composition:
Quartz - 45% (grain size between .10 and .15 mm.)
Plagioclase - (Andesine Ab\textsubscript{63} An\textsubscript{37}) - 1%
Muscovite - 1%
Magnetite - 2%
Sphene - 1%
Sericite, limonite (groundmass)

Only 1% of the plagioclase is fresh, the rest being altered to sericite which forms a considerable portion of the groundmass. Only about 2% of magnetite remains, the rest having been oxidized to limonite. The rock is grayish brown in color. The sandstone is fine grained and massive. Where well expressed the beds are separated by thin seams of slate. A section from Station V to the quartz "dike" is made up of 550 feet of sandstone and 215 feet of slate interbedded. Gradational shaly sandstone and sandy shale are present usually slaty and thin-bedded. Many grains of quartz and feldspar have been rounded, but this may be indicative of metamorphism. The freshness of 1% of the plagioclase indicates that the sandstone has been transported probably only a short distance from its source. More massive beds indicate a rapid accumulation. The source may have been the Pre-Cambrian granite (?) to the south. Although no fossils were found in the Upper Cretaceous series, some possible plant remains were seen in the arkosic sandstone, which in general, seem more likely to be fossiliferous than the slate.

The slates are thin-bedded, fine grained, and predominantly black or dark gray (although more rarely
green, brown, and even maroon). They have developed a slaty cleavage, although some beds, especially in the lower middle part of the series, are papery, and the cleavage is not clearly indicated. Much of the slate parts along its bedding as easily as across it on cleavage planes, but some near the intrusive is more altered and the bedding obscured or indicated by slight color differences on weathered surfaces. The black slate series is best shown along the road north of the quartz "dike". There is little sandstone here and the shales are black on both weathered and fresh surfaces. A maroon slate bed a few feet thick was observed in only one place in the lower, western section above the limestone. Brown slate is fairly common, but blue and black slate predominate. The series above the limestone is mainly composed of sandy limestone interbedded with limy, dark slate. In the mining area, hydrothermal alteration of the slate has formed a graphitic wall rock and pieces of slate in the quartz veins are largely graphitic. These slate inclusions are the result of quartz replacing the slate. The slates have been sheared, locally folded, and in general have been more favorable to hydrothermal alteration than have the massive sandstones.

The entire sandstone - slate series has been criss-crossed by quartz stringers and veins. The series has
an average strike of N 65° W and dips 65° northeast.

Several beds of sedimentary breccia in this series were observed in Juniper Canyon and about 250 feet south of the Gold Ridge lower adit along the wash. The latter was 25 feet thick; the former somewhat less. They reappear on the road just south of the latite dike but were not mapped separately because of their irregularity and difficulty in tracing individual beds in the series. Besides the above mentioned beds, several thin breccias are interbedded with the sandstone and slate. The breccia consists of flat, angular, unsorted arkosic sandstone and flinty, arenaceous slate pebbles. The sandstone pebbles are large, many over 1 inch long, and numerous. The breccia is well cemented by a fine sandy shale material so that it breaks across, as well as along, the pebbles. Its color is a mixture of gray and brown with some black areas. Although unsorted in some beds, in others the pebbles are roughly aligned.

Limestone
The limestone begins just west of the road and extends west beyond the edge of the map. Followed along the strike it becomes much thicker reaching some 250 feet in thickness. It dips uniformly north from 50° to 70°, averaging 65°. On the first ridge west of the road the
limestone is 6 feet thick and apparently unconformable with both the underlying slate and overlying latite. Here it is thin-bedded, and dark blue and gray in color, weathering light gray. It is cherty as is the whole formation; the chert occurring in thin bands up to an inch in thickness. 900 feet westward the lower 5 feet of the limestone (here 35 feet thick) is interbedded with papery, sandy shale. The greatly disturbed shale below is intruded by quartz stringers which do not extend into the limestone. Southwest of Station III the lower 60 feet of the limestone (here 90 feet thick) is brown and very sandy. It no longer rests on shale but is now on light-colored latite. The extreme western 1000 feet of the mapped limestone has a base consisting of brown sandy limestone between beds of quartzite. Above the quartzite is 200 to 250 feet of gray to blue limestone, thin-bedded, cherty and unfossiliferous. The top members become lighter in color going westward, being light gray and even pure white. Chert makes up about one fifth of the limestone. Locally, the lower part of this formation is silicified. There seems to be no doubt that this limestone is an upper member of the sandstone - slate series as evidenced by the local interbedding of sandy shale with the basal and upper portions of the limestone, and an interbedding of quartzite and limestone in one section.
Of particular interest are the small areas of limestone isolated in the lava flows. These areas are lenses in the flows being elongated along the strike. In the opinion of geologists who have studied these areas, as expressed in mining reports, the lava has stoped blocks of limestone. These blocks, however, are not altered greatly but appear similar to the main Upper Cretaceous limestone formation. They have been mapped in certain sections only, so are probably more widespread than shown. They lie along the flow bedding, but since these beds cannot be easily separated it cannot be said for a certainty whether they are interbedded limestones and flows or inclusions. That they represent interflow deposition and erosion seems the most likely explanation since otherwise their borders would be altered by the heat of the lavas.

This entire series has been considered Upper Cretaceous by the writer for two reasons. First, the lava flows of western Arizona are considered late Cretaceous and Tertiary, and the upper members of the series are later than the earlier lava beds since they are stratigraphically above them. Secondly, there is a similarity between these beds and those of the Clifton area. There the Pinkard Formation is referred to the Colorado group, which belongs in the upper part of the
Cretaceous. According to Lindgren\(^1\) there are "500 feet of alternating black shale and yellow or brown sandstone" in the Clifton area. "The shale and fine-grained sandstone are very much hardened, becoming in places even flinty and black or dark-green". The description closely parallels that of this series, whereas any correlation with the Bisbee Lower Cretaceous is impractical. However, the total thickness here is much greater than that at Clifton and may even approach that of Bisbee. If the lower part of the series is considered to be step-faulted, but without considering other possible repetitions, this series approaches 3000 feet.

