PETROGRAPHIC STUDY OF A QUARTZ DIORITE STOCK
NEAR SUPERIOR, PINAL COUNTY, ARIZONA

by

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SIGNED: 

APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

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Date
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ABSTRACT

An igneous stock in the vicinity of the Silver King mine, north of Superior, Pinal County, Arizona, has been mapped and studied. The stock has been found to be composed of five phases which from oldest to youngest are porphyritic hornblende quartz diorite, fine-grained biotite quartz diorite, medium-grained biotite quartz diorite, dacite porphyry, and aplite. This stock, of probable Laramide Interval age, has been emplaced into host rocks which are predominantly Precambrian Pinal Schist and Apache Group formations, and post-Cambrian diabase.

Chemical analyses of composite samples for two alteration zones and five intrusive phases provide data for trend diagrams and ternary diagrams of normative feldspars and normative orthoclase, quartz, and plagioclase. The trends are basically those to be expected from normal differentiation, but some details of the values of the total alkalies to silica ratio indicate a possible abnormal loss of volatile components; however, other interpretations can be made.

The Silver King ore body was an intricate stockwork about a barren quartz core. Two alteration zones show an introduction of sericite and quartz into dacite porphyry. This change in composition is shown best by the number of cations present in a unit volume of 100 oxygen anions.
INTRODUCTION

This thesis is a description and interpretation of the petrology of a quartz diorite stock three miles north of Superior, Pinal County, Arizona. A literature search and a field trip to the Superior district in 1963 suggested that a detailed study of this area might result in a worthwhile contribution to the knowledge of the geology of south-central Arizona because of at least three observations. First, the indicated history of emplacement of the stock is complex but still decipherable, possibly offering another example of crystallization differentiation. Second, the associated Silver King mine ore body with related wall-rock alteration is economically significant and possibly derived from the stock. Third, the stock was thought by Ettlinger (1928) to be a portion of his "central Arizona batholith." It is felt that some valuable observations have been made and the data herein are presented with the intent that others will find them useful in understanding the process of differentiation of an igneous intrusion, the development of a hydrothermal mineral deposit, and perhaps the characteristics of the postulated "central Arizona batholith."

The stock was mapped on a base map which is a portion of the 7.5 minute Superior quadrangle topographic map. The contour interval is 40 feet and the scale has been enlarged to 1:4400. The mapped area is located three miles north of Superior in the basin drained by Silver King Wash and its tributaries northwest of the prominent dacite cliffs and south of Peachville Ridge in the southernmost Superstition Mountains.
The stock has an exposure of about three square miles in secs. 13, 14, 23, and 24, T. 1 S., R. 12 E., Gila and Salt River Base Line and Meridian. The terrain is moderately dissected and the vegetation cover is light to moderate, so that there are good exposures of the rock units over most of the area. The area is accessible by a maintained dirt road which connects the Silver King mine and State Highway 60-70 one mile west of Superior. The field work was conducted during the summer of 1964 and the fall of 1965. Field mapping was supported by thin-section analysis and identification of rocks and chemical analyses of composite samples of the principal igneous rock types. These chemical analyses have been used to develop trend diagrams for the major oxides and a ternary diagram of normative orthoclase, plagioclase, and quartz for the principal igneous rock types.

Previous Geologic Studies

The Superior mining district has been of interest since 1873, the discovery date of rich silver ore on the Silver King property, the locale of the first mining claim to be entered in the Pinal County records. Several investigations of the economic geology of this district have been made. The earliest was by Blake (1883) in which the Silver King mine was described. Ransome (1914) described the mines of this district, and Galbraith (1935) mapped most of the stock as part of a dissertation on the economic geology of the Silver King mine. Short et al. (1943) described the geology and ore deposits of the district, and Wilson (1950) described the economic geology of the Superior district in a report which includes a geologic map.
Geologic Setting

The Superior quartz diorite stock is intruded into a sequence of metamorphic and sedimentary rock units of Precambrian and Paleozoic ages. The Precambrian complex consists of older Precambrian Pinal Schist and younger Precambrian Apache Group, the latter subdivided into Scanlon Conglomerate, Pioneer Shale, Barnes Conglomerate, Dripping Spring Quartzite, Mescal Limestone, and a basalt flow (Ransome, 1903; and Shride, 1961) A diabase of post-Cambrian age (Shride, 1961) is intrusive into this Precambrian complex. The Paleozoic section (Short et al., 1943) crops out in the vicinity of Superior, although only the Escabrosa Limestone crops out within the area mapped in this study.

At the base of the prominent escarpment to the east of Superior, the Whitetail Conglomerate of Tertiary age (Wilson, 1952) commonly fills depressions in an old erosional surface and occurs in depositional contact with the stock. Tertiary dacite flows (Wilson, 1952) form the prominent escarpment and overlie a large area to the east of the cliffs.

The areal relationships of the stock to the principal metalliferous occurrences and to other Laramide intrusive bodies in south-central Arizona is shown in Figure 1.
Figure 1. Map Showing Location of Study Area
METAMORPHIC AND SEDIMENTARY ROCKS

Pinal Schist

Pinal Schist, the oldest rock unit in the area and of older Precambrian age, was named and described by Ransome (1903) in the Globe-Ray area of central Arizona. Pinal Schist is the predominant rock unit bordering the stock. Here the Pinal Schist is typically a dark reddish-brown, very fine-grained, and imperfectly schistose metamorphic rock containing quartz, orthoclase, plagioclase, and hornblende. Along the western border of the stock, the schist locally contains lenses of coarse-grained quartz, grossularite, epidote, and calcite. In the north-west corner of the area, the Pinal Schist contains quartz, plagioclase, and orthoclase, with minor accessory biotite, and has a gneissic texture. Pinal Schist is overlain unconformably by the Apache Group.

Apache Group

The Apache Group was described by Ransome (1903) in the Globe-Ray area, although he assigned the age as Cambrian. Ransome divided the group into basal Scanlon Conglomerate, Pioneer Shale, Barnes Conglomerate, Dripping Spring Quartzite, Mescal Limestone, and a basalt flow. The age of this sequence has since been determined to be younger Precambrian (Shride, 1961).

The Scanlon Conglomerate occurs in the Silver King area as a two-foot-thick layer of reddish iron-stained quartzite pebbles and quartz
sand consolidated and metamorphosed into a quartzitic conglomerate, with an average strike of N. 70° E. and a dip to the south.

