Geology and Ore Deposits of the Sand Springs Mining District
Churchill County, Nevada

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Geology

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ABSTRACT

The Sand Springs mining district is 50 km southeast of Fallon, Churchill County, Nevada. The district was mined from 1937 to 1951 and has a recorded production of 39,300 kg of silver and 650 kg of gold, a total value of about $1,800,000.

The oldest rocks exposed in the district are phyllite, conglomerate, sandstone, and limestone which are probably correlative with the Upper Triassic Grass Valley Formation. In the Cretaceous, the sediments were intruded by the granitic Sand Springs pluton. The Tertiary was marked by multiple periods of volcanism, the oldest producing a thick accumulation of rhyolite tuffs. This was followed closely by the intrusion of dikes and plugs of andesite, rhyolite, and basalt. The youngest volcanism resulted in extensive basalt flows that unconformably overlay the tuffs.

Silver production was from the intrusive andesite hosted epithermal Summit King vein which ranges in width from 1 m to 5 m and trends east-west for over 4 km. Hypogene ore minerals consist of pyrite, argentite, gold-electrum, and possibly galena, sphalerite, chalcopyrite, and bornite. The near surface ores were enriched in secondary silver chloride and bromide. Gangue minerals include quartz, calcite, adularia, barite, and dolomite which exhibits epithermal vein characteristics of open-space filling, banding, and combing. The host andesite has been extensively propylitized adjacent to the vein.
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INTRODUCTION

Location and Physical Setting

The Sand Springs mining district is 50 km southeast of Fallon, Churchill County, Nevada (see Figure 1). The district is situated at Sand Springs Summit, a low pass separating the Stillwater Range to the north and its southern extension, the Sand Springs Range. Fairview Valley lies to the east, Fourmile Flat to the west. U.S. Highway 50 passes through the center of the district.

The mining district and adjacent areas mapped for this study are located in sections 1, 2, 3, 4, 10, 11, and 12, T61N, R32E, and Sections 6 and 7, T15N, R33E, Mount Diablo Baseline and Meridian. The area is covered by the Frenchman and Fourmile Flat USGS 7.5' quadrangles, 1:24,000 scale.

The Stillwater and Sand Springs Ranges are north-trending fault block mountains typical of the Basin and Range province. Fairview Valley and Fourmile Flat have minimum elevations of approximately 1,200 meters, the ranges attain a maximum of 1,600 m, making the relief of the area about 400 m. The low rolling hills of Sand Springs Summit give way to steep mountain slopes to the north and south. Figures 2 and 3 are photographs of the area.

Previous Work

B.M. Page (1965) compiled a preliminary geologic map of the
Figure 2: View of Sand Springs Pass and mine workings along the Summit King vein. Highway 50 is in the foreground. Looking southeast.

Figure 3: View of main mine workings. The Dan Tucker dump and shaft are on the left, and the mill foundation is on the right.
Stillwater Range (1:125,000 scale) published as Nevada Bureau of Mines Map 28. A large-scale map of the Sand Springs district by the Stanford Summer Field Camp (Compton and Page, 1951) appears in Nevada Bureau of Mines Bulletin 83 (Willden and Speed, 1974), which also contains a 1:250,000 geologic map of Churchill County and a brief description of the geology and production of the Sand Springs mining district.

The geology of the Sand Springs Range was mapped (Nevada Bureau of Mines, 1964) at a scale of 1:31,680 as part of the investigation prior to the Shoal Event, an underground nuclear test conducted by the Atomic Energy Commission. The mapped area included the Sand Springs district.

Triassic metasediments exposed in the southern end of the Sand Springs Range were mapped by Abdullah (1966) and by Banaszak (1969). A regional study of geology of the Carson Sink area was undertaken by Morrison (1964).

**Scope of the Project**

The ore deposits of the Sand Springs district are epithermal veins associated with Tertiary andesite volcanics. This study focused on the vein system with emphasis on regional geologic setting, host rock, structure, vein texture, mineralogy, and alteration.

In order to provide an adequate regional geologic setting, 25 km² was mapped at a scale of 1:10,000 (Plate 1). This area is about 3 km north to south by 8 km east to west, and extends from Fairview Valley to Fourmile Flat, and from the Sand Springs pluton on the south to the Tertiary volcanics on the north. The field mapping
was completed on black and white air photos and the information transferred to a 1:10,000 base map compiled from an enlarged topographic base.

Four weeks were spent on fieldwork during the months of January and February, 1977. Twenty thin sections of the metasediments and vein host rocks were examined. Seventeen samples from various locations throughout the district were analyzed for gold, silver, and other elements.