Upper Cretaceous - Tertiary (?) extrusives

Lying unconformably on the Upper Cretaceous series are thick beds of quartz latite lava flows. These flows make up the top of the Dos Cabezas range and are probably many thousands of feet in thickness. They are slabby and their bedding obscured, but the flows have approximately the same dip and strike as the underlying formations. Although dark purple lavas predominate, some beds also grade from a light to a dark brown in color. Their color is due to a large iron content. Two thin sections studied were very similar except that one had minute

quartz veins running through it at an angle to the flow structure (.06 millimeter average width). They had the following approximate composition:

- Plagioclase - (Andesine $Ab_{62} Au_{38}$)
- Orthoclase
- Magnetite - 10%
- Hornblende - 1%
- Chlorite - 1%
- Calcite - 10%
- Quartz - over 10%
- Sericite

Several large plagioclase laths largely altered to sericite and calcite, but showing twinning are present. Orthoclase occurs as simple twins and untwinned small enhedral grains. Orthoclase appears to predominate over the plagioclase, but no definite ration can be determined because of alteration and fineness of the groundmass. The hornblende has largely altered to magnetite, but was once present in much greater amounts. Much feldspar has altered to sericite. Chlorite is probably derived from biotite. Calcite has been introduced. These flows have been termed quartz latites, but may locally be rhyolitic. The purple lavas might be separated from the brown flows, but they are locally interbedded so it would prove difficult.
The main intrusive rock in the area is a quartz monzonite porphyry mass which lies to the south of the area and extends south and east. It evidently represents an upward extension or cupola of a granitic stock. Associated with this mass are quartz veins and rhyolite porphyry, diabase, and pegmatite dikes.

Quartz Monzonite Porphyry

The quartz monzonite porphyry is a dark gray, deeply weathered intrusive. Megascopically, it has numerous large feldspar phenocrysts two inches long and one inch wide. Smaller phenocrysts average 2/3 by 1/4 inch, and some appear kaolinized. These phenocrysts weather to a white color in a dark green or brown groundmass showing sericite. Opaque quartz grains 1/16 by 1/2 inch are scattered throughout the rock. Many residual porphyry boulders show from 10 to 20 per cent epidote. This light green epidote also occurs as stringers up to 2 inches in width in the monzonite.

Microscopically, a section of the porphyry taken 300 feet within the Dives adit has the following composition:
Essential Accessory Alteration

Andesine (Ab$_{67}$Au$_{33}$) - 35% Apatite, sphene Magnetite - 4%
Microperthite - 20% and zircon - 2% Chlorite - 6%
(Microcline - 7%)
Quartz - 23%

The thin section shows the rock to be porphyritic with andesine crystals up to 10 millimeters long. The larger andesine phenocrysts are extensively altered to sericite, but the twinning can still be seen, and some small phenocrysts are nearly fresh. Microcline and microperthite are essentially free from alteration, the larger laths averaging 6 millimeters by 3 millimeters. Microcline also occurs in a perthitic intergrowth with albite. Quartz is present as small interlocking grains averaging 0.2 millimeters in diameter.

Magnetite, chlorite, and epidote make up the groundmass, and are alteration products of biotite and perhaps of hornblende. The magnetite is earlier than chlorite or epidote. The groundmass is phanerocrystalline. Although slightly darker in color, this porphyry is very similar in appearance to the Texas Canyon granite of the Little Dragoon mountains.\(^1\) It is probably equivalent to the granite of Post-Lower Cretaceous age in the Courtland-Gleseson region.\(^2\) It is deeply weathered, producing a

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2 Wilson, E. D., op. cit.
thin covering of gravelly rubble. Fresh specimens are difficult to obtain on the surface.

In the extreme northeast corner of the map an intrusive occurs with associated basic dikes. This intrusive mass is very similar to the quartz monzonite porphyry and is evidently a small pipe or stock from this mass. A thin section shows the following:

<table>
<thead>
<tr>
<th>Essential Varietal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plagioclase (Andesine Ab$<em>{66}$An$</em>{34}$) 57%</td>
</tr>
<tr>
<td>Muscovite 1%</td>
</tr>
<tr>
<td>Orthoclase</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Accessory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnetite 1%</td>
</tr>
<tr>
<td>Sphene and apatite 1%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Alteration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaolin (mainly)</td>
</tr>
<tr>
<td>Sericite (a little)</td>
</tr>
</tbody>
</table>

Because of alteration the ratio between the alkaline feldspar and total feldspar could not be accurately determined, but they appear to be present in about equal amounts. The large amount of epidote is not surprising since, as was mentioned before, it is widely distributed in the intrusive area.

This intrusive is believed to be uncovered by erosion rather than intruded into the lavas. However, basic dikes extend from the monzonite into the flows.
It, or a more granitic mass, probably constitutes the core of the Dos Cabezas range.

Basic Dikes

These dikes are older than the quartz veins in the Philadelphia mining area and were apparently the first dikes to form after the solidification of the outer borders of the intrusive mass. Although present in the latite flows, they occur mainly in the intrusive itself. These dikes have smooth contacts with the intrusive, vary from a few inches to 30 feet in thickness, and dip steeply. Deeply weathered, fresh samples were not obtainable. A thin section was composed mainly of chlorite, limonite, and kaolin with a little epidote, magnetite, and perhaps 5% quartz. Limonite is derived from the magnetite and chlorite, which gives the rock a green color. These alteration products are from former ferro-magnesium minerals. The dikes may be diorite dikes or diabases.

Quartz Latite Porphyry

Quartz latite porphyries occur exclusively in the slate-sandstone series with the exception of one in the latite flows. This latter example is believed to be a light-colored sill in the darker flows since it seems to be paralleling the strike of the lavas. These intrusives
are white with brown spots and stains. Highly weathered they appear to be largely kaolin with a high iron content. A relatively fresh thin section indicated the following composition:

<table>
<thead>
<tr>
<th>Essential</th>
<th>Alteration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plagioclase (Andesine Ab_{64}An_{36}) - 25%</td>
<td>Kaolin 1%</td>
</tr>
<tr>
<td>Sanadine - 20%</td>
<td>Magnetite</td>
</tr>
<tr>
<td>Quartz - 22%</td>
<td>largely altered</td>
</tr>
<tr>
<td>Calcite - 30%</td>
<td>to Limonite - 2%</td>
</tr>
</tbody>
</table>

Rounded anhedral quartz and sanadine grains up to 3 millimeters in diameter and subhedral plagioclase crystals occur as phenocrysts in an aphanitic groundmass. The plagioclase crystals which average 1.0 x 0.5 millimeters are folded and sheared with a very evident flow structure. The phenocrysts are rounded by corrosion and the quartz which averages 0.3 x 0.3 millimeters has recrystallized into aggregates of grains of diverse size and irregular boundaries. Calcite is present throughout the section, but is especially abundant as partial replacements of feldspar.

