THE GEOLOGY OF THE CONTENTION MINE AREA
TWIN BUTTES, ARIZONA

by

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the requirements for the degree of
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Director of Thesis
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ABSTRACT

This report describes the geology of the Contention mine area, a small portion of the Twin Buttes district located in Pima County, 26 miles south-southwest of Tucson, Arizona.

The sedimentary rocks exposed in the area are the Bolsa quartzite and Abrigo limestone of Cambrian age, the Martin limestone of Devonian age, the Escabrosa limestone of Mississippian age, the Naco formation of Pennsylvanian age, and a quartzite of questionable Cretaceous age. The sedimentary rocks are intruded by a biotite granite of probable Tertiary age. Dikes of granite, rhyolite porphyry, and quartz diorite have intruded both the Tertiary granite and the sedimentary rocks.

The formations were intensely faulted presumably during the Laramide revolution. Faulting took place in three stages: before the Tertiary intrusion, after the intrusion but before mineralization, and after mineralization.

The ore deposits are of the contact metamorphic type with replacement of favorable limestone beds. The mineralizing solutions were apparently derived from the Tertiary magma. Localization of the deposits was mainly influenced by pre-mineral faults. The development of contact silicate minerals has been extensive, and the metamorphism of the sedimentary rocks, intense.

Metal production has come from two mines, the Minnie and the Contention. At the Minnie mine the ore mineral was mainly chalcopyrite, whereas at the Contention it was predominantly sphalerite with little chalcopyrite. A search for ore might locate small deposits, especially along the Morgan or Contention faults.
INTRODUCTION

Method of Study

The field work on which this thesis is based was started in October of 1947 and was continued until April of 1948. Approximately eight days were spent in the field each month. The area covered by this report, together with the adjacent area to the southeast described by Harold Whitcomb, was mapped topographically by use of the plane table and telescopic alidade. Whitcomb and the author cooperated in this portion of the work. The geology was superimposed on this base map by means of the intersection method with use of the Brunton compass. Trips were made to nearby localities for the purpose of more precise stratigraphic correlation. The igneous rocks were studied both macroscopically and microscopically. Literature on the area has been consulted, and, although sketchy, has been of assistance, especially with regard to mining history and production.

Acknowledgments

The writer desires to express his appreciation to Dr. B. S. Butler for his valuable advice and innumerable suggestions; to Dr. E. D. Wilson for maps and information concerning the surrounding area; to Dr. A. A. Stoyanow for his helpful discussions of the stratigraphy and paleontology; and to Dr. W. N. Short who cooperated in the petrographical determinations.

Mr. Edward Foy contributed information concerning mining and production in the area, and made available maps of the Contention mine.
The cooperation of Harold Whitcomb in the preparation of the topographic map and his assistance in familiarizing the writer with the stratigraphic column is fully appreciated.

The author is also very grateful to those whose patient criticisms have aided in the completion of this thesis.
CHAPTER I GEOGRAPHY

Location

The Contention mine area is located in the Twin Buttes mining district 26 miles south-southwest of Tucson (see plate 3). The area may be reached from Tucson by either the Twin Buttes road, which passes through the San Xavier mining district southward to Twin Buttes, or U. S. Highway 89 to Sahuarita then southwest on a well maintained dirt road to the Twin Buttes road. The area was connected by rail in 1905 to what is now the Southern Pacific’s Nogales route. This branch has been abandoned for many years.

The area described in this thesis consists of five square miles immediately northwest of a northeast line through the Contention mine. Twin Buttes, a small settlement inhabited by several Mexican families, is a mile to the northeast.

Climate

The climate of the area is much the same as that throughout southern Arizona at intermediate elevations. It is a warm, arid climate with a mean annual temperature of 68°F, a rainfall of 13 inches, and a humidity of 45 per cent. The winters are mild and the summers hot. The principal rainy season comes in July and August.

Topography

Regional

The Contention mine area is located about five miles east of the Sierrita Mountains, a rather low and unimpressive range with a length of 14 miles northeast-southwest, and a width rarely attaining four miles. The Sierritas rise 2000 to 3000 feet above the surrounding plain, the
highest elevation being 6206 feet.

Sloping gradually to the east toward the Santa Cruz River is the gently undulating pediment on which the Twin Buttes district is located. The sloping surface, as is characteristic of mountain pediments of arid regions, is cut on the granite bedrock and covered with a veneer of gravel and finer alluvium. It is dissected by shallow washes and arroyos. The prominent hills in the area under discussion are composed of relatively resistant rocks, mainly limestone and quartzite, that stand above the pediment.

The hills of the near by San Xavier district are composed largely of Palaeanoic limestones. The saddles and surrounding plains are on weak, easily eroded marls, shales, and sandstones of late Paleozoic and Mesozoic age, and on "granite".

To the south of the Twin Buttes region is a series of rather prominent hills of Tertiary (?) volcanics.

Local

The relief in the Contention area slightly exceeds 200 feet (see plate 1). The highest hill is barely over 3800 feet above sea level. The most prominent feature of the area is a ridge trending approximately east-west near the southern limit. It is composed mainly of Pennsylvanian quartzite and epidotized Cretaceous (?) quartzite, which strike with the trend of the ridge and dip steeply to the south. The saddles in this
ridge are determined by non-resistant granite.

Topographic development is related to faulting. The valley north of Gladstone Hill is delineated primarily by a zone of west-northwest faulting in the Naco quartzites (see plate 1).

Structural control is also well shown by arroyos immediately to the west of the Contention mine. Here the rectangular stream pattern displays definite control by faulting. Apparently only those fractures which have undergone slight garnetization affect the stream development to any great degree. Post-mineral faults and certain of the pre-mineral faults are included in this group. The more heavily garnetized faults, on the other hand, resist erosion and tend to stand out on ridge and hill tops. This is shown near the Contention mine by the northwest trending garnet zone.

The area surrounding the sedimentary rocks is composed of relatively unresistant granite and of numerous, somewhat more resistant quartz diorite dikes. Brown\(^5\) attributes some of the topographic development in this section to the effect of these dikes.

The hills immediately south and east-southeast of the Minnie mine were developed from the hard Middle Cambrian Bolsa quartzite and silicified Upper Cambrian Abrigo limestone.

CHAPTER II GENERAL GEOLOGY

Sedimentary Rocks

Cambrian

Bolsa Quartzite

The Bolsa quartzite represents the lowest stratigraphic unit of the Paleozoic sequence in the Contention mine area (see plate 4). It is vitreous, compact, and poorly sorted in many of the beds. The grains range from sub-angular to rounded, the majority being sub-rounded. They are mostly of white to colorless quartz. The pinkish color of the rock is due primarily to impurities in the cementing silica. The lower beds of the formation, which are not exposed in this area, are conglomeratic.


and, according to Brown, quite arkosic. The lower strata grade upward into beds of finer texture. Near the top silty beds predominate in the Contention mine area. Fresh surfaces of the quartzite are usually light pinkish-gray with many tan or dark gray layers. The rock in several places has a dark brown color which may be due to metamorphism of the silty beds near the top of the formation. Weathering has in many places darkened the original colors and reduced the vitreous appearance. In places, the weathered surfaces exhibit minute pitting in the cementing material.

Bedding is indistinct in many outcrops, but is emphasized on the more weathered surfaces. Crossbedding was noted at several zones.
Fracture surfaces are smooth breaks and somewhat consistently oriented with respect to bedding. This feature, together with color, aids in differentiating the Bolsa from certain quartzite beds in the Naco formation which are in other respects similar.

Outcrops of Bolsa have a definite orange or brick red color which contrasts with the surrounding, more subdued colors of other rocks in the area.

The thicker outcrops are cliff-forming and show a marked influence upon the topography. The hill immediately to the south of the Minnie mine is composed mainly of this resistant quartzite. Exposures are also present in the vicinity of the Contention mine, but many of these are too small individually to have much effect upon relief.

A complete section of the Bolsa quartzite is not shown in the Contention mine area, but according to Mayuga the total thickness in the San Xavier district, ten miles to the north, is approximately 1,300 feet. Brown cites a thickness of 700 feet to the Bolsa, 1 foot to the Pima sandstone, and 300 feet to the Cochise formation in the Picachos de la Calera. The most complete exposure in the Contention mine area indicates an approximate thickness of 500 feet.

No fossils were found in the Bolsa quartzite, consequently its correlation is based upon lithology and stratigraphic position.

The general character of the Bolsa quartzite, with its relatively coarse-grained lower portion, its cross-bedding, and its irregularity of grain, suggests a rather shallow marine deposit. The pre-Cambrian surface was probably composed of granitic rocks which have contributed to
the arkosic character of the lower beds.

Pima Sandstone and Cochise Formation

Neither the Pima sandstone nor the Cochise formation was recognized in the Contention mine area. The lower part of the Abrigo formation in the area may represent both the Pima sandstone and Cochise formation. They cannot be recognized by lithology owing to intense metamorphism. The strata immediately overlying the Bolsa quartzite are essentially identical with the Abrigo formation found stratigraphically higher. Other than separation into the Bolsa quartzite and Abrigo formation, differentiation of the Cambrian into lithologic subdivisions is not feasible in the Contention mine area.