The Pioneer Shale varies from a reddish-brown, massive, fine-grained quartzite to a thin-bedded arkosic quartzite in which some muscovite occurs along parting planes. The contact with the fine-grained biotite quartz diorite phase is sharp. Within the mapped area the Pioneer Shale is overlain by Dripping Spring Quartzite. The Barnes Conglomerate which is normally present between Pioneer Shale and Dripping Spring Quartzite is not present in the mapped area. Dripping Spring Quartzite is typically a tan to reddish, locally arkosic, medium-grained quartzite. There is no alteration of the quartzite at its contact with the quartz diorite. The Dripping Spring Quartzite is overlain by Mescal Limestone.

Mescal Limestone is typically a white to gray, siliceous dolomitic limestone with cherty layers. This unit has been intruded by medium-grained quartz diorite and shows some weak silication with minor development of serpentine, talc, chlorite, specular hematite, chalcopyrite, and andradite at the contact. The adjacent intrusive rock contains calcite and hornblende.

Along the southeastern edge of the stock there is a schistose biotite-rich rock which is strongly sheared. It weathers easily and is poorly exposed. The only fresh material crops out at the exposure of the contact in Yellowjacket Wash. This rock remains unidentified and its position in the stratigraphic sequence is unknown.
Diabase

Diabase is the name that has historically been given to a plagioclase- and hornblende-bearing rock which occurs in the mapped area. This rock does have a diabasic texture; however, the interstitial mafic mineral is hornblende rather than augite. It might be more accurately called a hornblende diabase than a diabase.

A typical outcrop of this diabase is a greenish-black massive rock which on closer inspection has a salt-and-pepper appearance resulting from a diabasic intergrowth of plagioclase and a mafic mineral. In thin section this mafic mineral was determined to be hornblende. In support of this observation Ettlinger (1928, p. 12) has found that hornblende is the "usual essential constituent" of the diabase at the Magma mine, three miles to the southwest of the study area.

In the mass of diabase entirely enclosed with the fine-grained quartz diorite in the southeast quarter of section 14 and in the nearby projection of diabase in section 13 (Fig. 2, in pocket) the diabasic texture has been largely destroyed and the rock has been recrystallized into an equigranular, medium- to coarse-grained rock composed of about 60 percent plagioclase and 40 percent hornblende with minor variable amounts of biotite, chlorite, epidote, and quartz in some thin sections. The rock commonly contains clots and stringers of coarse hornblende. Fine-grained quartz diorite adjacent to diabase has a higher percentage of biotite, a lower percentage of quartz, and a smaller grain size than the normal fine-grained diorite.

The diabase has intruded Pinal Schist, Pioneer Shale, and Dripping Spring Quartzite in the mapped area and has been intruded by
fine-grained quartz diorite and medium-grained diorite. The fine-grained quartz diorite locally has a chilled border up to twelve feet wide which is enriched in mafic minerals at the contact with diabase, as for example along the contact in the northwest quarter of section 13 and about the enclosed mass of diabase in the northwest quarter of section 14. This chilled zone shows a gradational contact with diabase and a sharp contact with fine-grained quartz diorite, and it contains clots and stringers of coarse hornblende. The diabase does not appear to have been affected by the intrusion of the medium-grained quartz diorite, the contact between them being sharp.

Thin-section examination shows the diabase to be an inequigranular diabasic phanerite composed of 50 percent plagioclase (An53), 40 percent hornblende, 7 percent magnetite, and 3 percent chlorite, with apatite and hematite present as accessory minerals. Plagioclase grains up to 5 mm long and 1 mm wide occur as euhedral tablets showing albite twinning and minor kaolinization. The plagioclase is 53 percent anorthite by optical determination on albite twins cut normal to (010). Hornblende grains up to 1 mm in size are anhedral and interstitial to the plagioclase laths. This hornblende appears to be primary, and there is no evidence that it has replaced earlier augite. Opaque minerals, predominantly magnetite with some hematite, occur as subhedral grains less than 1 mm in size. Chlorite after biotite occurs as anhedral grains less than 1 mm in size commonly enclosing magnetite grains.
**Escabrosa Limestone**

Although the Paleozoic section typical of central Arizona crops out in the vicinity of Superior, the only Paleozoic formation within the mapped area is the Mississippian Escabrosa Limestone. The Superior sequence of Paleozoic rocks has been described by Short et al. (1943). The Escabrosa Limestone east of the Silver King mine is a thickly bedded, white to gray, coarsely granular limestone. It shows no alteration near its contact with medium-grained quartz diorite.

**Whitetail Conglomerate**

The Whitetail Conglomerate, possibly of Miocene age (Wilson, 1952), occurs at the base of the dacite cliffs in low spots on the predacite surface. Whitetail Conglomerate is in depositional contact upon the medium-grained quartz diorite east of the Silver King mine. The Whitetail Conglomerate occurs as a white, unconsolidated gravel composed of fragments of intrusive igneous rock. Most of the material is in the coarse sand size range, but cobbles up to three inches in diameter are present. This unit was quite well exposed in 1965 by an earlier brush fire and heavy summer rains which then removed the overlying talus from the dacite cliffs. Bluffs of Whitetail Conglomerate up to ten feet high were exposed at that time.
IGNEOUS PETROGRAPHY

Early in the field mapping it was verified that the quartz diorite had a complex history of emplacement. It has been possible to divide the stock into five distinct phases on the basis of texture and mineralogy. From the oldest to youngest these phases are (1) porphyritic hornblende quartz diorite, (2) fine-grained biotite quartz diorite, (3) medium-grained biotite quartz diorite, (4) dacite porphyry, and (5) aplite. A later dike, locally known as the Grandfather Lead, is also described. Descriptions of each of these units are presented here and the genetic relationships are described in the section on petrogenesis.

Porphyritic Hornblende Quartz Diorite

A porphyritic border facies of the quartz diorite stock in which hornblende is the dominant mafic mineral is exposed in the northern part of the area as two principal masses forming a northeast-trending belt (Fig. 2, in pocket).

The porphyritic hornblende quartz diorite is intrusive into Pinal Schist and diabase and is in turn intruded by fine-grained quartz diorite. The contact with Precambrian host rocks is sharp except for a brecciated zone containing fragments of very fine-grained quartz diorite along the southern edge of the western porphyry body. The contact with fine-grained quartz diorite varies from gradational, where the percentage of phenocrysts decreases and the grain size increases as the fine-grained quartz diorite is approached, to sharp where the fine-grained quartz
diorite can be seen to be intrusive into the porphyritic quartz diorite.

The unit is exposed as rounded outcrops and residual boulders on the steep southern slope of Peachville Ridge. A typical outcrop is massive, dark gray, and has a spotted appearance attributable to the presence of hornblende phenocrysts up to 2.5 cm in length. The porphyritic hornblende quartz diorite is the most variable of the facies of the quartz diorite stock. The percentage of phenocrysts ranges from zero to 30 percent, and the texture ranges from aphanitic to phaneritic.