Acknowledgments

The writer is grateful for the assistance given by many individuals and companies. Particular gratitude is expressed to my thesis committee: Drs. Lawrence T. Larson (Chairman), Arthur Baker III, and Larry J. Larsen. Dr. Anthony Payne introduced the district to the writer and offered valuable suggestions during the course of the study. Dr. John W. Whitney gave freely of his time for discussions and help with complex field interpretations. Larry Garside, Nevada Bureau of Mines, aided in the understanding of the regional geology and arranged for an age date on the vein material. Invaluable assistance was received from Messrs. E.B. Bell and D.L. Stevens of Freeport Exploration Company, Reno office. Sand Springs Silver, Inc. and Mr. T.A. Brackney kindly gave permission to work on their properties.
History

Total recorded production from the Sand Springs district is 650 kg of gold and 39,300 kg of silver in 92,600 metric tons of ore. The total value was $1,756,000, based on metal prices at the time of production. Most of the mining activity took place during the years 1939 through 1941 and 1948 through 1951 (see Figure 4).

The area was first prospected by C.W. Kinney in 1905 (Schrader, 1947, pp. 297-299; Vanderburg, 1940, pp. 40-41). Vanderburg (1940, p. 40) relates the history prior to 1938:

"... very little work was done until 1912, when Leslie L. Leonard and C.W. Kinney sank a 100-foot shaft. The first production was made in 1919 by lessees, who shipped three carloads of ore yielding $215 to $300 per ton. The Dan Tucker Mining Company was organized in 1925, and in the following year it leased the mine to Smith, Towle and Young, who in 1927 erected a small amalgamation mill at Sand Springs in which 1,000 tons of ore was treated. In 1931, the property was acquired by another company, and in 1938 it was awarded to E.E. Tailleur, Fred Tailleur and Dick Kemp on a labor lien. The owners proceeded to work the mine and shipped 10 carloads of rich ore . . . ."

In 1938, Bralorne Mines, Ltd., of Vancouver, B.C., obtained a lease and organized a subsidiary, Summit King Mines, Ltd., to operate the Dan Tucker and other district mines. Dobson (1940, p. 50) reported that development work by Bralorne included the sinking of a shaft to the 60 and 90 m levels where a continuous orebody 1 to 3 m in width and approximately 250 m in length was blocked out. Ira Joralemon was mine geologist and president of Summit King Mines, Ltd. (Peter Joralemon, personal communication).

During 1939, Summit King Mines, Ltd. shipped 266 tons of
Figure 4: Recorded production from the Sand Springs Mining District
(From Willden and Speed, 1974, p. 80; compiled largely from U.S. Bureau of Mines Minerals Yearbook for years listed.)

<table>
<thead>
<tr>
<th>Year</th>
<th>Gold (kilograms)</th>
<th>Silver (kilograms)</th>
<th>Ore Mined (metric tons)</th>
<th>Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1923</td>
<td>**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1924-1929</td>
<td>**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1930</td>
<td>**</td>
<td>**</td>
<td></td>
<td>910</td>
</tr>
<tr>
<td>1931-1934</td>
<td>**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1935</td>
<td>0.3</td>
<td>4</td>
<td>10</td>
<td>460</td>
</tr>
<tr>
<td>1936</td>
<td>**</td>
<td>**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1937</td>
<td>0.7</td>
<td>54</td>
<td>130</td>
<td>2,140</td>
</tr>
<tr>
<td>1938</td>
<td>5.1</td>
<td>193</td>
<td>200</td>
<td>9,700</td>
</tr>
<tr>
<td>1939</td>
<td>6.5</td>
<td>325</td>
<td>300</td>
<td>14,400</td>
</tr>
<tr>
<td>1940</td>
<td>153.4</td>
<td>9,168</td>
<td>18,790</td>
<td>382,260</td>
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<tr>
<td>1941</td>
<td>179.3</td>
<td>9,283</td>
<td>18,770</td>
<td>414,040</td>
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<td>1942-1947</td>
<td>**</td>
<td></td>
<td></td>
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<tr>
<td>1948</td>
<td>82.0</td>
<td>5,113</td>
<td>10,680</td>
<td>241,100</td>
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<tr>
<td>1949</td>
<td>113.4</td>
<td>5,434</td>
<td>16,520</td>
<td>285,775</td>
</tr>
<tr>
<td>1950</td>
<td>75.0</td>
<td>6,227</td>
<td>16,510</td>
<td>265,590</td>
</tr>
<tr>
<td>1951</td>
<td>34.1</td>
<td>3,469</td>
<td>8,500</td>
<td>139,335</td>
</tr>
<tr>
<td>1952-1965</td>
<td>**</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>TOTALS</td>
<td>649.8</td>
<td>39,270</td>
<td>91,340</td>
<td>$1,755,820</td>
</tr>
</tbody>
</table>

* Based on gold and silver prices at time of production.
** No recorded production or not disclosed.
smelting ore containing 6 kg of gold and 320 kg of silver (Merrill and Gaylord, 1940, p. 385). In late 1939, a 65 mt/day countercurrent cyanide plant was constructed and production began in 1940. Selective mining resulted in mill heads averaging 7 g gold and 640 g silver per ton (Dobson, 1940, p. 52). With the exception of the war years, the mine and mill operated from mid-1939 to 1951.