Abrigo Formation

In the Contention mine area the Abrigo formation overlies the Bolsa quartzite with apparent conformity (plate 4). It is composed essentially of thin-bedded, impure limestone with shale beds in the lower part. The limestone is laminated by cherty layers which in unmetamorphosed rock stand out on the weathered surface. Where metamorphosed, however, the limestone layers have been silicated to such an extent that this differential weathering shows little development. The color on the fresh surface is light brown for the chert layers and dark brown for the limestone. In the shaly lower portions of the formation the freshly fractured surface is grey to grayish-brown. Also present at different horizons (from 100 to 150 feet stratigraphically above the base of the Abrigo formation) are several beds of quartzite ranging in thickness from 18 inches to 3 feet. These have a close resemblance on both the fresh and weathered surfaces, to the underlying Bolsa quartzite. However, they are not persistent, but pinch out or thin and thicken along the strike. The limestone has banded, dark brown, weathered surfaces where metamorphosed.
Southeast of the Minnie mine it is not highly altered and shows rather blue-gray fretted surfaces—the fresh fracture being light gray. Chert layers are less common or entirely absent, consequently, the laminated texture is not apparent. Several areas of Abrigo to the west of the Contention mine show light to moderate epidotization.

Although no fossils were found in the Abrigo formation in the Contention mine area, they have been described from other localities and indicate an Upper Cambrian age. Correlation, as in the case of the Bolsa quartzite, is based on lithology and stratigraphic position.

The two outcrops of the Abrigo formation in the area are south-southeast of the Minnie mine and west of the Contention mine.

The thickness of the Abrigo formation is about 360 feet in the San Xavier district. Brown cited 400 feet in the Picachos de la Calera.

Southeast of the Minnie mine the section is about 500 feet thick although there may be some duplication by faulting.

The following section of the Bolsa quartzite and the Abrigo formation is located approximately sixteen hundred feet west of the Contention mine. It was measured in a northeast direction.

Nabigo Fault
Abrigo Formation

1. Concealed.................................................. 51.0

2. Limestone; laminated by tan limestone and gray chert; fine to medium grained; thin bedded (1 to 2 inches); silicate and carbonate cement; epidote rare; forms slight ledges on the slope surfaces, weathers with an orange brown color; no fossils.................. 12.5
3. Limestone; laminated dark gray and brown limestone with brown chert; very fine grained; thin (3 to 6 inches), flat bedding; epidote common; resistant, forming small ledges or ridges on slopes, weathers to green and black pitted surfaces; no fossils.  

4. Limestone; laminated by brown limestone layers and light brown and gray chert layers; fine grained; thin (2 to 4 inches), flat bedding; epidote common; more resistant than #3; weathered surfaces are dark brown and crumbly; no fossils.

5. Concealed................................. 28.0

6. Same as #4.................................. 26.0

7. Same as #4 but less resistant.............. 21.0

8. Concealed..................................... 6.0

9. Quartzite; gray; very fine grained; thin (3 to 2 inches), flat and distinct bedding; silica cement; impure, abundant black inclusions (unidentified) with rather definite boundaries; non-resistant, slope forming, weathered surfaces are dark brown; no fossils.

Bolsa Quartzite

10. Concealed................................. 12.0

11. Quartzite; light gray; very fine grained; thin (2 to 5 inches), flat bedding; commonly mottled with black inclusions of indefinite boundaries; ridge forming, weathered surfaces are pitted and dark gray with orange stain; no fossils.

Total 222.0

Granite

Devonian

Martin Limestone

The Martin limestone was not found in sedimentary contact with the Abrigo in any part of the area, consequently the nature of the sedimentary contact was not determined. At other localities the Martin rests disconformably upon older formations.
The Martin limestone is compact, dark gray, medium gray or buff. The exposure of Martin limestone west of the Contention mine contains one of the Hexagonaria-Cladopora coral reefs common throughout the Devonian in southeastern Arizona. A similar reef is present one hundred feet west of the Garnet Queen mine. Both reefs show intense silicification. In the exposure west of the Contention mine several beds of limestone stratigraphically above the reef are bluish-gray in color and have aphanitic, almost lithographic textures. When metamorphosed the limestone is white, sugary, fine- to medium-grained marble. Many beds exhibit veinlets, stringers and irregular masses of silica. The beds range in thickness from 6 inches to 3 feet, a distinctive feature when compared to the thin-bedded Abrigo or the more massive Escabroza.

The buff limestone, which makes up the middle portion of the formation, weathers to a tan, sandy surface. The gray portion becomes fretted with a dark gray color on the weathered surface.

According to Stoyanow, the corals composing the reefs are

Hexagonoria davidsoni (Edwards and Haine), H. profunda (Hall), Pachyphyllum woodmani (White), Cladopora prolifica (Hall and Whitfield), and some others. Because of the intense silicification of these reefs in the Twin Buttes area the only definite determination that can be made by the writer is that of Cladopora sp. Correlation is based on this determination and on
lithological similarity to the Martin in other localities.

The Martin limestone in the Santa Rita Mountains has been determined by Stauffer\textsuperscript{17} to be 250 feet thick. Brown\textsuperscript{18} cites 261 feet at Picachos de la Calera. In Ransome\textsuperscript{19} type section at Mount Martin the formation is 340 feet thick. The most completely exposed section of Martin limestone (243 feet) in the Contention mine area is south of the Garnet Queen mine. The west and northwest side of the exposure is cut by the Garlon fault consequently the overall thickness of the Martin limestone cannot be determined. (See description page 14).

Mississippian

Escabrosa Limestone

The Escabrosa limestone in the Contention mine area is massive and coarsely crystalline with beds ranging from two to ten feet in thickness. Chert lenses, 1 to 3 inches thick, and irregular nodules are abundant at several horizons. The granular texture, consisting of rhombic crystals, is the result of metamorphism.

The Escabrosa is in most places white or very light gray on the fresh surface. The weathered surface retains the light color except in a few places where it takes on a dark brown to black coating. Two groups of beds near the Contention mine are definitely blue or dark gray both on fresh and weathered surfaces and contain chert lenses. These blue beds grade into the typical white ones along the bedding, whereas across the bedding the color changes are much more abrupt.

\textsuperscript{18} Brown, W. H., op. cit., p. 712, 1939.
\textsuperscript{19} Ransome, F. L., op. cit., p. 33, 1904.
The Escabrosa limestone outcrops in a northwest trending belt to the west and south of the Contention mine and in an area around the Garnet Queen mine. East of the Mimie mine there is an east-west belt which has been traced past the Copper Queen and Glance mines.

The thickness of the Escabrosa limestone in the Contention mine area was not determined by measuring directly because of the lack of a complete section. The most complete one (immediately southwest of the Contention mine) is cut on the northeast side by the Contention fault and on the southwest side it is in fault (?) contact with the Martin limestone. (See description page 11). The width of the outcrop extending southwestward from the Contention mine indicates a minimum of 650 feet and suggests a possibility of greater thickness. In the Tucson Mountains it was found to be 600 feet thick. In Bisbee the section varies from 600 to 800 feet.

Several fossils were found in the Escabrosa northwest of the Contention mine but owing to poor preservation could only be determined as Mississippian in age by Stoyanow. Correlation is based upon this determination and on lithologic similarity with the Escabrosa limestone in other areas.

The section of the Martin and Escabrosa limestones just west of the Contention mine was measured from the northeast to the southwest. It is as follows:


\[\text{\textsuperscript{21}}\] Ransome, F. L., op. cit., p. 43, 1904.