In thin section, this rock is seen to be a porphyritic hornblende quartz diorite composed of 20 percent hornblende phenocrysts in a fine-grained groundmass which is predominantly plagioclase and quartz with some orthoclase, hornblende, and magnetite. The hornblende phenocrysts are long, narrow, dark-green laths which occur singly and as clusters of several crystals which radiate from a central magnetite grain. The fine-grained groundmass is equigranular, and the individual grains are subhedral to anhedral.

The normative mineral assemblage given in Table 2 has been calculated from the chemical analysis given in Table 1. The values are given as percentages by weight as compared to the modal mineral analyses which are given as percentages by volume. The normative results for the porphyritic hornblende quartz diorite are orthoclase 8.5 percent, albite 30.0 percent, anorthite 34.5 percent, wollastonite 1.2 percent, enstatite 6.3 percent, quartz 14.4 percent, and magnetite 5.2 percent. The calculated plagioclase composition is 53 percent anorthite.
Table 1. Chemical Analyses of Principal Rock Types of the Quartz Diorite Stock Three Miles North of Superior, Pinal County, Arizona

<table>
<thead>
<tr>
<th>Oxide</th>
<th>As Run</th>
<th>Recalculated</th>
<th>As Run</th>
<th>Recalculated</th>
<th>As Run</th>
<th>Recalculated</th>
<th>As Run</th>
<th>Recalculated</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>58.11</td>
<td>58.71</td>
<td>59.26</td>
<td>59.53</td>
<td>60.20</td>
<td>60.81</td>
<td>64.53</td>
<td>65.23</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>19.30</td>
<td>19.50</td>
<td>18.93</td>
<td>19.02</td>
<td>18.23</td>
<td>18.42</td>
<td>17.88</td>
<td>18.08</td>
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<tr>
<td>Total Fe as Fe₂O₃</td>
<td>7.28</td>
<td>7.36</td>
<td>7.06</td>
<td>7.09</td>
<td>6.42</td>
<td>6.49</td>
<td>4.75</td>
<td>4.80</td>
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<tr>
<td>CaO</td>
<td>7.40</td>
<td>7.48</td>
<td>7.08</td>
<td>7.11</td>
<td>8.04</td>
<td>8.12</td>
<td>6.64</td>
<td>6.71</td>
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<tr>
<td>MgO</td>
<td>2.21</td>
<td>2.23</td>
<td>2.01</td>
<td>2.02</td>
<td>1.50</td>
<td>1.52</td>
<td>0.80</td>
<td>0.81</td>
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<tr>
<td>Na₂O</td>
<td>3.28</td>
<td>3.31</td>
<td>3.64</td>
<td>3.66</td>
<td>3.16</td>
<td>3.19</td>
<td>2.88</td>
<td>2.91</td>
</tr>
<tr>
<td>K₂O</td>
<td>1.40</td>
<td>1.41</td>
<td>1.56</td>
<td>1.57</td>
<td>1.44</td>
<td>1.45</td>
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<td>1.46</td>
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<tr>
<td>Loss</td>
<td>1.16</td>
<td>1.41</td>
<td>1.56</td>
<td>1.57</td>
<td>1.44</td>
<td>1.45</td>
<td>1.44</td>
<td>1.46</td>
</tr>
<tr>
<td>Total</td>
<td>100.14</td>
<td>100.00</td>
<td>100.15</td>
<td>100.00</td>
<td>100.02</td>
<td>100.00</td>
<td>100.04</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Accuracy of the "As Run" values is ± 0.1%. All values are given as weight percents. The "Recalculated" values are normalized to 100.00% on a loss-free basis for the first five analyses.
Accuracy of the "As Run" values is ± 0.1%. All values are given as weight percents. The "Recalculated" values are normalized to 100%. For the last two analyses, all loss is presumed to be due to chemically held water.
Table 2. Normative Mineral Assemblages of the Quartz Diorite Stock Three Miles North of Superior, Pinal County, Arizona

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Porphyritic Hornblende Quartz Diorite</th>
<th>Fine-grained Biotite Quartz Diorite</th>
<th>Medium-grained Biotite Quartz Diorite</th>
<th>Porphyry Dacite</th>
<th>Aplite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orthoclase</td>
<td>8.5%</td>
<td>9.4%</td>
<td>8.7%</td>
<td>8.8%</td>
<td>18.2%</td>
</tr>
<tr>
<td>Albite</td>
<td>30.0%</td>
<td>33.1%</td>
<td>29.0%</td>
<td>26.6%</td>
<td>34.1%</td>
</tr>
<tr>
<td>Anorthite</td>
<td>34.5%</td>
<td>31.1%</td>
<td>32.1%</td>
<td>32.5%</td>
<td>4.1%</td>
</tr>
<tr>
<td>Wollastonite</td>
<td>1.2%</td>
<td>1.8%</td>
<td>3.5%</td>
<td>0.6%</td>
<td></td>
</tr>
<tr>
<td>Enstatite</td>
<td>6.3%</td>
<td>5.7%</td>
<td>4.3%</td>
<td>2.3%</td>
<td>1.5%</td>
</tr>
<tr>
<td>Quartz</td>
<td>14.4%</td>
<td>14.0%</td>
<td>17.8%</td>
<td>25.9%</td>
<td>35.5%</td>
</tr>
<tr>
<td>Magnetite</td>
<td>5.2%</td>
<td>5.0%</td>
<td>4.6%</td>
<td>3.4%</td>
<td>1.1%</td>
</tr>
<tr>
<td>Corundum</td>
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<td></td>
<td></td>
<td></td>
<td>5.5%</td>
</tr>
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</table>

Values given are as molecular percentages.
**Fine-grained Biotite Quartz Diorite**

In the northern part of the mapped area, a fine-grained biotite quartz diorite occurs as an irregular body which is elongated in a north-westerly direction. Pendants of country rock project into the intrusion (Fig. 2, in pocket). The fine-grained quartz diorite is intrusive into Pinal Schist, Scanlon Conglomerate, Pioneer Shale, Dripping Spring Quartzite, diabase, and porphyritic quartz diorite and in turn has been intruded by medium-grained quartz diorite and the Grandfather Lead.