Quartz veins

These veins are widely distributed, occurring in all the rocks in the area. The age relation between the quartz veins and quartz latite dikes is
not clear, although in Juniper Canyon a quartz vein cuts the latite mass. The veins are continuous along both dip and strike, but are lenticular and highly variable in size. They have entered along shear zones and replaced the wall rocks. The veins are characteristically coarse grained, drusy, and are accompanied by much stringer quartz. The outstanding vein in this area is the quartz "dike", so-called to distinguish it from the other veins, for it is truly a vein itself. This "dike" varies from a thickness of 200 feet to a thin stringer, but is continuous and traceable for several miles to the east. It is white, coarse quartz locally iron stained and drusy. Many smaller veins of economic importance are associated with it and are discussed in the section on ore deposits.

Pegmatite Veins

Pegmatite veins were observed only in Dives Canyon in hornfels just south of the quartz "dike". These veins are located along east-west fault planes and are about 2 inches wide. Muscovite and black tourmaline are imbedded in a granitic matrix,
The monzonite has metamorphosed the Cretaceous series along the contact, and the basal quartzites have been completely recrystallized into a dense, white quartz rock, obliterating the bedding almost entirely.

Along the intrusive, arkose - slate boundary a quartz hornfels has been formed. The hornfels stands out in typical erosion pillar form having a width of approximately 75 feet where it crosses the road. Irregularly jointed, a fresh surface of this rock is greenish-black with a somewhat glassy appearance, suggesting a chloritic quartz composition. It appears to be evenly-grained and shows no signs of bedding or schistosity, which criteria indicates the absence of stress. The definition of a hornfels as given by Grout is:

"Hornfels is broadly used for dense sugary-grained rocks, no matter what the original may have been, recrystallized by contact action about as thoroughly as a schist, but under such uniform pressures as not to show much schistosity even if it once had a schistose structure. - - It includes a host of mineralogic varieties, most of them named by prefixing to the term hornfels the minerals considered essential."

The contact rock thus fits the above definition and there remains only the determination of the essential mineral or minerals. Three thin sections were made of the hornfels; two from the central portion, and one from the immediate contact. The former two sections were similar except in the ratio of quartz to sericite-chlorite groundmass. They have the following approximate compositions:

<table>
<thead>
<tr>
<th>Number 1</th>
<th>Number 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Essential: Quartz</td>
<td>Essential: Quartz</td>
</tr>
<tr>
<td>- 42%</td>
<td>- 70%</td>
</tr>
<tr>
<td>Groundmass</td>
<td>- 55%</td>
</tr>
<tr>
<td>Accessory:</td>
<td>Accessory:</td>
</tr>
<tr>
<td>Leucoxene</td>
<td>- 2%</td>
</tr>
<tr>
<td>Zircon</td>
<td>- 1%</td>
</tr>
<tr>
<td>Accessory:</td>
<td>Accessory:</td>
</tr>
<tr>
<td>Leucoxene</td>
<td>- 2%</td>
</tr>
<tr>
<td>Zircon</td>
<td>- 1%</td>
</tr>
</tbody>
</table>

The quartz occurs as rounded grains showing growth and replacement of the groundmass. Grains are of uniform size suggesting a sugary appearance and have an average size of .23 millimeters in diameter. The zircon occurs poikilitically in the quartz. The groundmass is extremely fine grained not exceeding .005 millimeter and has a shredded appearance. It is apparently made up of sericite and chlorite with the sericite predominating. Sericite is derived from the feldspar of the arkosic sandstone as is most of the quartz. The chlorite and leucoxene probably owe their presence to the shaly members of the arkose. Leucoxene is a weathering residual of probably rutile, commonly present in metamorphosed shale and occurring especially in aluminous
rocks. The amount of this mineral is notable. Number 1 is roughly banded having almost quartz-free bands. Shale evidently predominates in the quartz-free bands.

The hornfels would be best described by the name chlorite-quartz hornfels, but this unwieldy term has been shortened here to quartz hornfels.

An exact counterpart of this hornfels is described by James at Britannia Beach, British Columbia. Black Jurassic shales are in contact with a quartz diorite intrusion. James says:

"The shales, within a foot of the contact and for at least 50 feet from it, are recrystallized to a very fine-grained, quartz-sericite rock containing numerous grains of magnetite, and flocculent aggregates of leucoxene."

The third thin section is from a contact rock at the edge of the monzonite and is of interest because it represents a quartz-free oligoclase hornfels. This rock has phenocrysts up to 3 millimeters long of oligoclase which have been somewhat altered to epidote. The matrix has a dark green color, and the phenocrysts where altered are light green, where unaltered are white. Composition of this mineral is as follows:

---

1 James, H. T., - Britannia Beach Map-Area, B.C. Canadian Geol. Survey, Memoir 158, 1929.
Essential: Plagioclase (Oligoclase) - 79%
Epidote - 10%
Hornblende - 7%

Accessory: Leucoxene - 2%
Magnetite - 1%
Quartz - 1%

This hornfels has had notable additions of plagioclase, and probably hornblende, from the monzonite. The absence of quartz in a siliceous environment could be accounted for by filter pressing. That is, residual quartz was squeezed into the country rock just before complete solidification of the magma margin leaving the immediate margin quartz-free. This type of hornfels seems to be confined to the contact near Station IV. Also present in this vicinity is a small area of tremolite, the rock being made up of radial clusters of tremolite fibers.

In the vicinity of Station VIII the contact is characterized by a schistose chert which outcrops conspicuously in places but nowhere so strongly as the hornfels. The rock weathers from a medium to a very light gray color and is medium gray on fresh surfaces. It is a very fine grained slaty rock showing schistosity. The presence of a schistose structure is indicative of stress. In thin section this chert is composed of quartz phenocrysts up to .15 millimeter in length and a fine quartz matrix exhibiting a schistose banding. A little leucoxene, magnetite, sericite, and apatite are present, indicating a relationship between the hornfels and chert.
originals. Sandstone and slate were the original rock with more or less additions from the intrusive.