\[\text{\textsuperscript{22}}\] Personal communication.
### CONTENTION FAULT

**Escabrosa Limestone**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Limestone; gray; fine to medium crystalline; flat-bedding (1/2 to 3 feet); pure; ledge forming; weathers to rough, slightly pitted surfaces with light gray color; no fossils</td>
<td>10.0</td>
</tr>
<tr>
<td>2.</td>
<td>Zone of garnet which has, for all practical purposes, completely replaced the limestone. This zone closely follows the strike of the Escabrosa limestone and Contention fault</td>
<td>53.0</td>
</tr>
<tr>
<td>3.</td>
<td>Limestone; white; coarse crystalline; flat-bedding (1/2 to 6 feet); pure; cliff forming, weathers to rough surface and white or buff color; no fossils</td>
<td>51.0</td>
</tr>
<tr>
<td>4.</td>
<td>Limestone; blue, grading to white a hundred feet south of the Contention mine; medium to coarse crystalline; flat-bedding (3 to 6 feet); rare small silica inclusions; cliff forming, weathers to rough surface with no appreciable change in color; rare, silicified brachiopoda of Mississippian age</td>
<td>39.0</td>
</tr>
<tr>
<td>5.</td>
<td>Limestone; light buff; coarse crystalline; flat-bedding (2 to 6 feet); pure; non-resistant, weathers to a slight rough surface with no change in color; no fossils</td>
<td>12.0</td>
</tr>
<tr>
<td>6.</td>
<td>Limestone; white; coarse to very coarse crystalline; flat-bedding (1/2 to 6 feet); pure; ledge forming, weathers to rough surfaces light gray, white, or buff in color; no fossils</td>
<td>24.0</td>
</tr>
<tr>
<td>7.</td>
<td>Limestone; blue, grading into white along the strike; coarse crystalline; flat-bedding (2 to 5 feet); contains numerous dark gray to blue chart lenses (parallel to bedding) 2 to 6 inches thick and from a few inches to 6 feet long; cliff forming, weathers rough with a little darkening of color; no fossils</td>
<td>26.0</td>
</tr>
<tr>
<td>8.</td>
<td>Limestone; white; coarse crystalline; flat-bedding (3 to 6 feet); pure; non-resistant, weathers to smooth or slightly rough surfaces, light gray or white in color; no fossils</td>
<td>138.0</td>
</tr>
<tr>
<td>9.</td>
<td>Limestone; white; coarse crystalline; flat-bedding (2 to 6 feet); pure; non-resistant; weathers to a slight rough surface due to the calcareous nature of the rock; white and buff color; no fossils</td>
<td>57.0</td>
</tr>
</tbody>
</table>

**Marbrosa Fault (?)**

**Escabrosa Total** 631.0

**Martin Limestone**
10. Limestone; gray; fine to medium crystalline; medium bedding (1 to 3 feet); common silica masses (1 to 2 inches in size); forms slight ledges, weathered surfaces are slightly pitted and gray or buff in color; no fossils.................. 17.0

11. Limestone; dark gray; dense, compact; thin to medium bedding (6 inches to 3 feet) rarely silica stringers; slope forming, weathers to rough, pitted surfaces and medium gray color; no fossils........... 2h.0

12. Limestone; gray; finely crystalline; thin bedding (6 to 16 inches); commonly contains silica stringers and masses; ledge forming, weathers to a moderately pitted surface and very light gray or buff color; no fossils.......................... 21.0

13. Limestone; dark gray; dense, hard; thin to medium bedding (1 to 4 feet); some epidote; resistant—forming small ledges, weathers to rough, pitted surfaces and light gray color; Hexagonaria—Cladopora reef, 2 to 4 feet thick in the middle of the unit...... 49.0

14. Limestone; very light gray; finely crystalline; medium bedding (1 to 3 feet); silica masses up to 1 and 2 feet in size common; non-resistant; weathers to rough surfaces and light gray color; no fossils........... 64.0

15. Limestone; gray; finely crystalline; medium to thin bedding (6 inches to 2 feet); rare green inclusions of indefinite boundaries and more frequent silica stringers and masses (1/4 inch to 3 inches in size); more resistant than #11, weathers to a buff color; no fossils........................................ 42.0

16. Limestone; light gray; medium grained; thin bedding (4 to 16 inches); pure, with rare silica stringers and veinlets; slope forming; weathered surfaces are rough and of medium gray color; no fossils........... 31.0

Fault

Pennsylvanian

Naco Formation

The original "Naco limestone" as proposed by Ransome\textsuperscript{23} included all

\textsuperscript{23} Ransome, P. L., op. cit., pp. 136-135, 190h.

the Paleozoic rocks stratigraphically above the Mississippian and con-
tained faunas representative both of the Pennsylvanian and of the Permian periods. The term "Naco formation" as used in this report includes only that portion of the "Naco limestone" which contains Pennsylvanian fossils in other districts. Correlation is based wholly upon lithology as


paleontological proof is absent. No evidence was found in the Contention mine area to suggest the presence of Permian strata.

The contact between the Escabrosa limestone and the Naco formation is located between those beds with faunas of Mississippian age and those with faunas of Pennsylvanian age. A conglomerate, thought to be the basal bed of the Naco formation is reported by Whitcomb as occurring in


the northeast part of the area studied for his thesis.

At the base of the Naco, limestone members are similar to those of the Escabrosa limestone but thinner and interstratified with beds of hornfels which weather to dark brown. Higher in the section the limestone is finer grained, darker in color and more thoroughly silicified. Near the top it is aphanitic, hard, and gray to pale green or blue. Some beds have a pink tinge and in many places the limestone is dark brown or black on the weathered surface. Siliceous veinlets are common. The long exposed surfaces are rough, fretted or covered with irregular pits.

The hornfels at the base of the limestone suggests an original shaly texture of the rock at most horizons. Most of the beds are laminated. Colors of the laminae are varying combinations of gray, dark gray, bluish
gray, greenish gray, and white. Some beds are of consistent color and show no lamination or mottling. Most of the hornfels layers are lighter in color where weathered, but a few are dark. Several beds of quartzite are pure white on the weathered surface. One of these, a vitreous quartzite much like the Bolsa quartzite, has been traced almost the entire width of the area from east to west.

The Naco limestone occurs as a wide belt which trends in an east-northeast direction on the slope and in the valley north of Gladstone Hill. The actual thickness of the Naco limestone in this area is unknown. Mayuga\(^{27}\) estimates at least 900 feet as the Naco thickness in the section that he examined in the Mineral Hill area. The outcrop in the Contention mine area suggests a thickness of about 1300 feet, but faulting is present; consequently, an accurate thickness was not measured.

The following partial section of the Naco formation was measured from north to south in a gully 2000 feet west of the Contention mine.

### Granite
#### Naso Formation

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Concealed</td>
</tr>
<tr>
<td>2.</td>
<td>Hornfels; light gray; dense; thin beds (3 to 6 inches); pure; non-resistant, weathered surfaces very light gray or white; no fossils</td>
</tr>
<tr>
<td>3.</td>
<td>Hornfels; gray; very dense; flat; thin beds ((\frac{1}{2}) to 2 inches); pure; non-resistant, weathered surfaces are smooth and light gray; no fossils</td>
</tr>
<tr>
<td>4.</td>
<td>Concealed</td>
</tr>
<tr>
<td>5.</td>
<td>Limestone; light gray; fine crystalline; thick beds (1 to 3 feet); contains some small stringers of gray silica; ledge-forming, weathered surfaces are gray to light bluish gray; no fossils</td>
</tr>
</tbody>
</table>

---

\(^{27}\) Mayuga, M. N., op. cit., p. 22, 1942.
6. Hornfels; light blue; very dense; flat, distinct, thin beds (1 to 3 inches); pure; non-resistant, weathered surfaces are smooth and gray in color; no fossils......................... 14.5

7. Hornfels; gray; dense; thin bedding (3/4 to 1 inch); pure; non-resistant, weathered surfaces are smooth, and white or bluish gray; no fossils.......................... 7.0

8. Concealed........................................ 18.0

9. Zone of resistant garnet and epidote.......................... 12.0

10. Concealed.......................................... 23.0

11. Hornfels; light gray; dense; flat, thin bedding (2 to 8 inches); pure; non-resistant, weathered surfaces are smooth and white with black specks; no fossils. 29.5

12. Concealed.......................................... 27.0

13. Hornfels; bluish gray; dense; flat, thin bedding (2 to 4 inches); pure; non-resistant (highly fractured), weathered surfaces are light gray or white, and chalky; no fossils............................. 3.5

14. Hornfels; gray; dense; thin bedding (1 to 3 inches); pure; non-resistant, weathered surfaces are smooth and light gray; no fossils........................................ 3.0

15. Hornfels; pale greenish gray; dense; thin bedding (3/4 to 2 inches); contains some epidote; non-resistant, weathered surfaces are light gray, and chalky; no fossils.......................... 6.0

16. Limestone; light gray; medium grained; flat bedding (1 to 12 inches); pure; non-resistant, weathered surfaces are bluish gray, rough, and gritty; no fossils.......................... 10.0

17. Hornfels; greenish gray; dense; thin, indefinite bedding (1 to 3 inches); contains small amount of epidote; non-resistant, weathers bluish gray; no fossils........... 1.5

18. Limestone; white and pinkish white; fine crystalline; flat, thin bedding (3 to 6 inches); contains small gray silica inclusions; ridge forming, weathers to a crumbly, gray surface; no fossils.......................... 7.0

19. Concealed.......................................... $5.0

Nabigo Fault

Total 331.0
Permain

No strata of Permain age, or assumed Permain age, were found in the Contention mine area. There are a number of exposures of Permain (?) beds in the southeastern part of the adjoining area. These are discussed by Whitcomb.28


Cretaceous (?) Quartzite

The formation described as Cretaceous (?) quartzite is found in the southernmost part of the Contention mine area. A greater portion of Gladstone Hill is composed of this formation.