The contact with the metamorphic Precambrian units is sharp and well defined, but the contact with diabase is locally gradational. In places the contact is marked by a zone of brecciated country rock, as for example along the southern edge of the prominent projection of diabase (Fig. 2). At this location, the contact is marked by a zone of diabase fragments in a matrix of mafic, chilled border facies igneous rock. In section 14, near where the road crosses from medium-grained quartz diorite onto the fine-grained quartz diorite, the host rock is Pinal Schist, and there is a contact breccia containing fragments of quartzite and silicified limestone from a stratigraphically higher formation. Contacts between porphyritic quartz diorite and fine-grained quartz diorite range from sharp to gradational, as previously described. The contact between fine-grained quartz diorite and medium-grained quartz diorite is sharp and well defined and is marked both by a physical discontinuity and an increase in grain size of the feldspars and mafics in the younger medium-grained quartz diorite.

A typical exposure of fine-grained quartz diorite shows a medium-gray, fine-grained phanerite as weathered, rounded outcrops
and residual boulders. A hand sample is composed of nearly equal amounts of plagioclase and quartz and 10 percent biotite. This unit characteristically is fine-grained and weathers to a sandy soil. The rock is poorly jointed at spacings of about one to two feet.

In thin section, this rock is a fine-grained, equigranular, hypidiomorphic phanerite composed of 44 percent plagioclase (An\textsuperscript{47}), 40 percent quartz, 6 percent biotite, 4 percent magnetite, 4 percent orthoclase, 1 percent chlorite, and up to 1 percent apatite by point count. Plagioclase occurs as euhedral grains up to 2 mm in size, showing albite and Carlsbad twinning, and with uncommon oscillatory zoning. The plagioclase is 47 percent anorthite by optical determination using the Michel-Levy technique, the method used on all plagioclase determinations in this study unless otherwise noted. Orthoclase occurs as rare euhedral grains up to 2 mm in size, showing Baveno twinning, compositional zoning, and some minor alteration of cores. Biotite occurs as shreds up to 1 mm in size, some of which are altered to chlorite. The pleochroism of the biotite is from light yellowish brown to dark brown, and the cleavage planes are bent. Quartz grains are less than 1 mm in size, anhedral, have undulatory extinction, and are interstitial to the other mineral grains. Small apatite crystals are present, usually within quartz grains.

The normative mineral assemblage is orthoclase 9.4 percent, albite 33.1 percent, anorthite 31.1 percent, wollastonite 1.8 percent, magnetite 5.0 percent, enstatite 5.7 percent, and quartz 14.0 percent (Table 2). The calculated plagioclase composition is 47 percent anorthite.
Medium-grained Biotite Quartz Diorite

The third stage of intrusion resulted in a medium-grained biotite quartz diorite. This name is not altogether appropriate and is discussed in the section on petrogenesis. It occurs as an irregular mass which is elongate in a northwesterly direction. There is a notable narrowing of the unit between the mass of diabase and quartzite forming Silverado Ridge and a hill of quartzite to the southwest (Fig. 2).

The medium-grained quartz diorite is intrusive into Pinal Schist, Pioneer Shale, Dripping Spring Quartzite, Mescal Limestone, diabase, and Escabrosa Limestone. There is a nonconformity between the medium-grained quartz diorite and Whitetail Conglomerate. The medium-grained quartz diorite also is intrusive into fine-grained quartz diorite, and in turn is intruded by dacite porphyry and several aplite bodies.

The medium-grained quartz diorite and country rock contact is sharp except where the Mescal Limestone is in contact with the intrusion. The limestone has been silicified adjacent to the stock and to igneous dikes which cut the limestone. These igneous dikes contain calcite and hornblende. As described above, the contact with fine-grained quartz diorite is sharp. The contact with dacite porphyry is not well exposed, but it is sharp where it can be seen. The contact with aplite is also sharp.

The medium-grained quartz diorite is typically exposed as weathered, rounded outcrops of a light-gray, medium-grained phanerite containing slightly more plagioclase than quartz, some orthoclase, and either biotite or chlorite. There are outcrops of the fresh, unweathered
material in the main washes. As this unit weathers it breaks down to a coarse, sandy soil. The rock is well jointed, with joints spaced 6 to 12 inches apart.

In thin section, the main mass of medium-grained quartz diorite is typically an equigranular, hypidiomorphic phanerite composed of 45 percent plagioclase, 35 percent quartz, 10 percent orthoclase, 8 percent biotite or its alteration product chlorite, 2 percent magnetite, and accessory apatite. The sequence of crystallization is plagioclase, magnetite, biotite, orthoclase, and quartz. Plagioclase occurs as euhedral grains less than 3 mm in size, showing albite, Carlsbad and pericline twinning. In some thin sections the plagioclase is partially kaolinized. Biotite forms anhedral shreds up to 3 mm in length. These shreds show typical light yellowish-brown to dark-brown pleochroism and wavy extinction. Chlorite is common as an alteration product of the biotite. Anhedral quartz grains less than 2 mm in size are interstitial and show moderate undulatory extinction. Small dikes cutting the Mescal Limestone contain as calcic-rich components pale-green euhedral hornblende crystals less than 1 mm in size and anhedral interstitial patches of calcite in addition to the more common plagioclase.

The chemical analysis is shown in Table 1. The normative mineral assemblage is orthoclase 8.7 percent, albite 29.0 percent, anorthite 32.1 percent, wollastonite 3.5 percent, magnetite 4.6 percent, enstatite 4.3 percent, and quartz 17.8 percent (Table 2).

Just south of the medium-grained quartz diorite body and about 1500 feet southeast of the Silver King mine is a dike, 10 to 15 feet thick, composed of plagioclase with quartz and some hornblende which is
intrusive into Mescal Limestone. This rock is described here because of its spatial position even though it is best termed a quartz microdiorite. Locally this rock is intensely epidotized. In thin section, the quartz microdiorite is a fine-grained, inequigranular phanerite composed of 50 percent plagioclase, 15 percent quartz, 5 percent hornblende, 2 percent orthoclase, 2 percent magnetite, and accessory chlorite, apatite, and sphene in a very fine grained matrix which comprises 25 percent of the rock. Quartz grains are euhedral and show only slight undulatory extinction. Plagioclase grains are euhedral with Carlsbad, albite, and pericline twinning, and are unaltered but corroded. The anorthite content is 46 percent. Hornblende occurs as euhedral to subhedral grains which are commonly twinned. There is some chloritization of the hornblende. Orthoclase grains are euhedral, show Carlsbad twinning, compositional zoning, and minor development of perthite. The orthoclase is strongly kaolinized, as is the groundmass interstitial to the closely packed visible grains.