The Cretaceous quartzite south of the quartz "dike" has been almost everywhere thoroughly recrystallized. Thin bands of darker or lighter material in places indicate the bedding, but block jointing always obscures determination of the strike and dip. This quartzite described under "Sedimentary Rocks" is apparently interbedded with the quartz hornfels. It is notable that strong metamorphism has not extended north of the quartz "dike" although the monzonite reaches the "dike". A normal fault along this zone would account for hornfels on the upthrow side, and slate on the downthrow side.

North of the quartz "dike" the shales have been metamorphosed into bedded slates in most places, but the arkose beds have only locally been altered to quartzite. Slaty cleavage has developed and averages 70° to the bedding which is always present. Some shale is papery, and some shows little or no cleavage, probably being argillaceous.

The limestone is perhaps locally somewhat altered, but it and the lava flows are essentially free from metamorphism.

Metamorphism has occurred in the epi-zone which is
characterized by the formation of sericite, talc, chlorite, and epidote. An absence of more complex contact silicates and gneisses is also criteria of epi-zone conditions.
STRUCTURAL GEOLOGY

The Pre-Cambrian structure is not exposed in the area. All existent structure is believed to be of Laramide age, which revolution occurred at the close of the Mesozoic era.

The structures in this area are, in order of occurrence: folding and thrusting, doming, and steep normal faulting.

Folding and Thrusting

The rocks in the area strike from east to north-west, and dip from north to northeast. Gilbert\(^1\) writes that twelve miles eastward near Camp Bowie the sediments dip gently to the south, but northward the dip increases until it is more than 90° in the Ewell Spring area. There has been no obvious overturning of the sediments here with the possible exception of the Upper-Cretaceous(?) series. This series has been locally folded as is exhibited by the slate, but there is no sign of great regional folding. It is possible that they have been closely folded and slightly overturned, but this type of extreme folding is not common in southern Arizona. Thrusting occurred before folding and probably introduced the Laramide revolution. Pennsylvanian (?) limestone was thrust over the Upper-Cretaceous (?) by a force from the south or southwest.

\(^1\) Gilbert, G. K., op. cit. p. 513
Only one area of this thrustted limestone remains.

Doming

Following the above mentioned compressive forces, lavas were extruded and later the monzonite was intruded. The intrusion domed the sediments imparting to them their present dip.

Normal Faulting

The east-west faults were the earlier set and are exemplified by the Twin Peaks fault. This fault is downthrown on the north and may represent a settling due to gravity after the extrusion of lavas. Accompanying this major fault were smaller, parallel faults which assumed the form of a shear zone. In the eastern area less steeply dipping bedding-plane faults formed.

Later, north-south rotational (?) faulting took place. The one obvious fault of this type is the Dives fault. The eastern side of the Dives has been downthrown, and the Twin Peaks fault displaced. Since there is a fractured zone many feet across in the limestone and yet no evidence of displacement, it seems likely that the fault was hinged in this formation and did not extend into the later lavas.

Mascot Gulch appears to be a north-south structural axis, not because of any apparent offsets, but because of opposing structure on either side, especially noticeable in the monzonite. On the western side of the
gulch dikes have filled east-west fissures, while on the east, dike and veins fill north-south fissures. The east-west dikes near the Dives Mine do not cross the gulch.

A possible explanation for this is that the south side of the Twin Peaks fault has been upthrust, more on the west side of Mascot gulch than on the east. Both systems would be tension openings. On the other hand they may merely represent cracks formed in the monzonite margin as it cooled.

All these fissures and shear zones represent areas of weakness, that were in part occupied by dikes and veins, representing the last stage of intrusion.
Although not present in this area, a complete Paleozoic series was deposited in the Dos Cabezas area ending with the Permian Snyder Hill formation. No known Mesozoic sedimentation occurred until Upper Cretaceous (?) time.

The first observed sediments to be deposited in Upper Cretaceous (?) time were great thicknesses of sandstone and sandy shale, later metamorphosed to quartzite and quartz hornfels. The probability of step faulting makes it difficult to estimate the thickness, but, in all, at least 3000 feet must have been deposited in Upper Cretaceous (?) time. The latest sediments were less altered and represent a sandstone-slate horizon.

The Upper Cretaceous was characterized by receding seas, hence marine deposition changed to fresh water sedimentation. At Patagonia, Stoyanow\(^1\) has named and correlated 4000 feet of shales and limestones as the Molly Gibson of upper Lower Cretaceous time. The Molly Gibson represents the end of the marine in southeastern Arizona. Fresh water sandstone, arkose, and conglomerate sediments rest on lava flows at Patagonia and have been named the Fort Buchanan and Fort Crittenden formation, and they are apparently similar in position to the Upper Cretaceous.

Cretaceous (?) limestone at Dos Cabezas. Whether the sandstone-slate series is equivalent to the Molly Gibson or to these later formations cannot be known at the present time.

There is a surface of unconformity between the sandstone-slate series and the limestone. During this period of non-sedimentation lava flows covered the sandstone-slate series. Where these flows were later locally eroded off, the fresh-water, thin-bedded limestone was deposited on the sandstone-slate contact. In other places the limestone rests on lava. Isolated beds of limestone between lava flows are probably the result of deposition of sediments and lava flows.

Intrusion of the monzonite stock followed the earlier lava flows and terminated the deposition of the limestone. The Upper Cretaceous (?) beds were then tilted to the north, and faulting occurred in east-west and north-south directions.

Dikes and veins were intruded along fissures caused by faulting. Basic dikes filled fissures in the monzonite, slate, and lavas. Quartz latite dikes do not occur in the lava and may be the earliest dikes to have been intruded. Since their composition is the same as the
monzonite, they may be closely connected in age with the stock intrusion. Quartz veins were, with the pegmatites, the last intrusive action to have taken place.

A quartz latite sill is present in the later lavas.
Types of ore deposits.

The ores of the district are lode deposits in steeply dipping fissure and replacement veins along shear zones in Cretaceous sandstone and slate near a quartz monzonite porphyry.

There are four types of occurrences:

1. Veins roughly paralleling the quartz "dike"\(^1\) on the north and dipping towards it at a steep angle. (Dives Mine).

2. In the quartz "dike" where it is narrow and has split up along the strike. (Gold Ridge Mine).

3. As north-south trending veins in the monzonite. (Philadelphia Mine. This mine is but briefly described).

4. "As quartz veins striking with the basic dikes north of the quartz 'dike'"\(^2\) (Gold Prince Mine. This mine is immediately east of the Gold Ridge Group and not discussed herein.)