The elastic nature and thin-bedded appearance distinguish it from the other rocks of the district. Ransome29 described a comparable unit as a calcareous sandstone which has been epidotized and silicified. The sand grains are fine, sub-angular to sub-rounded, and rather well sorted. Cross-bedding is well developed at many horizons. The fresh surface is gray or greenish gray and weathers to a brick red or rust brown. The green is due to the introduced epidote which varies in quantity throughout the rock. Dark gray to black shale is interbedded with the quartzite.

The assignment of Cretaceous age to the rock is open to question and therefore is only suggestive. No fossils were observed by the writer. Lithologically, the formation is dissimilar to others seen in the area or nearby areas.

Outcrops are limited on all sides by either igneous or fault contacts, consequently a complete section is missing. The extent of the
exposure indicates a thickness of over 900 feet.

The following partial section of the Cretaceous (?) quartzite was measured southward on Gladstone Hill 1100 feet west of the old Morgan shaft.

Granite
Cretaceous (?) Quartzite

1. Quartzite; bluish gray; very fine grains of varying size although uniform in some thin beds; bedding thin to medium (6 inches to 2 feet); cross-bedding at some zones; silica cement with minor amount of epidote in some of the beds; ridge forming; weathered surfaces are brick red to dark brown in color; no fossils.......................... 162.0

2. Concealed.................................................. 24.0

3. Quartzite; dark gray; fine grains of regular size; bedding thin (1 to 2½ inches) and flat; silica cement; no inclusions; ridge forming, weathered surfaces are bluish gray and gritty; no fossils.... 8.0

4. Quartzite; gray; medium grains of varying size; thin beds (6 to 18 inches); cross-bedding common; silica and some epidote cement; a few small (½ to 3/4 inch), black inclusions; non-resistant, weathered surfaces are crumbly and of dark brown color; no fossils........................................... 38.0

5. Quartzite; light bluish gray; fine grains, slightly varying in size; thin beds (3 to 9 inches); some cross-bedding; silica and abundant epidote cement; rarely contains small, black inclusions similar to those in #4; ridge forming, weathered surface is brown or brick red and crumbly; no fossils.............. 23.0

6. Concealed.................................................. 73.0

7. Quartzite; light gray; medium grains of nearly uniform size; thin to medium bedding (3 inches to 1 foot); occasional cross-bedding; silica and epidote cement—the epidote making up to fifty per cent of the cement; non-resistant, weathered surfaces are brown or brick red and crumbly; no fossils...................................................... 26.0

Total 354.0

Morgan Fault
Generalized Columnar Section for Contention Mine Area
Scale 1 in. = 500 ft
Plate 4
Tertiary and Quaternary Deposits

The Tertiary and Quaternary deposits in the Contention mine area consist of small scattered patches of "caliche"; lithified conglomeratic material; a large amount of unconsolidated gravel and talus; and sand of the arroyo bottoms.

The unconsolidated gravel and talus is by far the most prevalent of the Cenozoic deposits. It covers many of the slopes so completely that much of the underlying structure is obscured. The largest area overlain by this material is in the eastern part of the valley to the north of Gladstone Hill. Here it covers all the bedrock except on the arroyo side and attains thicknesses up to 15 feet. In other parts of the area the gravel is less extensive and thinner, rarely exceeding 6 feet in thickness.

The gravels were derived from the higher country to the west where granite is the predominate rock and from the sedimentary and granite hills immediately surrounding the area. The intermittent, but powerful movements of water down the relatively bare slopes are mainly responsible for most of the accumulated gravels. A minor amount of the gravels have traveled only a short distance from their source to their present position.

The sand in the arroyo bottoms is composed mainly of material derived from the rapidly weathering granite to the west. Feldspar is the most abundant constituent, followed by quartz and mica with minor amounts of magnetite and other heavy minerals.

Igneous Rocks

General

The Sierrita Mountains, lying to the west of the Contention mine area, are made up mainly of plutonic granite. The rocks on the west
of this range, formerly conglomerates, sandstones, shales, and limestones, have been intensely metamorphosed and deformed and appear to be older than the less intensely metamorphosed rocks on the east. The large masses of granite surrounding the Twin Buttes district are supposedly related genetically with this Sierraita core. At Twin Buttes the granite is coarse, somewhat porphyritic, and gray in color.

Eckel\(^{31}\) believes that at Mineral Hill the exposed granite is the top of a stock. Ransome suggests the possibility of a sill whereas Mayuga agrees with Eckel and favors the idea of a stock, basing his preference upon the intensity of metamorphism. Similar relations exist at Twin Buttes where the general setting rather suggests the presence of a stock.

Ransome\(^{32}\) found that the granite intrusion cuts Paleozoic rocks and what he thought were probably Mesozoic sandstones and shales. Mayuga\(^{33}\) confirmed this and correlated the "probably Mesozoic" rocks of Ransome with the Cretaceous rocks of the Tucson Mountains. Eckel\(^{34}\) favored a post-Cretaceous age for all the granite in the Mineral Hill area.

\(^{30}\) Ransome, F. L., op. cit., p. 699, 1921.


\(^{32}\) Ransome, F. L., op. cit., p. 612, 1921.


\(^{34}\) Eckel, E. B., op. cit., p. 14, 1930.
Brown was doubtful as to the age of the granite in the Twin Buttes district. He states (in speaking of the granite):

"It seems to underlie the pre-Carboniferous quartzite although the contact is very unsatisfactory for the determination of the relations. Its relation to the older rocks of the district seems to indicate that it is pre-Carboniferous and its lithologic character suggests that it is pre-Cambrian...Its coarse texture and gneissic structure suggest that it is an older granite than the others in the region. On the other hand fresh specimens from shafts sunk in this granite yield a gray rock which is quite similar to the granite intrusive into the limestone of Queen Hill."

The recorded descriptions and the geologic setting, together with examinations of the present writer, seem to indicate a correlation between the granite of the San Xavier district and that of Twin Buttes. The irregular contacts between the granite and the sedimentary rocks, the lack of evidence to indicate a sedimentary contact at any of the locations observed, and the probable genetic relation with an intrusion of post-Cretaceous age, all point rather strongly to a post-Cretaceous age for the granite of the Twin Buttes district. The contact west of the Contention mine is of pronounced irregularity and certainly does not appear to be a sedimentary contact. South and southwest of Gladstone Hill the granite has very definitely intruded the Cretaceous (?) quartzite. The exposure of a practically horizontal Bolsa-igneous contact in a prospect pit southeast of the Contention mine shows no basal conglomerate, nor even a tendency toward conglomeratic material, in the Bolsa quartzite. On the other hand, the contact is suggestive of either intrusion or low angle thrusting. Brown describes the granite as having

intruded the Carboniferous limestone at the Copper Glance and Copper
Queen mines.

The possibility of some pre-Cambrian granite has not been overlooked. However, there has been no evidence observed indicative of that age.

**Biotite Granite**

Megascopically the granite of the Contention mine area is medium grained and dark gray on the fresh specimen. It weathers to a tan or brown and commonly presents a rough crumbly surface on the hand specimen. Quartz and orthoclase are the predominant minerals with subordinate plagioclase. Biotite is the only original mafic constituent (see plate 168).

Examination of a thin section shows subhedral to subhedral orthoclase and plagioclase, both altered in varying amounts to sericite and kaolin. Biotite has been largely altered to chlorite. Crushed or bent plagioclase lamellae indicate that the rock has undergone stress. Quartz, the last mineral formed as is usually the case, was found occupying interstices between the preceding minerals. The following table presents the approximate percentages of minerals which indicate a biotite granite according to Johannsen's classification.

<table>
<thead>
<tr>
<th>Essential Minerals:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
<td>44.0%</td>
</tr>
<tr>
<td>Orthoclase</td>
<td>30.0%</td>
</tr>
<tr>
<td>Plagioclase</td>
<td>18.0%</td>
</tr>
<tr>
<td>Biotite</td>
<td>6.0%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Accessory Minerals:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnetite</td>
<td>1.0%</td>
</tr>
<tr>
<td>Apatite</td>
<td>100.0%</td>
</tr>
</tbody>
</table>
Classification:  
Quarfeloids-mafides = 92%-8% (Class 2)  
Plagioclase (Andesine) = (Order 2)  
Quartz in quarfeloids = 47%  
Orthoclase-plagioclase = 62.5%-37.5%  
226P - Biotite Granite (with biotite as mafic mineral)

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38 Essentials for the microscopic determination of rock-forming minerals and rocks in thin sections, Univ. of Chicago Press, pp. 40-52, 1922.

Minor Intrusives

Three different dike rocks are present in the area. The age relations of these intrusives was indeterminable because nowhere were they observed in contact with each other or mutually in contact with a formation. They have all intruded and are consequently younger than the main granite mass and the sedimentary rocks. Only the more prominent occurrences have been recorded on the map for many of the outcrops are too small to be noted.

The numerous quartz diorite dikes, or dike-like masses, which are in the granite mass are confined to the central portion of the area (plate 1). This localization is due to one of three causes. The central area may consist of an independent mass of granite, in which case it obviously must be either older or younger than the surrounding granite. If so, there would most probably be other evidence, either compositional, lithological, or structural, or a combination of these, to suggest a difference in age. No such evidence was observed.