Although plagioclase compositions of An46 for the microdiorite dike and An50 for the medium-grained quartz diorite would seem to indicate that the dike is less calcic, it is important to note that there is an increase in the amount of plagioclase and that hornblende is present in place of biotite in the microdiorite dike. The dike, assumed to be a derivative of medium-grained quartz diorite developed by assimilation of Mescal Limestone, has been mapped as medium-grained quartz diorite.
**Dacite Porphyry**

Dacite porphyry, a very fine grained porphyritic rock of quartz diorite composition, is younger than and intrusive into medium-grained quartz diorite. The dacite porphyry occurs as an oval body elongate in an east-west direction (Fig. 2). There are few good exposures of this rock type because it crops out in a topographic low. A typical exposure is one of dark-gray aphanite which is well jointed in three directions at about three- to six-inch intervals. The material tends to be unweathered even in outcrop, and the lack of relief could be due to mechanical erosion of a well-jointed rock. The soil cover is transported gravel.

The dacite porphyry is intrusive into diabase, Dripping Spring Quartzite, and medium-grained quartz diorite. In thin section, the dacite porphyry is seen to be an inequigranular, porphyritic aphanite with 75 percent groundmass. The phenocrysts, which range in size from 1 mm to 5 mm, are plagioclase 10 percent, orthoclase 5 percent, chlorite 5 percent, quartz 3 percent, and magnetite 1 percent by point count. Plagioclase is 57 percent anorthite as determined optically, a value close to the 55 percent anorthite calculated from the normative mineral analysis. Orthoclase occurs as euhedral grains up to 2 mm in size showing Carlsbad twinning and some kaolinization. Chlorite pseudomorphic after biotite is present as anhedral shreds up to 1 mm in size. Quartz grains up to 1 mm in size are anhedral and do not show undulatory extinction. The normative mineral assemblage is orthoclase 8.8 percent, albite 26.6 percent, anorthite 32.5 percent, wollastonite 0.6 percent, magnetite 3.4 percent, enstatite 2.3 percent, and quartz 25.9 percent (Table 2).
Aplite
dikes are intrusive into quartz diorite at several places within the mapped area. In outcrop, the aplite is white to pink, fine grained, sugary textured, and massive.

The aplite is intrusive into medium-grained quartz diorite near the Bilk Shaft and has been intruded along the contact between the medium-grained quartz diorite and dacite porphyry east of the Silver King mine. The contact is very sharp and no contact effects are apparent.

In thin section, the aplite is seen to be a fine-grained, equi-granular, hypidiomorphic rock of aplitic texture composed of 62 percent perthite, 35 percent quartz, 2 percent plagioclase, and 1 percent muscovite, with accessory biotite and apatite present. Pyrite is present in amounts up to 5 percent in the aplite body just north of the Bilk Shaft. The quartz grains are less than 1 mm in size, anhedral, and show undulatory extinction. Very small biotite flakes are wholly enclosed in quartz grains and have not been exposed to alteration. Microperthite, as subhedral grains up to 1 mm in size, is composed of an intergrowth of albite and orthoclase, in which the orthoclase is kaolinized and the albite is unaltered. Plagioclase grains are up to 1 mm in size, subhedral, and partially kaolinized. Muscovite occurs as interstitial blades and masses up to 1 mm replacing orthoclase.

Based on the chemical analysis of the aplite given in Table 1, the normative mineral assemblage is orthoclase 18.2 percent, albite 34.1 percent, anorthite 4.1 percent, enstatite 1.5 percent, quartz 35.5 percent, magnetite 1.1 percent, and corundum 5.5 percent (Table 2).
Grandfather Lead

In the eastern half of section 14 and the northwestern quarter of section 13, a seven-foot thick dike, referred to by local residents as the Grandfather Lead, trends northwesterly. It continues beyond the border of the mapped area to the southwest. Within the mapped area the dike has been offset by several northwest-trending faults.

The Grandfather Lead is intrusive into fine-grained quartz diorite and Pinal Schist. The intruded wall rock does not show any alteration adjacent to the contact, which is sharp and well defined in all cases. The dike rock has been completely altered to a very fine-grained, white, massive rock with the destruction of whatever original textural features that may have been present. It is now composed of quartz, sericite, and limonite after pyrite and is best described as a felsite. In thin section it shows an interwoven structure with abundant sericite blades.
STRUCTURE

Most of the individual phases of the quartz diorite stock show northwesterly to westerly elongations. The literature on the Silver King mine reports that the mineralized stockwork plunges to the west at 70° (Blake, 1883). The Grandfather Lead is offset by several northwest-trending minor faults. Exceptions to this predominant alignment are the porphyritic hornblende quartz diorite, the Grandfather Lead, and some of the veinlets and minor faults which trend northeasterly. A joint attitude analysis of the medium-grained quartz diorite shows an indistinct orientation (Fig. 3).

In mapping the stock, one outcrop was noted which showed a distinct orientation of the biotite parallel to a nearby contact. This orientation was noted in an outcrop of medium-grained quartz diorite east of the Silver King mine.

There is a notable scarcity of xenoliths in this stock. The very few that were noted are up to two inches in diameter and about one-half inch thick with a schistose texture and are composed predominantly of biotite and plagioclase in about equal proportions, with quartz and orthoclase in lesser amounts.
Figure 3. Joint Attitude Diagram of the Medium-grained Quartz Diorite
INTRUSIVE CONTACTS

In places the contact of porphyritic hornblende quartz diorite and fine-grained biotite quartz diorite is gradational. The porphyritic quartz diorite shows a decrease in the percentage of hornblende phenocrysts and an increase in the average grain size as the contact is approached. In other places the contact is sharp and the fine-grained quartz diorite can be seen to be intrusive into the porphyritic quartz diorite. The contact between fine-grained quartz diorite and medium-grained quartz diorite is sharp, well defined, and easily recognized by the increased grain size of the younger medium-grained quartz diorite and by a physical discontinuity. The contact between medium-grained quartz diorite and dacite porphyry is not well exposed, but where it can be seen it is sharp. The contact of the aplite bodies with both medium-grained quartz diorite and dacite porphyry is also sharp.
ALTERATION

The most intense alteration in the area mapped is that which has affected dacite porphyry adjacent to the Silver King ore body. The development of this ore body was accompanied by the development of two zones of alteration with distinctive appearances about a cylindrical core of quartz.

The outermost zone is annular in plan and has a maximum diameter of about 250 feet and a minimum diameter of about 150 feet. The inner ring is also annular in plan and has a maximum diameter of 150 feet and a minimum diameter of about 50 feet. The innermost portion of the mineralized zone is a core composed predominantly of hydrothermal quartz which has entirely replaced the original rock.