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1 The "dike" is a "true fissure vein", but the word "dike" is used for convenience in referring to the wide, main quartz vein.

Mines in the area.

Dives Mine.

The history of the Dives Mine is as follows:  

1877 - Located as the Bear Cave Claim.
1880's - Ore treated in a stamp mill at Dos Cabezas.
1911-14 - Yielded more than $20,000 worth of gold.
1919 - Acquired by the Dives Mining Company.  
10-ton stamp amalgamation-concentration mill erected and operated actively for a few years.
1920 - Total production estimated at $40,000 in gold from 5,000 tons of ore.
1922 - Twin Peaks Mining Company took over property. Little or no production.
1931 - Lessees took $5,000 (?) worth of ore from old workings.
1932 - Property acquired by Consolidated Gold Mines Company, Limited.
Drove lower adit workings (500-foot level).
1934 - 50-ton flotation mill completed in May. 31 men employed.

1935 - Mining continued. Concentrates shipped to El Paso smelter.

1936-7 - Mostly idle.

1938 - $7000 believed produced. Work ceased in November.

1939 - In May property leased to Mines Developing and Operating Company of Newark, N. J., for 25 years. C. B. McIntire in charge at mine.

1940 - Mine and mill put in order for contemplated mining. Production from 1932 to 1938 has been approximately $48,500.

The total production of the Dives property from 1877 is believed to be about $93,500.

The block diagram of the Dives workings, Plate No. 3, shows the position of the veins and ore shoots. Not shown is the 503 West Drift which is 150 feet north of the 501 drift on the main adit. The 503 West Drift extends approximately 300 feet west on the No. 3 vein, and connects by a winze with the 600-foot level. From this drift the main adit has been driven 600 feet further north, intersecting the No. 4, No. 5, and No. 6 veins. Diamond drilling in the face has indicated the presence of limestone and rhyolite to the north. The water supply comes
from 5 holes in the limestone. Excluding stopes, approximately 7800 feet of adit, drifts, winzes, and raises have been completed on the 300, 500, and 600-foot levels. A 400-foot level is contemplated as well as workings below the 500-foot level. The No. 9 orebody has been stoped up for a distance of 114 feet.

At the present time the 600-foot level is flooded and inaccessible. Rotten timbers are giving off gas which can be detected on the 500-foot level. Just north of the No. 3 vein the main adit has caved and water backed up, so that this part of the mine was also inaccessible. This mine water comes from the limestone bed to the north which holds much water behind the less permeable slate and sandstone beds. The 500-foot level is developing 16000 gallons of water per day which will prove inadequate for the mill if run at capacity.

Two veins have been mined and partly developed. The No. 1 vein is 100 feet north of the quartz "dike" on the 500-foot level in the adit, and the No. 3 vein about 250 feet north of the "dike". Since the hanging wall of the "dike" is indistinct, however, this is only approximate. The veins and "dike" diverge towards the surface. Both veins appear to join the "dike" to the east; they are difficult to trace westward.
Since both veins dip approximately 70° to the south, and the quartz "dike" dips steeply north, they probably join the "dike" at depth. Continuing at the same dips from the 500-foot level, the No. 1 vein would intersect the "dike" at a depth of about 700 feet. It is evident that mining to greater depths on the No. 1 and No. 3 veins would eventually extend into the monzonite, downthrown on the north side of the quartz "dike". Because of the magnitude and character of the major fault zone, a displacement of 1000 feet or more seems likely, and the cutting of the monzonite above the 900-foot level unlikely. A narrowing of the vein and decrease in values may occur in the monzonite. The cross-section C-D in Plate No. 2 shows these relationships.

The country rock north of the quartz ledge is composed of the Cretaceous sandstone and slate series. The sandstone is very massive and resistant to deformation so that all the faulting is confined to the slate members. The slate has been greatly compressed, developing carbonaceous gouge and slickensides. It appears locally to have been susceptible to silicification and replacement whereas the vein developed a "book structure". The formation of graphite, especially on the footwall where pressure has been greatest, is notable almost throughout the workings. This highly carbonaceous slate
is commonly folded and compressed between the vein and a sandstone wall.

Wall rock alteration consists in the development of graphite, and, less often, a white or reddish clay gouge. More prominent alteration occurs south of the quartz "dike" near the monzonite intrusive. A section through the adit beginning at its entrance is as follows:

0 - 450 feet - Quartz monzonite porphyry.
450 - 685 feet - "Contact rock". A green, fine-grained somewhat talcose rock. Apparently a talc-chlorite schist.
685 - 735 feet - Very talcose chlorite schist. Adit is timbered here where back caved. Soft ground.
735 - 785 feet - Sandstone and schist.
785 - 975 feet - Quartz "dike" with schist locally.
975 - 1083 feet - Massive sandstone and slate interbedded. Alteration of slate no longer intense.

Paragenesis of the Dives orebodies.

The order of mineralization has been determined as follows:
1. Calcite, siderite
2. Quartz
3. Pyrite
4. Sphalerite
5. Chalcopyrite, galena, gold (?)
6. Quartz, gold (?)
7. Gold (?)
8. Cerussite, covellite, azurite, malachite

No calcite or siderite was observed in polished sections of the ore, but samples from the dump showed barren carbonates partly replaced by quartz. The carbonates occur as veins and stringers in the country rock. Siderite predominates over calcite in this mine. The presence of considerable iron in sphalerite was shown by microchemical tests. The first stage of quartz is represented by the main quartz "dike" and parallel veins. Where this early, barren quartz was fractured, sulphide deposition took place, followed by late quartz which replaces all the sulphides. No gold was observed but its late character is held by some writers.¹ Galena is quite extensively altered to cerussite. Covellite is sparingly present as veinlets in and along edges of the chalcopyrite. Downward circulating solutions have deposited malachite on the 300-foot and 500-foot levels. Azurite was observed as a coating on the vein outcrops.