Another possibility is that these dike-like masses are earlier solidified basic portions of the magma which were partly reworked by the
main granite magma. This is suggested by the shape and distribution of the "dikes" as mapped (plate 1). The exact contacts were obscured by a thin talus covering, consequently the actual outlines of these "dikes" might vary from those mapped. An actual exposure of the contact (plate 14b) was observed in an arroyo 1500 feet northwest of the Contention mine. In this exposure the quartz diorite "dike" appears younger than the granite.

The third possibility is that the central part of the area is actually a section of the hood of the batholith which subsequent to solidification was intruded by the basic differentiates of the magma. If so, the part under discussion is most likely the trough section judging from the relations. However, it may have been faulted into its present position, during or after solidification and penetration. These dikes are cut by quartz-bearing faults north of the Contention mine and northwest of the Garnet Queen mine.

Biotite Granite

The biotite granite was noted at two places in the extreme southwest part of the area. Both dikes cut the Naco formation and the main granite mass.

Megascopically, the rock is light gray, weathering to a tan or gray. It is medium grained but finer than the older granite. The main minerals are quartz, orthoclase and biotite.

Microscopic examination shows subhedral plagioclase and orthoclase. The biotite present has been largely altered to chlorite. The plagioclase and especially the orthoclase have undergone kaolinization. Compositionally this granite is very similar to the main intrusive. It possibly represents a slightly more basic portion which was intruded into the hood shortly after the hood solidified. The approximate percentages are listed below.
Table 2  Biotite Granite

<table>
<thead>
<tr>
<th>Essential Minerals</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Orthoclase</td>
<td>34.0%</td>
</tr>
<tr>
<td>Quartz</td>
<td>33.0%</td>
</tr>
<tr>
<td>Plagioclase (Andesine)</td>
<td>24.0%</td>
</tr>
<tr>
<td>Biotite</td>
<td>8.0%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Accessory Minerals</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Apatite</td>
<td>0.3%</td>
</tr>
<tr>
<td>Titanite</td>
<td>0.3%</td>
</tr>
</tbody>
</table>

Table 3  Quartz Diorite

<table>
<thead>
<tr>
<th>Essential Minerals</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
<td>38.0%</td>
</tr>
<tr>
<td>Hornblende</td>
<td>28.0%</td>
</tr>
<tr>
<td>Biotite</td>
<td>20.0%</td>
</tr>
<tr>
<td>Plagioclase (Bytownite)</td>
<td>6.0%</td>
</tr>
<tr>
<td>Orthoclase</td>
<td>3.0%</td>
</tr>
</tbody>
</table>

Quartz Diorite "Dikes"

The occurrence of the quartz diorite "dikes" has been discussed under "Minor Intrusives".

The rock is dark gray to black and weathers to a light gray or brown. The texture is fine grained to aphanitic. Quartz, however, is distinguishable. The mafic minerals give the pronounced dark color.

Microscopically euhedral biotite and hornblende crystals make up roughly fifty per cent of the rock. Anhedral quartz is interstitial. Magnetics, apatite, and zircon are disseminated in small amounts. Plagioclase is predominate over orthoclase and both are anhedral. The minerals appear only slightly altered. The amount of each constituent is as noted in the following table.
Accessory Minerals:

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnetite</td>
<td>2.0%</td>
</tr>
<tr>
<td>Apatite</td>
<td>1.0%</td>
</tr>
<tr>
<td>Zircon</td>
<td>1.0%</td>
</tr>
<tr>
<td>Total</td>
<td>99.0%</td>
</tr>
</tbody>
</table>

Rhyolite Porphyry

The field relations indicate that this rock is intrusive. The single occurrence observed is at the west end of the east-west valley north of Gladstone Hill.

The rock is light gray to gray and contains about 20 per cent of relatively large phenocrysts. The microscope shows that the largest phenocrysts are orthoclase and the smaller are biotite, quartz, and magnetite. The orthoclase occurs as euhedral crystals and is the most plentiful. The groundmass is holocrystalline.

<table>
<thead>
<tr>
<th>Phenocrysts</th>
<th>20%</th>
</tr>
</thead>
</table>

Table 1: Rhyolite Porphyry

<table>
<thead>
<tr>
<th>Essential Minerals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orthoclase</td>
</tr>
<tr>
<td>Quartz</td>
</tr>
<tr>
<td>Biotite</td>
</tr>
<tr>
<td>Plagioclase (andesine)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Accessory Minerals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnetite</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

Metamorphism

The profound metamorphism of the sedimentary rocks was brought about by the heat and solutions released from the intruding magma. The impure limestones were altered to silicates in many places. The pure limestones like the Escabrosa have been recrystallized and now
exhibit an extremely coarse-grained texture. This is well seen in the Escabrosa outcrop west of the Contention mine. The shales have been mostly altered to hard, aphanitic, chert-like hornfels. Many of the shale beds of the Naco formation have been metamorphosed in this manner. The Cretaceous (?) quartzite, which was probably a calcareous sandstone at one time, has undergone epidotization together with silicification.

The degree of metamorphism depended on the proximity to the granite, the available fractures along which the solutions could travel, and the permeability of the rock. Heat, perhaps the most important factor influencing the rocks, has been much more effective near the magma or near major solution channels. Magmatic gaseous or liquid solutions, or both, also had a great influence in the alteration. These penetrated along faults, through smaller fractures and pores, and not uncommonly through bedding planes. Stresses brought about by the intruding magma were relieved mostly by fracturing and probably to some extent by granulation. Recrystallization by pressure is not apparent. Some of the pre-mineral faults and much of the jointing of the area might be correlated with these pressures.

The impure limestone beds found in the Abrigo formation were silicated largely by alteration of the impure constituents with a relatively smaller amount of additive metamorphism. Heat was probably the main factor that brought about the reactions between the calcium, silica, and various impurities in the limestone. On the whole, only a small proportion of the Abrigo limestone in the area was altered completely. Most of the formation was affected only partially and has retained much of its former character. Some additive metamorphism may be represented by the substantial amounts of epidote in many of the beds. Aluminum and iron, if not originally present in the limestones, were brought in by the
solutions. Much iron was transported from the magma by emanations and was available during alteration. This is evidenced by the prevalence of epidote and garnet in the relatively pure limestone near major solution channels.

Some of the limestone beds of the Naco formation were not as susceptible to the severe silication which altered limestone beds of the Abrigo formation. Perhaps this degree of silication was due to a difference in original impurity.

The pure limestones, such as the Escabrosa limestone and some beds of the Naco formation, were metamorphosed in two different ways — by replacement and by recrystallization. Epidote and garnet are the most abundant of the replacement minerals although some minor amounts of other contact metamorphic silicates such as actinolite, hedenbergite, and wollastonite were present together with some magnetite and sulfides. Epidotization of the limestone was extensive in many of the beds. However, garnet replaced the limestone more completely and as a rule is more prevalent. Both epidote and garnet were concentrated along bedding planes and major fractures. It is very doubtful that the limestone originally contained enough iron and aluminum to make up the quantities of epidote and garnet present. Additive metamorphism very probably played the more prominent role of alteration in these beds. This is more clearly illustrated by the direct relationship of the epidotization and garnetization to the structural controls. This relationship also emphasizes that where there has been little or no addition of the necessary constituents there is a complete lack of silicate replacement.

The recrystallization of the Escabrosa limestone and the pure limestone beds in the Naco formation has been partial or complete in most cases. Only small portions of either have escaped the effects of this
form of metamorphism. The agencies responsible for this recrystallization were probably the heat and rather barren solutions that penetrated these rocks so thoroughly. Although the solutions may have been heavily charged with elements upon leaving the magma, they were depleted by their participation in the formation of the contact minerals at the margins of the areas so extensively recrystallized. The Escabrosa limestone west of Contention mine was penetrated along fractures normal to the bedding by solutions which had traveled up the Contention fault. Upon first striking the limestone the substances carried in solution together with the heat affected the garnetization which is so predominant along Contention fault. The solutions then went beyond this replacement zone to effect the recrystallization.

The ore minerals are closely associated with the garnetization, epidotization, and other silicate alteration. The sulfides, as pointed out in the section on ore deposits, may have been deposited with the silicates or succeeding them. The silication, on the other hand, evidently took place during the initial, normal metamorphism that recrystallized the major portions of the Escabrosa limestone and parts of the Naco formation.

The Martin limestone, although relatively pure, was not so susceptible to the heat and hydrothermal solutions and recrystallization was not so thorough nor so far-reaching as in the Escabrosa limestone and Naco formation. The small amount of epidote throughout the rock is probably indicative of the minor effect of additive metamorphism.

The shale beds of the Naco limestone consistently show the strong influence of metamorphism. They have been altered to hard, dense hornfels. The process was not complete in some beds where the shaly structure is still observable, testifying to the original character of the rock. Much hornfels has been thoroughly and intricately fractured by
some deforming stress during or after alteration. It is this type of rock that underlies most of the valley in which Nabigo fault is situated.