The outer alteration zone is composed of a rock which is soft, very fine grained, grayish green and which weathers brownish red. By X-ray diffraction analysis this rock was found to be composed of quartz and sericite. A chemical analysis of this altered rock is given in Table 1. There is very little pyrite to be seen in the rock, and the iron-bearing mineral is undetermined.

In thin section, this altered rock is seen to be a very fine-grained material in which quartz is the only optically identifiable mineral. Ghosts of former phenocrysts can be seen as rectangular areas which are slightly darker greenish gray than the surrounding rock.

The inner alteration ring is a very light gray, fine-grained rock containing up to 50 percent white altered phenocrysts or metacrysts. By
X-ray diffraction analysis this rock also has been determined to be predominantly quartz and sericite. A chemical analysis of the inner alteration zone is given in Table 1.

In thin section, rock of the inner alteration zone is seen to be a very fine grained rock in which quartz is the only optically identifiable mineral. Quartz occurs both as small anhedral grains in the main mass of the rock and in thin veinlets composed of anhedral grains up to 2 mm in size.

The contact between the outer alteration zone and unaltered dacite porphyry is not well exposed anywhere. The contact between the inner alteration zone and the outer alteration zone is well exposed and is very sharp. The main differences between the two alteration zones are the darker greenish color of the outer zone presumed to be caused by the presence of an undetermined iron-bearing mineral and the presence within the inner alteration zone of numerous white altered phenocrysts or metacrysts.

From the chemical analyses, a standard cell containing 100 oxygen atoms has been calculated and the number of the various cations in that cell is shown in Table 3. This volumetric presentation should be valid if the assumption that there has been little change in porosity is valid. The specific gravity of the unaltered dacite porphyry is 2.83 as compared to 2.74 for the outer alteration zone and 2.72 for the inner alteration zone as determined by the use of a Beckman Air Comparison Pycnometer.

As compared to the unaltered dacite porphyry, the outer alteration zone shows an increase in chemically held hydrogen, potassium,
and silicon. In decreasing order, calcium, sodium, aluminum, iron, and magnesium show losses. And as compared to the outer alteration zone, the inner alteration zone shows an additional gain of silicon and a slight loss in potassium and hydrogen. In decreasing order, aluminum, iron, calcium, magnesium, and sodium show losses (Table 3).

The main effects of the alteration have been the addition of quartz and sericite and the breakdown of plagioclase and biotite with a leaching of the basic components.
Table 3. Number of Cations per Unit Cell of 100 Oxygen Atoms for Altered and Unaltered Rock in the Vicinity of the Silver King Mine, Pinal County, Arizona

<table>
<thead>
<tr>
<th></th>
<th>Dacite Porphyry</th>
<th>Outer Alteration Zone</th>
<th>Inner Alteration Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si</td>
<td>36.3</td>
<td>+0.9</td>
<td>37.2</td>
</tr>
<tr>
<td>Al</td>
<td>11.8</td>
<td>-1.4</td>
<td>10.4</td>
</tr>
<tr>
<td>Fe</td>
<td>2.0</td>
<td>-0.6</td>
<td>1.4</td>
</tr>
<tr>
<td>Ca</td>
<td>4.0</td>
<td>-3.4</td>
<td>0.6</td>
</tr>
<tr>
<td>Mg</td>
<td>0.7</td>
<td>-0.3</td>
<td>0.4</td>
</tr>
<tr>
<td>Na</td>
<td>3.1</td>
<td>-2.8</td>
<td>0.3</td>
</tr>
<tr>
<td>K</td>
<td>1.0</td>
<td>+1.8</td>
<td>2.8</td>
</tr>
<tr>
<td>H</td>
<td>-</td>
<td>+10.5</td>
<td>10.5</td>
</tr>
<tr>
<td>Specific Gravity*</td>
<td>2.83</td>
<td>2.72</td>
<td>2.74</td>
</tr>
</tbody>
</table>

*Specific gravity by Beckman Air Comparison Pycnometer.
MINERALIZATION

Small quartz-calcite veinlets which locally contain galena, chalcopyrite, sphalerite, and tetrahedrite occur commonly in fine-grained quartz diorite. Wall rock adjacent to these veinlets has been altered to a greenish rock which is a mixture of quartz and sericite.

Near the head of Fortuna Wash, the area around the Fortuna mine shows extensive brecciation and alteration. The Mines Handbook (Weed, 1931) states that the workings of this mine consisted of a 430-foot shaft and two adits which explored the intersection of two veins. Tetrahedrite, argentite, ruby silver minerals, galena, and chalcopyrite are reported but cannot be seen on the property today. No ore shipments are known to have been made.

The surface expression of the Silver King ore body is a small but conspicuous hill in an otherwise low-lying basin. The ore body was mined to a depth of 800 feet, and a glory hole about 100 feet in diameter has been opened in what was the top of the hill. The ore body occurred as a stockwork of sulfide-bearing quartz veinlets in the previously described inner alteration zone. This entire zone had been shattered into blocks averaging some two or three feet in diameter. According to Blake (1883), the ore zone was an annulus about 150 feet in outer diameter with a plunge of 70° W., which surrounded a core of barren massive quartz with kaolinized orthoclase, barite, calcite, and minor sulfides. The wall rock at the surface is dacite porphyry, which has been profoundly altered, although some of the dump material indicates that
altered medium-grained diorite occurs as the wall rock some place at depth. The ore minerals are native silver, argentite, polybasite, stromeyerite, tetrahedrite, chalcocite, galena, green sphalerite, and chalcopyrite. Pyrite was observed in the outer alteration zone but not in the ore zone. These minerals can still be seen on the dump. Ransome (1914, p. 158) indicates that the workings probably bottomed in uneconomic sphalerite-bearing vein material. The mineralized veinlets are composed of quartz with common open spaces lined with comb quartz. The ore minerals occur in the central portion of the veinlets as discontinuous stringers and can occur well crystallized in open spaces.
CHEMICAL TRENDS

A composite sample of three, four, or five typical hand specimens was made for each of the five intrusive phases and the two alteration zones. These samples were ground to minus 200 mesh using a ceramic mortar and pestle and analyzed by the methods in specification C114-63, Standard Methods of Chemical Analysis of Portland Cement, of the American Society of Testing Materials. This method was dictated because the analyses were made by the author in the portland cement plant laboratory of the California Portland Cement Company. In such a laboratory, SiO$_2$, Al$_2$O$_3$, CaO, MgO, Na$_2$O, K$_2$O, and loss on ignition are determined routinely; however, TiO$_2$ is not determined and FeO is oxidized to Fe$_2$O$_3$. All separations are made by double precipitation and direct oxide weighing. The results are accurate to $\pm 0.1$ percent. The results of these analyses are shown in Table 1. The samples were not run in duplicate.