From 1952 until 1975, the mine lay idle except for small high-grading operations done by property owners. In 1975, Sand Springs Silver, Inc. was formed and a small heap leaching operation started. Approximately 10,000 mt of ore was mined from a vein footwall zone that varies from 8 to 30 m in width. The average grade was 1 g gold and 70 g silver per ton (John Whitney, personal communication).
DISTRICT GEOLOGY

INTRODUCTION

The Sand Springs mining district is situated in an area of complex geologic structure and history. Plate 1 is a 1:10,000 geologic map of the district. The oldest rocks exposed are shale, phyllite, quartzite, conglomerate, and limestone of probable Triassic age which have been subjected to slight regional metamorphism. They are typical of sediments exposed in the surrounding region. In Cretaceous time, the sediments were intruded by the Sand Springs pluton, a granite to granodiorite stock that makes up most of the Sand Springs Range south of the Sand Springs mining district. Contact metamorphism of the sediments was extensive.

Tertiary volcanics are exposed in the northern part of the mapped area, generally in fault contact with the metasediments and granitic rocks. Miocene rhyolite tuffs are unconformably overlain by Pliocene olivine basalt, a sequence typical elsewhere in the Carson Sink.

The structural trend is generally east-west across the pass (see Plate 1), and is a reflection of a major fault system. This fault, hereafter referred to as the Summit King Fault, controlled Tertiary intrusive activity and epithermal vein mineralization. The Tertiary intrusive phase emplaced numerous dikes that cut the granitic, metamorphic, and early Tertiary rhyolitic tuff terranes.
MESOZOIC ROCKS

Triassic Sediments (Trms, Trls)

The oldest rocks exposed in the Sand Springs mining district are sediments of probable upper Triassic age which crop out along the northern contact of the Sand Springs pluton. They are generally confined to a zone 1 to 2 km wide across the entire Sand Springs district.

Structural complexity, contact metamorphism, and lateral variability make individual units difficult to trace in the field. Three distinct sediment lithologies are present having a combined thickness of at least 1,000 m: (1) sandstone, quartzite, and quartzite pebble conglomerate; (2) fine-grained, dark gray carbonaceous shale and phyllite; and (3) fine- to medium-grained recrystallized limestone. Regional metamorphism of the sediments is slight, but contact metamorphism related to the Cretaceous granite is extensive. Due to their complexity, all of the sedimentary and metasedimentary rocks were mapped as a single unit (Trms) with the exception of the thicker exposures of limestone (Trls).

Sandstone, Quartzite, and Quartzite Conglomerate (Trms)

Although definitive stratigraphic relationships are difficult to determine, field relationships indicate that the lowermost mappable sedimentary unit is composed of sandstone, quartzite, and quartzite conglomerate. The unit is in excess of 400 m thick and is variable both laterally and vertically. Outcrops are generally colored white to reddish buff and the rock is characterized by slaty partings and
and blocky, resistant ridges.

The least metamorphosed rocks of this unit consist of arkose and quartz arenite sandstones with angular grains 1 to 2 mm in size. In the upper part of the section there are locally 2 to 5 m thick beds of quartzite pebble conglomerate containing well rounded, cream to light gray colored clasts averaging 1 to 2 cm with occasional clasts up to 10 cm.

Thin sections of the arkosic sandstone show 50 to 60 percent quartz grains, 15 to 20 percent relatively unaltered plagioclase (An_{20-40}), 10 to 15 percent muscovite, and detrital hornblende less than 2 percent. Small quartzite clasts up to 3 mm constitute as much as 5 percent of the rock. The quartz and plagioclase grains are angular to subangular, averaging 0.5 to 1 mm. Sorting and grading were not evident in the thin sections, although definite graded beds were seen in the field.

The plagioclase content of the sandstones is variable. Finer grained varieties contain little or no feldspar, consisting of 60 to 70 percent angular to subangular quartz grains less than 0.3 mm, 20 to 25 percent muscovite, and 10 to 15 percent biotite-chlorite.