The Cretaceous (?) quartzite has undergone silicification and epidotization. The silicification may or may not have occurred during the period of contact metamorphism. That silica was available at the time of metamorphism is shown by the large quantities of contact silicate minerals in the pure limestones. Whether or not enough silica was available is largely a matter of speculation. The epidotization of the quartzite is contemporaneous with the epidotization in the other rocks of the area. The degree of replacement throughout the section of quartzite by epidote varies considerably. In some beds epidote is absent whereas in others it may make up as much as fifty per cent of the cementing material.
CHAPTER III  STRUCTURAL GEOLOGY

General

The Contention mine area structurally includes portions of two blocks of sedimentary rocks and the surrounding granite. These sedimentary blocks are similar to those that make up parts of the San Xavier mining district to the north. In brief, the area was faulted and folded prior to intrusion; intruded by granite; faulted again, perhaps by adjustment of the hood of the stock; penetrated by mineralizing solutions; and faulted again. Butler summarizes the sequence of events during the post-Cretaceous intrusions in the Rocky Mountain region as follows:

"The Laramide revolution opened with uplift of the region accompanied by close folding and overthrust faulting along certain belts. This was followed by igneous activity that locally at least was influenced and directed by the faults but in a broad way does not seem to have been controlled by them. Following the igneous activity was the formation of steeply dipping reverse and normal faults. These were later than much of the igneous activity but earlier than the ore deposits and locally exerted an important control over the mineralization. Finally came the settling of the region and a great system of normal faults, mainly later than the igneous activity and most of the mineralization."

The relationships in the Contention mine area show that the structural and igneous evolution coincides with this series of events. The sedimentary rocks may have been overthrust, either before or after intrusion, along a northeast-southwest or east-west direction.
proposes a pre-granite thrusting in the Mineral Hill area and compares it with that found in the Tucson Mountains by Brown. The igneous activity is apparently post-Cretaceous.

The relative age of many faults in the area has not been definitely determined. The age classification for the faults is pre-intrusion including those which occurred before igneous invasion; pre-mineral for those produced after invasion but before mineralization. The Morgan fault (plate 1) has been occupied by the magma, consequently is of pre-intrusive age. The Gartion fault is pre-mineral in part for it was traced a considerable distance into the granite to the northeast where it contains a thick quartz vein. The Contention fault is also pre-mineral and is offset by the Gartion. The Nabigo fault is post-mineral. Most of the remaining faults are probably pre-mineral in age but a more definite assignment cannot be made without further evidence.

The folding noted in the area consists of the east-west trending Simpson syncline (plate 1) and a similarly trending anticline both of which are present in the Abrigo limestone. The relations strongly suggest a pre-intrusive age for these structures (plate 6).

A much larger fold is represented by the north and south sedimentary blocks of the area, which may actually be the flanks of an anticline.

Descriptive Faulting

The following discussion of faulting is in general chronological order.
The Morgan fault is a high angle normal fault striking generally N 80° W which has brought the Cretaceous (?) quartzite on the south against the Naco formation. The dip at its western end is 75 degrees to the south. The fault has been invaded by the granite intrusion at two exposures along the strike, hence is classified as pre-intrusion in age. Evidently this fracture was responsible for the localization of mineralization as shown by the closely associated garnet together with some metallic minerals in the western extension. In the Senator Morgan area the mineralization has been intense in the fault or in the nearby rocks. The Morgan fault is cut by a northeast trending fault east of the Gladstone shaft and by a similarly trending fault west of the shaft. South of the Morgan fault the Cretaceous (?) rocks have a southerly dip of 68 to 75 degrees and strike N 55° W to N 70° W. The Naco formation of the Gladstone block strikes in the same direction as the Cretaceous (?) quartzite and dips 65 degrees to the south, a dip which is maintained as far west as the formation is exposed.

Contention Fault

The northwest striking fault through the Contention mine is named the Contention fault. It is a normal fault dipping steeply to the south-west and determined as of pre-mineral age because of the intense mineralization along its trend. A prospect pit southeast of the Contention mine shows Bolsa quartzite on granite on the northeast side of the fault. The close proximity of the granite to the present surface as shown in the prospect on the east side of the fault suggests strongly that the faulting occurred after consolidation of the batholith hood. Whether or not the granite was definitely faulted could not be determined because direct observation of the fault was not possible. The Escabrosa limestone has
been faulted to its present contact with portions of the Bolsa quartzite in some places and Abrigo formation in other places.

The fault has been cut by the Cartion fault about 400 feet north-northwest of the Contention mine. The northwest striking fracture just north of the Garnet Queen is possibly an extension of the Contention fault. This extension was again offset to the southwest by another northeast fault west of the Garnet Queen mine. The block containing the Garnet Queen shaft shows a small exposure of Martin limestone resting against the Bolsa.

The dip of the Bolsa and Abrigo which strike along the fault is 57 degrees to the southwest. North of the Garnet Queen the Bolsa strikes west-northwest and dips to the south about 40 degrees. The Escabrosa west of the Contention mine strikes N 50° W and dips 70 degrees to the south. Just south of the Cartion this strike swings to S 80° W with an increase dip of 10 to 15 degrees. Northwest of the Cartion fault the Martin and Escabrosa strike N 70° W and dip 60 degrees to the south.

Marbrosa Fault

The name Marbrosa was obtained by combining parts of the names of the two formations, the Martin and the Escabrosa, which it separates. This fault parallels the Contention fault just described, and may be cut by the Cartion as shown by the extension in the stream bed southwest of the Garnet Queen. The presence of the Marbrosa is inferred from the relation of the Martin limestone on its southwestern side. The Martin here is dipping to the southwest at an average of 70 degrees and strikes roughly parallel to the Escabrosa.

The Martin is terminated on the southwest by a northwest trending fault and has been brought against the Maeo formation. This fault apparently dips to the southwest, consequently it would be of the normal type
SECTION B-B'

EXPLANATION

Quaternary Cretoceous Pennsylvian Mississippian Devonian Cambrian Tertiary

Alturium Quarzite Naco Escabroa Martin Abrija Belna Granite Granodiorite Garnet

PLATE 6
on the basis of stratigraphic movement. It strikes approximately parallel to the Marbrosa fault and has been traced to the stream bed on the south where it is cut by the Nabigo fault. A small exposure of Escabrosa limestone at the southeast end of the fault is apparently conformable with the Martin. The Naco formation on the southern side of the fault strikes N 80° W and dips to the south at 45 to 50 degrees.

West of the Gladstone shaft a northeast fault is cut by the Nabigo fault to the north. This fault meets the Morgan fault at the granite contact. It is evidently steep and probably normal. The strong garnetization and epidotization associated with the fault indicate a pre-mineral age, although it may be pre-intrusion.

East of the Gladstone shaft is a short, more northerly trending fault dipping 72 degrees to the southeast. It is cut by an east-west fracture to the north and by a northeast fault to the south.

A few hundred feet north of the Gladstone shaft there is a fault striking N 75° W with a steep southerly dip. It is pre-mineral as evidenced by the generous garnet alteration along its outcrop.

Gartion Fault

The name Gartion is a combination of the names Garnet Queen and Contention, the mines on either side of the fault. The Gartion fault strikes northeasterly but swings more easterly on entering the granite, and dips about 75 degrees to the southeast. It offsets the garnetized zone of the Contention fault but contains a quartz vein in the granite at the northeastern end. On the basis of this relation and data found by examination of polished sections, it is suggested that mineralization was in two stages, the first a strong contact replacement stage, and the second a feeble hypothermal stage.

A similar trending fault northwest of the Garnet Queen also dips
southwestward at 75 degrees. It too cuts the garnet but, unlike the Garnion fault, shows no second stage mineralization. It cuts the granite and a quartz diorite dike. The movement of the northwest block has been upward and to the southwest. This fault is cut by a northwest fault with a steep southwest dip located in the stream bed. The fault in the stream bed may be an extension of the Martrosa fault but definite evidence is lacking.

The northeast striking fault east of the Gladstone shaft which cuts the Morgan fault to the south, presumably dips to the southeast at a rather steep angle. The slight displacement of the southeast block was toward the southwest.

Two short faults occur at the eastern end of the Bolza outcrop north of where the Garnion and Nabilgo faults intersect. In both the northwest block has been moved up. The fractures are probably vertical although there is little evidence to determine the attitude on either. The longer of the two might be a part of the northeast fracture west of the Garnet Queen but movement within the granite was not evident.

Nabigo Fault

The Nabigo fault is the youngest fault and cuts the area in a general east-west direction. It dips at a steep angle, perhaps 75 degrees, to the south. As a result of the Nabigo fault the southern portion of the area has been lowered so that the Naco formation rests against the Abrigo formation for a considerable distance. Westward along the strike the Naco does not appear to have been intruded by the granite in the few exposed outcrops but rather to have been faulted against the granite.