¹ Mawdsley, J. B., - Econ. Geol. March - April, 1938, p. 194.
In general the outcrop of the main quartz "dike" has been little altered by oxidation because of its lack of sulphides. A little limonite stain and solution cavities indicate the former presence of some sulphides. The parallel veins to the north show more signs of a former sulphide content. Oxidized copper stain and boxwork structure indicate the presence of copper sulphides as well as pyrite. Gold has been enriched at the surface and has become free-milling. Absence of manganic oxide has prevented the solution of the gold. No placers are associated with these veins although nuggets have been found south of Dos Cabezas, and colors may be obtained by panning almost anywhere in the washes. The presence of cerussite associated with sphalerite as deep as the 500-foot level is unusual because zinc is ordinarily more readily oxidized than lead. Lower levels may have anglesite and little cerussite, but the sphalerite appears unaltered above. Carbonate ores are to be expected in the presence of calcite and siderite. Oxidation probably has not extended below the 600-foot level since the water table is normally present at that depth as evidenced by the rapid flooding of the level when pumping is stopped. Enrichment has not been important except a negative enrichment at the surface which has concentrated the gold and made it free-milling. The sparsity of
sulphides throughout the quartz veins discourages any thought of enriched copper, lead, and zinc deposits at depth in any of the mines.

The quartz of the main dike is commonly coarse and massive. It is milky-white, and much of it often exhibits drusy cavities containing crystals, and locally stained brown or red by iron. The walls of the quartz "dike" have sharply defined boundaries indicating fissure filling, and there is evidence of post-mineral faulting in a north-south direction. Numerous quartz veinlets have extended northward into the Cretaceous series perpendicular to the quartz "dike" and occasionally along the bedding planes of the sediments. East of the road these perpendicular offsets seem to extend southward from the "dike" rather than northward, are wider, and less numerous.

The No. 1 and No. 3 veins are made up predominately of quartz which is more glassy in appearance and more fractured than the quartz of the "dike". In places the quartz is brecciated by later faulting. East of the Emma fault, the Emma ore shoot is fractured by faulting in a N 10° W direction with a dip of 86° W. This minor cross-fracturing gives the quartz an appearance of jointing. This movement is probably connected with the Emma fault, and its strike varies from north-south to N 25° W.
Cross-fracturing is present in other parts of the mine but is less obvious. This shattering of the brittle quartz appears later than the sulphide introduction, but may be earlier and thus account for the presence of ore shoots.

The No. 1 and No. 3 veins pinch and swell in the slate along both dip and strike, and vary in width from a few inches to ten or even twenty feet. An example is a two or three foot vein with gouge on both walls that breaks up along the strike into a book structure with frozen walls. Fissure filling is found in zones of intense shear and replacement in less open places. Commonly the vein of quartz contains stringers of the wall rock. Distinct banding was not observed. Whether filling or replacement predominated could not be determined.

The quartz "dike" in the vicinity of the Dives Mine contains very little gold. It has been reported to carry up to .10 ounces per ton, but this is exceptional. Lindgren writes, "it is rather unusual to find large structural faults, normal or overthrust, which have been

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1 "In quartz veins in fissile rocks a peculiar 'book structure' may result from numerous parallel sheets of slate, alternating with quartz."

2 "Arizona Lode Gold Mines & Gold Mining", op. cit.

extensively mineralized. Shear and sheeted zones often result in veins or lodes." This statement appears to apply in the area.

In the two workable veins the sulphides are but sparingly present. Although in the Emma ore shoot galena locally makes up as much as 20 per cent of the ore, the average content of sulphides is only one or two per cent. Galena, sphalerite, and pyrite are the chief sulphides. Chalcopyrite is usually present. Gold occurs, it is believed, as sub-microscopic intergrowths in galena and pyrite. As has been stated, the gold is free-milling at the surface. Galena and massive pyrite are indications of good ore. Pyrite occurs as a thin film on graphite slickensides, but whether this is ore is not known. Mineralization has not extended into the country rock although pyrite cubes are present in places.

As previously mentioned, the ore occurs in lodes shown on the block diagram of the mine workings. The Dives ore-shoot has been stoped from the surface to the 300-foot level and lies to the west. The Emma ore-shoot is encountered on the surface (?) and on the 500-foot level east of the Emma fault. Another probable ore-shoot lies between these two on the 500-foot and 600-foot levels. This ore-shoot is blind and does not extend to the 300-foot level. Mr. McIntire believes that the Emma ore-shoot is
in reality part of the main quartz "dike". This appears likely from its position, but this interpretation is opposed by the character of the quartz and amount of mineralization. As indicated, the Emma fault is believed to have shifted this orebody from the north rather than from the south.

According to Tenney,¹ a general average of all stoping and development faces in the shoots yields between $8 and $12 a ton in gold and silver, with variations between $1 and $100 a ton. The ratio of silver to gold is reportedly about equal in ounces per ton, but varies considerably.

The composition of four smelter concentrate shipments picked at random are shown below.

Deductions were made for insoluble, zinc, sulphur, and in one case bismuth. The insoluble represents slate and graphite. The occurrence of bismuth is interesting, but evidently of no importance. The one available 1938 report is the only one to mention bismuth.

<table>
<thead>
<tr>
<th>DATE</th>
<th>8/26/38</th>
<th>1/15/35</th>
<th>1/30/35</th>
<th>8/8/35</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wt. in Dry Tons</td>
<td>15.75</td>
<td>9.50</td>
<td>6.19</td>
<td></td>
</tr>
<tr>
<td>Gold oz. per ton</td>
<td>1.16</td>
<td>11.516</td>
<td>22.87</td>
<td>2.89</td>
</tr>
<tr>
<td>Silver &quot;</td>
<td>7.8</td>
<td>10.7</td>
<td>15.1</td>
<td>11.1</td>
</tr>
<tr>
<td>Lead per cent</td>
<td>8.8</td>
<td>7.8</td>
<td>8.7</td>
<td>10.7</td>
</tr>
<tr>
<td>Copper &quot;</td>
<td>1.37</td>
<td>0.66</td>
<td>-</td>
<td>1.82</td>
</tr>
<tr>
<td>Insoluble</td>
<td>53.4</td>
<td>44.8</td>
<td>58.8</td>
<td>39.0</td>
</tr>
<tr>
<td>Silica</td>
<td>40.0</td>
<td>-</td>
<td>-</td>
<td>14.4</td>
</tr>
<tr>
<td>Iron</td>
<td>9.9</td>
<td>17.2</td>
<td>12.8</td>
<td>-</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lime</td>
<td>0.2</td>
<td>-</td>
<td>-</td>
<td>7.0</td>
</tr>
<tr>
<td>Zinc</td>
<td>5.5</td>
<td>3.5</td>
<td>2.8</td>
<td>12.2</td>
</tr>
<tr>
<td>Sulphur</td>
<td>10.2</td>
<td>15.5</td>
<td>11.0</td>
<td>7.1</td>
</tr>
<tr>
<td>Aluminum</td>
<td>6.9</td>
<td>5.5</td>
<td>5.9</td>
<td>-</td>
</tr>
<tr>
<td>Bismuth</td>
<td>0.01</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Value per ton before $47.71 $390.09 $765.74 $101.15
deductions

Mining and milling costs have been about $7 per ton of ore.