Metamorphism within the clastic unit is evident as far away as 500 m from the contact with the Sand Springs pluton. The unit adjacent to the granitic rocks is often a light colored lustrous quartz-muscovite schist which becomes more schistose towards the contact. Foliation generally parallels original bedding. Pebble conglomerate clasts often are elongate or "stretched" along the direction of the bedding plane.
Shale and Phyllite

Argillaceous shale, slate, and phyllite are the most common Triassic sediments and metasediments in the district. Unmetamorphosed carbonaceous shales crop out over a limited area approximately 1 km north of Highway 50 in the western part of the district (east half of Section 3, see Plate 1). Slaty partings characterize the rock, which breaks into plates 1 to 4 cm thick. The shales form low, rounded hills of a distinctive blue-gray color. Variations due to contact metamorphism are marked, the rocks ranging from shale and slate to a lustrous foliated phyllite, and finally into an andalusite or chloritoid schist adjacent to the intrusive.

In thin sections, the less metamorphosed shales are seen to contain 40 to 50 percent opaque carbonaceous material located along fine laminations or concentrated in elongate masses. Fine flakes of clay minerals and mica are abundant and are oriented along the bedding. Small (less than 0.2 mm) relict plagioclase crystals partially altered to clay make up a considerable portion of the rock. Angular fine quartz grains constitute 2 to 5 percent.

The metamorphosed phyllitic equivalents of the shale crop out extensively throughout the district and are the dominant metasedimentary rock type. The phyllites are generally medium gray to black and have a lustrous appearance due to the mica content. They are foliated parallel to the bedding, and often have abundant andalusite and/or chloritoid porphyroblasts oriented with the foliation.

Under the microscope, the dark gray phyllites show a strong
schistose texture. Andalusite crystals up to 1 x 8 mm constitute 20 to 30 percent of the rock, organic material 20 to 30 percent, quartz grains, both discrete and in aggregates, 10 to 15 percent, muscovite 20 percent, and biotite less than 5 percent. The andalusite crystals are often rimmed or replaced by sericite. The groundmass may contain 70 to 80 percent organic matter.

Limestone (Tr1s)

A prominent limestone unit forms a ridge extending east-west across the district, situated immediately to the south of the through-going epithermal vein system. Two other sizable outcrops of the same (?) limestone occur in contact with the granitic rocks: one is located in the southwest corner of Section 12; and the other in the west central part of Section 3 (see Plate 1). This thick limestone is interpreted to be younger than the sandstone and slate-phyllite.

The total thickness of the limestone unit is variable, ranging from 75 to 100 m. East on the limestone ridge, the unit locally thickens due to imbricate thrusting. The limestone is thin-to-medium-bedded, light to medium gray, and medium-to-coarse-grained. The base of the exposed limestone is often silty, fine-grained, finely laminated and platy. A tan chert is sometimes present in discontinuous laminations 2 to 4 cm thick. The limestone is generally recrystallized, often quite coarsely. Large calcite rhombs are common along rehealed fracture zones.

Contact metamorphism is less pervasive in the limestone than in the clastic and argillaceous sediments. Marbleization is best
developed adjacent to shear zones near the pluton. Skarn is absent along the limestone-granite contact, except for a large outcrop in the west-central part of Section 3. At this location, there is an extensive calc-silicate zone consisting largely of light green, fine-grained, epidote-bearing skarn. The granitic rocks adjacent to the limestone are more mafic, almost gabbroic, and contain abundant hornblende, perhaps due to assimilation of the calcium-rich sediments.

Thin, discontinuous beds of limestone are intercalated within the sandstone-quartzite unit. These limestone beds are generally less than 10 m thick, massive, light blue-gray colored and totally recrystallized. The number of individual intercalated beds cannot be determined because of faulting, but at least two are present. The intercalated limestone beds become calc-silicated readily and are the preferred host rock for tungsten mineralization where located near the intrusive contact.

Age and Correlation of Sediments

The Sand Springs district is approximately midway between two areas of west-central Nevada where the Mesozoic sediments have been studied in detail. Specifically, these are the Winnemucca and Augusta Sequences 50 km to the north (e.g., in the northern Stillwater and Humboldt Ranges) and the Gillis and Luning Sequences 50-75 km to the south and southeast (as in the Paradise, Shoshone and Gabbs Valley Ranges) (Silberling and Roberts, 1962, pp. 10-11).

Metasediments of the southern Sand Springs Range, 15 to 20 km south of the district (see Figure 5) are metamorphosed shale, tuffaceous
Figure 5.
Location of correlated Mesozoic sediments referred to in text.