Folding

The folding of the area consists of one possible major fold of which only the flanks remain as represented by the sedimentaries of the area.
and two smaller folds — an anticline and the Simpson syncline. The possible existence of the major fold will be discussed under "Interpretation".

The small anticline and Simpson syncline are present in the Abrigo formation just west of the Cartion fault. The axis of the Simpson syncline plunges in a generally southeast direction until it is cut by the granite contact. The anticline parallels the Simpson structure and plunges in the same direction. Both are slightly asymmetrical toward the northeast. The southern limb of the Simpson syncline dips 60 to 65 degrees to the north whereas the north limb dips 50 to 55 degrees to the south. This folding probably occurred during pre-intrusion time as a result of compression exerted upon the area, and may be genetically related to the thrusting which very possibly occurred in the region.

Interpretation

The structural deformation of the Contention mine area is probably the result of regional forces acting during the post-Cretaceous Laramide revolution. The dominant event of the revolution that may have had an influence upon the development of the area was thrusting which is recognised to the north in the Tucson Mountains13 and in the Mineral Hill area. The compression was strongest along a northeast-southwest to east-west direction as shown by the deformation in other nearby areas and the folding in the Twin Buttes area.

The folding of the Abrigo formation west of the Cartion fault suggests
compression along a northeast-southwest line. However, it should be pointed out that a slight directional change in the sedimentary block, or in the folded portion of the sedimentary block, could have occurred after folding, conceivably from the force of the granite intrusion. If this directional change in the block was made, then the apparent northeast-southwest direction of compression would be in error to the extent of the amount of directional change. The amount of change, however, was evidently only slight for the direction of compression conforms well with the overall flexing that occurred in the area.

The southern and northern sedimentary blocks in which the Contention mine and the Minnie mine are located respectively, illustrate this more clearly. The strike of the sedimentary rocks of both blocks is remarkably consistent, varying between N 40° W and N 50° W. The dip of the rocks is invariably steep and to the southwest, except in the eastern half of the north block where they dip steeply northeastward. The stratigraphic sequence of the south block is generally reversed to that of the north block. In the southern block the sequence from top to bottom is as follows: the Cretaceous (?) quartzite, the Naco formation, the Escabrosa limestone, the Martin limestone, the Abrigo formation, and the Bolza quartzite. This is the normal sequence but in the northern block it is reversed.

This relationship of the strata together with the conformable strike suggests that the two sedimentary blocks are actually the limbs of an anticline. The northern block may be considered as a steeply dipping and partly overturned limb of the anticline, and the southern block as a southwestwardly dipping limb of the anticline. The dips of the strata, as discussed before, indicate that the western half of the anticline was quite closely folded. The eastern half, on the other hand, is an open
type fold. To allow the more extensive folding in the western half of the anticline there must have been a cleavage of the two halves of the northern block by faulting normal to the strike of the folds. The northeast-southwest faults in the central part of the northern block may represent this cleavage.

An uplifting of the area probably accompanied, and may have partly preceded the folding. The first stage of faulting, the pre-intrusion stage, probably occurred at this time.

Overthrusting, although not definitely recognized in the area, probably occurred along the major northeast-southwest direction of compression. As pointed out in the discussion of folding, this direction may be in error slightly owing to movement of the sedimentary block or blocks involved.

Following this period of uplift and compression, the area underwent intrusion which may have been influenced to some extent by the thrusting in the region. Locally, the pre-intrusion reverse and normal faults had the greatest effect in the emplacement of various parts of the stock.

Most of the faults of the area were formed prior to mineralization and after the consolidation of the hood of the stock. Evidence of this age relationship is found in the mineralized Gartion fault which extends into the granite. The highly mineralized Contention fault brought granite in contact with the Escabrosa limestone in several places. The localization of the quartz diorite "dikes" found in the granite in the central part of the area may have been influenced by fracturing of the stock hood. Although the pre-mineral faults may not have occurred simultaneously they probably occurred within a relatively short time.

Mineralization and alteration were then affected by the solutions from the cooling magma. When the stock became cooled to a sufficient
temperature there occurred a settling and adjustment of the area. This caused the final stage of normal faulting. The Nabigo is the only fault that can be definitely assigned to this age, although several of the minor faults are possibly post-mineral.

Summary

In summary it may be said that during the Laramide revolution the area was compressed causing folds, reverse faults, and probable over-thrusting. Intrusion then occurred, followed immediately by pre-mineral faulting. Contact metamorphism began shortly after intrusion. Minor amounts of other igneous rocks invaded both the hood of the stock and the sedimentary rocks. Cooling and shrinkage of the stock caused a settling and readjustment of the crust. This produced the final, post-mineral stage of faulting.
The ore deposits in the Contention area are of the contact metamorphic type. The mineralogical assemblage, especially that of the gangue minerals, and the metamorphism of the sedimentary rocks of the area lead to this conclusion. Brown\(^5\) pointed out that the deposits at the Contention mine and in the upper portion of the Senator Morgan resembled high temperature vein deposits. He also mentioned that if this is true then they were superimposed upon the earlier contact deposits.

The ore minerals, pyrite, chalcopyrite, pyrrhotite, sphalerite, magnetite, specularite, and some galena, are closely associated with the contact gangue minerals, garnet (andradite), actinolite, hedenbergite, wollastonite, chlorite, and epidote. The ore is in favorable beds in limestone near the contact with the granite. The ore minerals have replaced the limestone, having been localized by faults and fractures.

The gangue minerals were probably deposited during the initial metamorphism which caused the recrystallization of the Escabrosa limestone. The additive metamorphism is represented by both the gangue minerals and by the sulfides. The sulfides may have been contemporaneous with or later than the silicates.
Hypogene Mineralization

Copper is the most abundant metal in the deposits as a whole, and occurs predominantly as chalcopyrite. Zinc occurring as sphalerite is predominant at the Contention mine although some copper with silver is present. The small quantities of chalcocite and native copper are apparently secondary.

The ore-bearing solutions were probably given off shortly after intrusion of the magma and continued until after the consolidation of the hood as evidenced by the mineralized fractures in the granite itself. One such fracture to the southeast of the Contention mine contains a remnant of mineralization in the form of oxidized copper minerals. The solutions may have been either gaseous or liquid or both. In the Contention area they evidently contained iron, magnesium, sulfur, silica, copper, zinc, lead, some silver and a small amount of manganese. The source of these elements cannot be stated for certain. The base metals, copper, lead, zinc, silver, manganese, and sulfur, probably came from the magma itself. The iron, magnesium, and silica probably also came from the magma but may have been derived in part from the alteration of the sedimentary rocks. From all indications, it appears that the sedimentaries in the area are relatively shallow, on the periphery at least, so not a great quantity of material would be supplied by them.

Several pockets in the garnet contain ore associated with a relatively small amount of silicate gangue. Where the granite has been exposed in the mine workings, the ore is on the limestone side at a distance from the contact. Garnet was the first gangue mineral deposited and quartz the last, according to Brown.\(^6\)

\(^{66}\) Brown, R. L., op. cit., p. 29, 1926.
Supergene Mineralization

Most of the ore produced at the Contention mine and in the Twin Buttes district as a whole has been from unenriched deposits. The cause of the lack of secondary enrichment in the deposits is probably due to the impermeable character of the rocks as a result of the massive silicates and the easily and quickly mended fractures in the limestone. Then, too, it is possible that a sufficient amount of ore has not been exposed in the geologic past to supply the necessary materials for extensive enrichment. The only large secondarily enriched deposit which was found close to the surface occurred at the Senator Morgan mine.

Mineralogy

Ore Minerals

Native Copper (Cu) — The native copper found in the area is evidently secondary. A considerable amount\(^{17}\) was taken from the upper part of the chalcocite zone in the Copper Queen mine.

\(^{17}\) Foy, William, personal communication.

Pyrite (FeS\(_2\)) — Pyrite is very widely distributed, having been found in all the mines. It was the first of the sulfides to be deposited and occurs as euhedral crystals cut by, or altered in part to, chalcopyrite. At the Senator Morgan\(^{18}\) pyrite is closely associated with the contact silicates.

\(^{18}\) Brown, R. L., op. cit., p. 32, 1926.

Pyrrhotite (Fe\(_{1-x}\)S with \(x\) between 0 and 0.2) — Although occurring in minor amounts, pyrrhotite is commonly associated with pyrite and was deposited earlier than chalcopyrite.
Chalcopyrite (CuFeS₂) — The chief ore mineral of copper in the area has been chalcopyrite. It is later than pyrite and pyrrhotite, the minerals with which it is almost invariably associated. A study of polished sections of ore from the Contention mine showed some chalcopyrite altered to chalcocite and earlier than sphalerite.

Sphalerite (ZnS) — Sphalerite is not abundant in the Twin Buttes district except at the Contention where zinc is the chief metal produced.

Galena (PbS) — Galena was reported from the upper portions of the Senator Morgan deposit. Some was found at the Contention mine.