Silica shows a range among the five intrusive phases from 58.71 percent to 74.19 percent. Alumina varies from 16.4 to 19.50 percent, iron oxide from 1.58 percent to 7.36 percent, and lime from 0.82 to 8.12 percent. Magnesia shows a variation of 0.55 to 2.23 percent, sodium oxide varies from 2.91 to 3.77 percent, and potassium oxide varies from 1.41 to 3.05 percent.

When the intrusive phases are arranged in the order determined by field relationships as brought out in the section on igneous petrography, there is a systematic increase in silica from the oldest to
youngest phase. There is a corresponding drop in alumina, iron oxide, and magnesia, as shown on the variation diagram (Fig. 4). The percentage of potassium oxide increases, the percentage of calcium oxide generally increases, and the percentage of sodium oxide varies irregularly within a small range as silica decreases, as shown on the variation diagram (Fig. 5). The nonsystematic variations shown on the variation diagrams are the lower than expected percentage of calcium oxide for the fine-grained quartz diorite and the higher than expected percentages of sodium oxide for the fine-grained quartz diorite and the aplite. These trends follow the normal pattern of an igneous rock series formed by crystal differentiation (Huang, 1962).
Figure 4. Variation Diagram of $\text{Al}_2\text{O}_3$, $\text{Fe}_2\text{O}_3$, $\text{MgO}$ : $\text{SiO}_2$
Figure 5: Variation Diagram of $K_2O$, $Na_2O$, CaO : SiO$_2$
PETROGENESIS

One of the initial observations in this study was the variation in grain size and composition of the igneous rocks occurring in the mapped area. The major portion of the study has been the task of deciding what differences exist among the rock types, if any, and which variations in rock type are significant and consistent enough to be mappable. The earlier works already cited have consistently termed the rock of this stock a quartz diorite. Only Galbraith (1935) had previously recognized any separate phases. In his dissertation he termed the rock in the vicinity of the Silver King mine a quartz monzonite porphyry.

The ratio of orthoclase to total feldspar is 0.8:10 for the fine-grained biotite quartz diorite and 1.8:10 for a medium-grained biotite quartz diorite. A quartz diorite (tonalite) is classically defined as having less than 10 percent of the total feldspar as orthoclase. On the basis of this classification the stock observed was initially of a quartz dioritic composition and later developed a granodioritic composition.

A ternary diagram (Fig. 6) is presented which shows the five phases plotted in terms of their normative contents of quartz, orthoclase, and plagioclase. The trend line developed shows no enrichment of potassium until the development of the aplite as the stock crystallized.

It is difficult to know what to call the dominant rock of the stock. Since the initial phases were quartz diorite and historically the term quartz diorite has been applied to this stock, the present study has
Figure 6. Ternary Diagram of Normative Quartz, Orthoclase, and Plagioclase
used the term quartz diorite to describe the stock and the term medium-grained biotite quartz diorite to describe the third phase.

The intrusion of hornblende-bearing magma into a cupola-like chamber as a northeast-trending arcuate mass of porphyritic hornblende quartz diorite was the first event in the emplacement of the stock to leave evidence at the present surface.

The intrusion of the porphyritic hornblende quartz diorite was followed by the development of the fine-grained biotite quartz diorite as shown by the previously described contact relationships. The change in composition from porphyritic hornblende quartz diorite to fine-grained biotite quartz diorite shows an increase from 0.080 to 0.086 in the proportion of alkalies to silica ($\%Na_2O + \%K_2O$/\%SiO_2). These values have a precision of ± 4 percent and the ranking may be significant.

Barth (1962) comments that hornblende is the usual mafic mineral in a quartz diorite. He has also cited Rittman in describing how the relative concentration of alkalies to silica reflects certain events which have occurred during the emplacement of a composite stock. In particular, Barth (1962) states that a relative enrichment of alkalies to silica can be indicative of a transfer of volatile components from deeper in the magma chamber. He further comments that potassium contributing to form biotite rather than orthoclase can be indicative of a high water content in the magma.

The gradational contact observed locally between the porphyritic hornblende quartz diorite and the fine-grained biotite quartz diorite indicates that these two rock types are part of the same event and the second rock type has developed from the first essentially in place with some
local movement where there is a sharp contact between the two rock
types.

The chemical and mineralogic evidence indicates that this por-
tion of the magma was being enriched in alkalies and water concurrent
with the crystallization predominantly of plagioclase and the dissolution
of hornblende. One possible mechanism for this enrichment is by the
introduction of components from deeper portions of the magma chamber
as suggested by Barth (1962). Another possible mechanism is by the
introduction of components from outside the magma chamber. It has been
shown by Kennedy (1955) that a magma undersaturated in water can cause
a chemical gradient in the adjoining host rock and that water could mi-
grate in the direction of undersaturation into the magma until the defi-
ciency was met. An additional possible source is the relative
concentration of components not being incorporated into crystallizing
fractions until the concentration reaches a level at which a fraction
containing that component is stable.

Development of the medium-grained quartz diorite was the next
event in the history of the stock. The change in composition from the
fine-grained biotite quartz diorite to the medium-grained quartz diorite
shows a decrease from 0.088 to 0.076 in the proportion of alkalies to
silica. Barth (1962) cites Rittman in describing how such a decrease can
indicate that the magma chamber was ruptured thereby allowing a portion
of the volatile components to escape from the magma. An alternative
explanation for the relative enrichment of silica might be assimilation
of a quartzite; however, there is no evidence of assimilation at the con-
tact with Dripping Spring Quartzite, and there are no quartzite xenoliths
in the quartz diorite. An additional explanation is the relative depletion due to crystallization with corresponding enrichment of other components. A plot of normative feldspars (Fig. 7) shows a reversal of trend between fine-grained biotite quartz diorite and medium-grained biotite quartz diorite. This reversal is contrary to what would be expected to result from typical magmatic differentiation and indicates an abnormal loss of sodium.

The next even in the history of the stock was the development of the dacite porphyry in the vicinity of the Silver King mine. The change in composition from the medium-grained biotite quartz diorite to the dacite porphyry shows a further decrease in the proportion of alkalies to silica from 0.076 to 0.067. Figure 7 indicates that the direction of the trend line between these two rock types is still contrary to that expected if magmatic differentiation were the only mechanism.

There is also a marked textural difference between medium-grained biotite quartz diorite and dacite porphyry. This change is consistent with a change of environment which could be due to a cooling of the magma or a release of pressure, which could have been caused by fracturing of the magma chamber and loss of volatiles or removal of overlying host rock.