Photographs of the Dives Mine are shown on Plate No. 6.

Gold Ridge Mine.

The history of the Gold Ridge Mine is summarized as follows:

1878 - Located as the Juniper Mine.

1881 - Produced $6,000 in gold and silver prior to 1881.

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1881-82 - 100 tons of ore containing $45 in gold per ton was treated in the Dos Cabezas Mill.

1890's - Casey brothers worked mine in a small way.

1915-17 - Small production.

1917 - Dos Cabezas Gold Ridge Mining Corporation organized. Mr. Welty in charge.

Development work.

1922 - Mr. Huntsman, president of company, obtained property as highest bidder.

1933-34 - C. D. Kirby shipped 600 tons of ore to El Paso.

1935 - Alice Huntsman and Berry & Smith as lessees shipped 270 tons to El Paso and Douglas smelters.

July 1933 to January 1936, 1009 dry tons gave a total value of $21,187; gold at $35.00. Average value $21.

1940 - Gold Ridge Group owned by Alice Huntsman of Tucson.

The total Gold Ridge production has been approximately $36,000. The group comprises 9 claims. The main workings consist of an upper and lower adit near the mouth of Juniper Canyon, and numerous surface workings to the east as far as Gold Ridge. The map of the under-
PLAN VIEW
OF THE
GOLD RIDGE MINE

April, 1940.
ground workings is not accurate, but shows the approximate location of the quartz veins and basic dike. The upper adit is shown, but a drift to the east from this adit is not. This drift parallels a quartz vein of about 1 foot in thickness that dips steeply northward and strikes about east-west, and which is labeled No. 1 vein in Plate No. 7. After following the vein for 300 feet, the drift bears to the north for 400 feet and then cross cuts south to pick up the vein. All but the first 200 feet are almost impassable and this drift was not examined. The No. 1 vein has been stoped to the surface but was not mined down from this level. The vein is made up of approximately 1 foot of basic dike on the hanging wall, 2 feet of coarsely crystalline calcite, and 1 foot of quartz vein on the footwall. The wall rock is carbonaceous gouge and sandstone. Only the quartz is mineralized and that not extensively.

About 60 feet farther south the adit intersects the wider No. 2 vein, which is 15 feet in thickness and roughly parallels the No. 1 vein. A basic dike several feet in thickness is also found on the hanging wall of this vein, although in the adit, vein and "dike" are separated by a few feet of sandstone. The basic dike

1 From a report by Sterling B. Talmage, April 12, 1918.
is criss-crossed by quartz veinlets. This No. 2 vein likewise carries little sulphides. It has been stoped upward an unknown distance.

The lower adit has opened, as shown, two veins north of the adit and one vein to the south. The two veins to the north probably represent the No. 1 and No. 2 veins of the upper level. The No. 2 vein has a basic dike footwall indicating that the quartz vein probably crosses it between levels. A basic dike was not seen associated with the No. 1 vein as on the upper level, and may have joined the No. 2 vein between levels. According to Talmage,¹ these two veins are parallel and the sum of their widths constant at 15 to 16 feet. He also states that the vein south of the adit is very irregular.

The quartz containing the greatest sulphide mineralization was in the No. 1 vein. A study of polished sections of this ore gives a paragenesis similar to that given for the Dives Mine. The galena here seems to have a longer range of deposition than the chalcopyrite; some is younger, and some apparently older. The sulphides are present along cracks in quartz and are disseminated through it. Cerussite replaces galena along cleavage planes, and covellite occurs as minute shreds and blebs in chalcopyrite.

¹ op. cit. 130772
Some of the ore is massive pyrite which reportedly carries the best values.

About 350 feet in this lower adit a cross fissure has been leached by circulating waters and malachite was deposited along several feet of the adit.

The No. 3 vein is 3 feet wide and brecciated on the hanging wall, resembling the Philadelphia vein in this particular, except here there is no basic material in the breccia. Little calcite was observed on the lower level. The eastern crosscut on the No. 2 vein exposes small areas of calcite containing pyrite in the quartz. Siderite was seen only on the dumps, and is much less abundant than in the Dives Mine. The Dives Mine has a preponderance of siderite over calcite, resembling the Philadelphia Mine in this respect. The siderite in the area varies from very dark to very light brown.

The veins in the Gold Ridge Mine join, or diminish to, a single vein eastward. On Gold Ridge the vein is 10 feet thick and has been stoped on two levels for a total of about 30 feet in depth and perhaps 100 feet in length. Caving has been extensive. Northward along the upper reaches of Juniper Canyon there are many surface pits and shear zones in the slate. Quartz
stringers and small veins occur in these zones of shear. The slates are crumpled but only very locally altered. The quartz is drusy and often contains crystals. The dip of these veins is 60° to 65° north which indicates a bedding-plane shear.

Oxidation of the Gold Ridge veins has been similar to the workable veins of the Dives Mine. No enriched copper, lead, or zinc deposits are to be expected. Because of drainage to the south oxidation may have extended to a depth comparable to that of the Dives Mine. This would be considerably below the lower level of the Gold Ridge Mine.

Shipments of ore during 1933 and 1934 returned values of from 5.16 dry tons @ 1.87 ounces of gold per ton to 93 dry tons @ 0.31 ounces per ton. All shipments have been hand picked ore. Silver content averages about 1 ounce per ton. Copper did not exceed 1/4 of 1 per cent. Impurities in per cent had the following range in 22 Douglas smelter returns.