Chalcocite (Cu₂S) — Apparently the Minnie ore contained chalcocite in the upper 50 feet. Some has been noted in the polished sections from the Contention where it replaces chalcopyrite.

Magnetite (FeFe₂O₄) — Magnetite is very abundant at the Senator Morgan mine.

Hematite (Fe₂O₃) — Hematite, as an alteration product of magnetite, occurs in quantity at the Senator Morgan.

Pyrolusite (MnO₂) — The presence of pyrolusite (?) as dendritic deposits on fracture surfaces is common.

Malachite (CuCO₃ · Cu(OH)₂) — Malachite is the most common carbonate of copper and occurred in nearly all the near surface deposits.

Azurite (2CuCO₃ · Cu(OH)₂) — Azurite occurred sparingly throughout the area. It is commonly associated with malachite.

Chrysocolla (CuSiO₃ · 2H₂O) — Chrysocolla is widely distributed but not abundant in near surface deposits.

Allophane (Al₂SiO₅ · nH₂O) — Allophane is present in small quantities as a vitreous, pale blue, and brittle surface coating on chrysocolla.
Gangue Minerals

Andradite ($\text{Ca}_3\text{Fe}_2\text{(SiO}_4\text{)}_3$) – Andradite is very common and quite abundant in the area. It is widely distributed, being localized in favorable limestone beds by faults and fractures. It is practically always associated with the other contact silicates, especially epidote. At the Contention it is practically the only silicate present according to Foy, and occurs mostly between the ore and the granite. So extensive are the exposures of the garnetized limestone that the larger ones have been plotted on the map.

Actinolite ($\text{Ca}_2(\text{Mg,Fe})_5\text{Si}_8\text{O}_{22}(\text{OH})_2$) – Actinolite is found at the Senator Morgan with chlorite, magnetite, pyrite, chalcopyrite, and some sphalerite.

Hedenbergite ($\text{CaFeSi}_2\text{O}_6$) – An examination of the Senator Morgan dump showed hedenbergite closely associated with actinolite and chlorite.

Epidote ($\text{Ca}_2(\text{Al,Fe})_3\text{(SiO}_4\text{)}_3(\text{OH})$) – Epidote is very widely distributed throughout the area, being most abundantly associated with the garnet. It is common in the Cretaceous (?) quartzite and in some places makes up about 50 per cent of the cementing material.

Quartz ($\text{Si}_2\text{O}_4$) – At the Contention mine quartz is the most common gangue mineral. Two generations are observed in the polished sections. Replacement quartz occurs in much of the sedimentary rock in varying amounts.

Wollastonite ($\text{CaSiO}_3$) – Wollastonite is common at the Senator Morgan mine where it is associated with actinolite, hedenbergite, and chlorite.

Chlorite ($\text{(Mg,Fe)}_5(\text{Al,Fe})_2\text{Si}_3\text{O}_{10}(\text{OH})_8$) – The dump at the Senator Morgan shows chlorite closely associated with actinolite, hedenbergite, pyrite, magnetite, chalcopyrite, and some sphalerite.
Calcite (CaCO₃) - Calcite occurs in small amounts as a secondary mineral in the gangue at the Contention mine. It is, of course, the main constituent of limestone.

Aragonite (CaCO₃) - Aragonite is commonly found in the limestone fissures and is secondary.

Siderite (FeCO₃) - A small mass of siderite was found on the surface in the vicinity of the Contention mine.

Paragenesis

Brown⁴⁹ states that the order of deposition of the ore minerals was

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⁴⁹ Brown, R. L., op. cit., p. 29, 1926.

pyrite, pyrrhotite and magnetite, chalcopyrite and sphalerite, and marcasite. The writer's examinations of polished sections made of the ore from the Contention mine showed that pyrite was deposited first, followed by quartz, sphalerite, chalcopyrite, chalcocite, and a little second generation quartz, and calcite.

No definite sequence was determined for the gangue minerals although garnet was evidently first with chlorite and quartz last. This late stage quartz can probably be correlated with the late quartz in the Garnion fault and in other fissures of the granite. It may possibly represent a second, feeble but yet separate, stage of mineralization.

Mining

Historical Summary

The history of mining in the Twin Buttes district began in 1896⁵⁰

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with the claims located by a Mr. Baxter who, with E. G. Bush, later formed the Bush-Baxter Mining Company. Some work was carried on in portions of the Senator Morgan and Copper Queen ore bodies but the extensive development did not begin until 1903 when the Twin Buttes Mining and Smelting Company took control of the area. Operations from that time up through 1926 were intermittent but reasonably productive. The companies concerned were the Twin Buttes Mining Company; the Bush-Baxter Mining Company; the Glance Mining Company; the American Smelting and Refining Company; and the Midland Copper Company. The mines consisted of the Copper Queen, Copper Glance, Bullion, Minnie, Senator Morgan, Gladstone, and Contention (formerly the North Star). Several other prospects are present throughout the area.

Contention Mine

Work began at the Contention Mine in 1919 when the shaft was sunk to a depth of 210 feet. Several crosscuts have been made from the 150 and 210 levels to the south and west. These intersect a garnet zone containing the ore, and the Escabrosa limestone, both dipping southwest and striking approximately N 60° E. The ore was mainly of zinc with some copper and silver but none was shipped in the early days.

The mine was operated from 1914 to 1916, and for a short period in 1917. Production during this period amounted to $230,000. The ore contained about 11.5 per cent zinc, 1.9 per cent copper, and about 1.6 ounces of silver per ton.
Minnie Mine

The Minnie Mine is located in the north part of the area, about 1 1/2 miles west of the Copper Queen mine. The depth reached was 250 feet with levels every fifty feet. Oxidized copper ore was located in the upper portion and copper sulfide, mainly chalcopyrite, in the lower part down to the quartzite on the lowest level. The shaly limestone was apparently more easily replaced than was the purer limestone which has been silicified. 53


Production was carried on in the early days of the district and also in 1929 when a small shipment was made. Apparently, there is still some ore available at this mine. The total production, according to Foy, 54 has been about $1,282,000.

54 Foy, William, personal communication.

Gladstone Mine

The Gladstone shaft was sunk in 1924 and 1925 by Edward Foy. Water, which was later used to supply the Twin Buttes camp, was struck at a depth of 365 feet. The total depth of the shaft is 420 feet, and, according to Foy, 55 was all in garnet. On the 400 level 700 to 800 feet of drifting was done mostly in the general direction of the Senator Morgan. One drift extends from the shaft to the north for 60 feet. No granite was found in the workings, and metallic sulfides were entirely absent.

55 Foy, Edward, personal communication.
Map of southern Claims of Twin Buttes Area
Garnet Queen Prospect

The Garnet Queen prospect consists merely of a shaft 100 feet in depth. No granite was struck, and like the Gladstone, no metallic sulfides were noted.

Other Prospects

To the west on the Morgan fault there is a prospect where some copper carbonate was located. Several other prospecting shafts are located throughout the area but apparently were in zones devoid of mineralization. The deeper prospects are noted on the geologic map (Plate 1).

Future of the Area

Most of the known ore bodies of the area are exhausted. Some low-grade copper remains at the Minnie mine and zinc and copper ore is still present at the Contention mine. The possibility of small deposits elsewhere still exists, especially in connection with the Morgan fault. The Gladstone shaft, although 120 feet deep, may still be too shallow to expose some small ore bodies. A close investigation of the area should be preceded by a detailed preliminary study of past operations.
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A. View looking northeast from a point west of the Gladstone shaft. Hills in left background are the Twin Buttes.

B. Head frame of Minnie mine, looking northeast. Twin Buttes town is in right background.
A. View looking northeast showing Cartion fault from a point 400 feet west of the Contention mine.

B. Abrigo formation showing differential weathering.
A. Nanno formation.

B. Mass of garnetized Escabrosa limestone near Contention mine.
A. Abrigo formation, view on bedding plane surface.

B. Contact of quartz diorite and granite in arroyo 1500 feet northwest of Contention mine.
A. Photomicrograph of biotite granite showing orthoclase (o), plagioclase (p), quartz (q), and alteration products. Crossed nicols. X 55.

B. Rhyolite porphyry with phenocryst of highly altered orthoclase (o). Crossed nicols. X 55.
A. Photomicrograph of biotite granite dike showing fine-grained quartz (q), plagioclase (p), and sericitic alteration. Crossed nicols. X 55.

B. Biotite granite showing zoned euhedral crystal of plagioclase (p) in quartz (q), orthoclase (o), and plagioclase. Crossed nicols. X 55.
A. Polished section of ore from Contention mine showing quartz (q), gangue, chalcopyrite (cp) as blebs in sphalerite (sp) and being replaced by chalcocite (cc). X 70.

B. Polished section of chalcopyrite (cp) blebs in sphalerite (sp). X 70.
A. Polished section of ore showing chalcocite (cc) replacing chalcopyrite (cp) and surrounded by quartz (q). X 70.

B. Photomicrograph showing sphalerite (sp), chalcopyrite (cp), and carbonate gangue (cg). X 70.