The larger gap shown in Figures 4 and 5 between medium-grained biotite quartz diorite and dacite porphyry at first suggests an interval of time of longer duration between the development of these two rock types than occurred between the development of earlier rock types; however, the relative sizes of surface exposures of the various rock types suggests that the relative enrichment in silica could be the result of
Figure 7. Ternary Diagram of Normative Feldspars
magmatic differentiation in a magma of a much reduced volume as compared to earlier phases. In such a reduced volume, the crystallization of a given volume of a component should occur in a shorter period of time.

The development of the aplite bodies was the next intrusive event. The chemical composition of these bodies is much different than that of the preceding phase. Figure 7 indicates a reversal of trend back to the direction to be expected during magmatic differentiation and the alkalies to silica ratio changes from 0.067 to 0.092 between dacite porphyry and aplite. Figure 6 indicates a marked increase in potassium whereas the trend up to this point does not show the expected enrichment of potassium which should be developed during magmatic differentiation.

With the exception of the contact with hornblende diabase, along which there appears to have been some chemical reworking of the host rock, the available evidence indicates that the development of the porphyritic hornblende quartz diorite and the fine-grained biotite quartz diorite was by physical displacement rather than by anatctic development in place or by chemical assimilation by an advancing magma. This evidence is the generally sharp but locally brecciated contact between igneous and host rocks, the lack of partially digested xenoliths, and the lack of visible mineralogic change in the host rocks near the contact.

The sharp contact between fine-grained biotite quartz diorite and medium-grained biotite quartz diorite, the sharp igneous-host rock contact, and the lack of chemical change except for limited silication of Mescal Limestone are interpreted as indicating a second distinct
injection of magma by physical displacement of the preexisting host rock. One limited area shows a network of dikes intruding the host rock in such a manner as to indicate that there has been some stoping of host rock.

The final event in the emplacement of the quartz diorite stock was the development of various hydrothermal mineral deposits, in particular the Silver King ore body. When the chemical composition of the inner alteration zone about the Silver King ore body is compared with that of the aplite, the aplite is seen to be lower in silica and higher in alumina, iron, and lime. If the assumption is valid that the inner alteration zone was in equilibrium with the hydrothermal solution which developed the Silver King ore body, then the ore body was formed after the emplacement of the aplite bodies by a mineralizing fluid which was saturated in silica and potassium and undersaturated in alumina, calcium, sodium, iron, and magnesium as indicated by the gains and losses shown on Table 3.

Even though the outer alteration zone is conspicuously colored, presumably by an iron-bearing mineral, the percentage of iron present is 1.4 percent, which is intermediate between that of the unaltered dacite porphyry and that of the inner alteration zone (Table 3). The scarcity of pyrite and the light-green color of sphalerite in the ore of the Silver King mine and the decrease in iron in both alteration zones as compared to the unaltered dacite porphyry indicate that iron was not an abundant constituent of the ore fluid. These findings, in particular the chemical analyses, show that there is not a "basic front" about the ore body as
might be assumed upon casual inspection of the outcrops of the outer alteration zone.

Hand-specimen and thin-section study and chemical analyses of the altered and unaltered dacite porphyry indicate that the predominant effect in the outer alteration zone has been the decomposition of plagioclase and a leaching of calcium and sodium with an accompanying addition of water and potassium and the crystallization of sericite. The main effect in the inner alteration zone has been the addition of quartz with an accompanying leaching of aluminum and iron.
SUMMARY

The stock located three miles north of Superior, Pinal County, Arizona has been found to have an overall composition which places it at the dividing line between a granodiorite and a quartz diorite. As the indicated initial composition is that of a quartz diorite and the trend line on a diagram of normative quartz, orthoclase, and plagioclase does not show an enrichment in potassium until the last stage in the development of the stock, the name quartz diorite or the aphanitic equivalent dacite has been used for all but the last of the rock types of the stock. Five separate rock types have been recognized and mapped as separate units. They are porphyritic hornblende quartz diorite, fine-grained biotite quartz diorite, medium-grained biotite quartz diorite, dacite porphyry, and aplite. This order is by decreasing age as shown by field relationships and by increasing silica content of the chemical analyses.

The typical mafic mineral of a quartz diorite rock is hornblende. The presence of biotite rather than hornblende in all except the earliest phase of the quartz diorite stock indicates higher than normal water, and possibly potassium, content of the magma. This saturation of water in the magma and the weak contact metamorphic effect on adjacent limestone host rocks are discrepancies which have not been resolved in this study.

In addition to the chemical trends that would be expected for a composite body developed by normal magmatic differentiation, there is an abnormal loss of sodium and potassium between some phases. One
explanation considered in the section on petrogenesis is the loss of volatiles from the system at times during crystallization of the stock. But others must be considered.

The presence of sharp igneous-host rock contacts, contact breccias, small dikes in the host rock, and a large mass of diabase completely engulfed by quartz diorite suggests that the magma was injected by a process of physical displacement of the host rock accompanied by some stoping but with little chemical assimilation evidenced from the field observations. Late in this study it became apparent that the question of the role of assimilation has not been completely resolved and detailed observations of the plagioclase compositions near contacts might best resolve this question.

The mineralized pipe at the Silver King mine has been found to have two distinct zones of alteration as halos about the pipe. The outer zone shows a strong development of sericite and a leaching of calcium and sodium while the inner zone shows an addition of quartz and a leaching of aluminum and iron. If the assumption that the compositions of the alteration zones were in equilibrium at the time of their formation is valid, then the points plotted on Figures 5 and 6 indicate something of the composition of the hydrothermal fluid from which the sulfides and sulfosalts of the Silver King ore body were deposited.

The chemical analyses place this stock in the extreme calcic class of the Rittman classification and indicate that the stock could be orogenic in origin (Barth, 1962, p. 172). Ettlinger (1928) noted the areal relationships of mining districts and Laramide intrusive igneous outcrops in central Arizona as shown in Figure 1. He proposed that these features
were the surface expression of a poorly exposed "central Arizona batholith" of Laramide age and further suggested a causal relationship between the batholith and the ore deposits of the region.

The Laramide intrusive outcrops in Figure 1 occur in an area approximately 40 miles northwesterly by about 20 miles northeasterly. This areal extent is certainly adequate to meet the requirements of a batholith, but this does not indicate whether or not these bodies are from the same magmatic source. This question cannot be resolved by considering any one igneous body but rather only by comparisons between intrusive bodies. The chemical analyses and petrogenic conclusions presented in this study together with additional similar data for other nearby intrusive bodies should provide such comparisons.
REFERENCES


REFERENCES