<table>
<thead>
<tr>
<th>Impurity</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insoluble</td>
<td>94.6 to 88.2</td>
</tr>
<tr>
<td>Silica</td>
<td>89 to 86</td>
</tr>
<tr>
<td>Iron</td>
<td>6.9 to 2.2</td>
</tr>
<tr>
<td>Lime</td>
<td>0.2</td>
</tr>
<tr>
<td>Zinc</td>
<td>0.1</td>
</tr>
<tr>
<td>Sulphur</td>
<td>1.5 to 0.3</td>
</tr>
<tr>
<td>Alumina</td>
<td>5.9 to 0.8</td>
</tr>
</tbody>
</table>

The ore evidently contained little shale. Debits were made for basing charges, and a copper deficiency
when under 8 pounds per ton. Silver under 1/2 ounce per ton was not paid for.

Photographs of the Gold Ridge Mine are shown on Plate No. 7.

Philadelphia Mining Area.

This gold area comprises two parallel quartz vein systems striking N 05° W. The vein on the west side of the wash is designated as No. 1; the eastern vein as No. 2. Both vein systems lie in normal fault zones in the monzonite.

Nothing is known of this property except that its title is in doubt. A little gold ore has evidently been mined in the past. In March, 1940, some ore from the No. 2 vein sent to El Paso returned $19.50 per ton.

No. 1 quartz vein is two feet wide, dips east 67°, and extends northward very uniformly for at least several hundred feet. This vein does not crop out, but is exposed by an adit driven on the footwall for perhaps 200 feet. Both walls are monzonite. The quartz observed contains a small amount of disseminated galena and pyrite.

No. 2 quartz vein extends for over one quarter mile on the surface and is associated throughout most of its length with an earlier basic dike. The dike was
brecciated by later movement and quartz, then intruded, cemented the breccia and caused a very tight fissure vein. The basic dike seems to be partly replaced. Where the dike is absent the vein averages two feet; where present the quartz is either on the hanging wall or entirely in the dike. In the northern part of this system the dike is 3 feet and the quartz 4 feet wide including breccia. Here the basic breccia contains much crystallized pyrite and was apparently most favorable for sulphide deposition. Calcite is associated with the breccia, contains pyrite, and is replaced by quartz. Farther south 4 feet of quartz lies between 3 feet of dike on the footwall and 1 foot of dike on the hanging wall. The quartz is tighter on the walls than that in the Dives and Gold Ridge veins, and it is drusy in some places. Pyrite and a little galena entered with the quartz, or later, and spread into the basic dike in part. In two places this vein has been stoped from the surface to a depth of 40 feet. Siderite veins in the monzonite were noted.

This area is of interest because the occurrence of north-south quartz veins associated with a basic dike in the monzonite is a third type of ore deposit, and is similar to the LeRoy Mine about 1 mile eastward.
Photographs of this mining area are shown on Plate No. 8.

Conclusions:

The deposits have been formed under mesothermal conditions at moderate depths as indicated by the presence of siderite, talc, chlorite, sericite, and epidote. Carbonatization and silication have affected the wall rock.

Fissure filling of the shear zones in the slate was followed by replacement of the wall rock. The shears occur most often in the slates rather than the sandstone since slates were more susceptible to shearing stresses.

Besides the major veins there are small quartz stringers throughout the area even extending into the lower lava flows. A one inch vein in andesite north of Station V showed copper stains and assayed 70 cents in gold per ton. It contained approximately 5 ounces of silver and 5 per cent copper, and is typical of these smaller veins.
The future of the district will depend upon the concentration of low-grade ores, and shipping or trucking concentrates to the El Paso smelter. Since the veins are "true fissure veins" and should continue well in depth, a considerable tonnage of this low-grade ore could undoubtedly be developed. A mill constructed to treat the ore from all the mines on the "big ledge" would prove the most economical method of exploitation.
BIBLIOGRAPHY


Heineman, R.E.S., - Petrography and Petrology, 1st ed., 1932.


Lindgren, Waldemar, - Britannia Beach Map-Area, B. C., Canadian Geol. Survey, Memoir 158, 1929.

Mawdsley, J. B., - Econ. Geol. March - April, 1938, p. 194.


Talmage, S. B., - private report, April 12, 1918.


Maps in pocket.
PLATE NO. I.

V 

eins

I 

ntrusive

ROCKS

EXPLANATION

Q uartz veins

Q uartz latite porphyry

B asic dikes

Q uartz monzonite porphyry

I ntrusive stock

Q uartz latite (flow and sill)

Q uartz hornfels

L imestone

S andstone - slate

Q uartzite

L imestone - sandstone

Upper Cretaceous - Tertiary

Upper Cretaceous - Tertiary

Upper Cretaceous

Pennsylvanian

Sedimentary rocks

INTROUSIVE ROLKS

EXTRUSIVE ROLKS

APPROXIMATE MEAN ELEVATION 7,300 FT.

AREAL GEOLOGY

OF THE

DIVES AND GOLD RIDGE GROUPS

DOS CABEZAS, ARIZONA

SCALE 1 IN. = 1400FT

CONTOUR INTERVAL 50 FT.

DATUM MEAN SEA LEVEL

TOPOGRAPHY

PLATE NO. I.

EXPLANATION

 Quarz veins

 Quarz latite porphyry

 Basic dikes

 Quarz monzonite porphyry

 Intrusive stock

 Quarz latite (flow and sill)

 Quarz hornfels

 Limestone

 Sandstone - slate

 Quartzite

 Limestone - sandstone

 Upper Cretaceous - Tertiary

 Upper Cretaceous - Tertiary

 Upper Cretaceous

 Pennsylvanian

 Sedimentary rocks

 INTROUSIVE ROCKS

 EXTRUSIVE ROCKS

 APPROXIMATE MEAN ELEVATION 7,300 FT.

 AREAL GEOLOGY

 OF THE

 DIVES AND GOLD RIDGE GROUPS

 DOS CABEZAS, ARIZONA

 SCALE 1 IN. = 1400FT

 CONTOUR INTERVAL 50 FT.

 DATUM MEAN SEA LEVEL

 TOPOGRAPHY

 PLATE NO. I.
CROSS SECTIONS
DIVES AND GOLD RIDGE GROUPS
DOS CABEZAS, ARIZONA.

VERTICAL AND HORIZONTAL SCALE 1 IN. = 400 FT.

April, 1952.
James C. Shibley