Type section—Grass Valley Formation
(Muller and others, 1951 & B.
Burke and Silberling, 1973)

In the Chalk Mountain and Westgate Mining District, approximately 20 km to the east, 600 to 900 m of recrystallized dolomite was correlated by Bryan (1972, p. 8) with the upper Triassic Gabbs Formation. The same correlation was made by Corvalan (1962, p. 37) for identical dolomites at Westgate.

In the southern Stillwater Range, between Mountain Wells and Eleven Mile Canyon, 15 to 20 km north-northeast of Sand Springs, 1,500 to 3,000 m of predominantly gray-black slates with minor intercalated beds of feldspathic quartzites and limestones contain poorly preserved fossils (Holobia sp) indicative of an upper Triassic age. Page (1965) correlated these sediments with the Grass Valley, Dun Glen, Winnemucca, and Raspberry Formations found further to the north. These and five other formations have been included within the Auld Lang Syne Group by Burke and Silberling (1973, p. E1). The combined formations represent over 7,500 m of argillaceous and sandy strata, with minor limestones and dolomite, deposited during the Upper Triassic and Lower Jurassic (?). The sediments are postulated to have been deposited within a shallow marine deltaic environment.

No fossils were found during the field mapping of the Sand Springs district. Page (1965) reported finding fossils 2 km west-northwest of the Summit King Mine. They were identified by S.W. Muller
as *Myophoria* sp. and *Alectryonia* sp. of probable late Triassic age. Re-examination of these fossils by N.J. Silberling indicates they were misidentified and that no age assignment is possible (Willden and Speed, 1974, p. 12). Without fossil evidence, no definitive age or correlation can be assigned to the sediments. However, based on lithologic similarities to the rocks described by Page (1965) in the southern Stillwater Range, and to the general description of the Grass Valley Formation (Silberling and Wallace, 1969, p. 31; Burke and Silberling, 1973, p. E6; Muller and Ferguson, 1951), it is probable that the Sand Springs sediments are correlative. The age would therefore be Upper Triassic (Upper Karnian and Norian). Age and stratigraphic relationships would also make them correlative with the Luning Formation as described in exposures to the south of Sand Springs (Ross, 1961, p. 23; Silberling and Roberts, 1962, p. 30).

**Cretaceous Granitic Rocks (Kg)**

The granitic Sand Springs pluton constitutes the largest portion of the Sand Springs Range. Exposures of the stock are 5 to 8 km in width and 12 to 15 km in length. Mapping for this study was not carried a great distance into the pluton south of the contact (see geologic map, Plate 1).

Geologists of the Nevada Bureau of Mines (1964) mapped the pluton preliminary to an underground nuclear test conducted by the Atomic Energy Commission. Granite and granodiorite were identified. The granite is generally porphyritic and is more extensive than the granodiorite, which is most common in the west-central portion of the
The granodiorite is intruded into the granite, and in most cases the contact between the two is gradational. Potassium-argon age dating of the granite indicates 79.6 (±2) million years, and the granodiorite 76.0 (±2) million years (Nevada Bureau of Mines, 1964, p. 26), indicating the rocks to be phases of the same intrusive event.

Petrographic work (Nevada Bureau of Mines, 1964, p. 26) shows the granite to consist of 30 to 60 percent hypidiomorphic-granular groundmass of 40 to 60 percent strongly zoned myrmekitic plagioclase (An$_{10-25}$), 25 to 40 percent quartz, 5 to 10 percent microcline, 5 to 10 percent biotite, 0 to 1 percent hornblende, and less than 1 percent sphene, apatite, and magnetite. Microcline phenocrysts up to 5 cm in varying amounts are common in the granite. Petrographic work on samples obtained from the southern portion of the pluton indicate a composition nearer quartz monzonite (Abdullah, 1966, p. 9).

The granodiorite is generally hornblende-rich, equigranular, and medium-grained. Thin sections show a hypidiomorphic-granular texture consisting of 60 to 75 percent zoned myrmekitic plagioclase (An$_{10-35}$), less than 10 percent microcline, 5 to 10 percent quartz, 5 to 10 percent hornblende, 1 to 5 percent biotite, and less than 1 percent sphene, apatite, and magnetite (Nevada Bureau of Mines, 1965, p. 26).

Both granite and granodiorite crop out in the Sand Springs mining district, but are portrayed as a single unit (Kg) on Plate 1. The granodiorite predominates in the western portion of the district, and is typified by varying amounts of hornblende. Locally, large hornblende crystals up to 3 cm long constitute 10 to 20 percent of
the rock.

Several smaller granitic bodies were mapped north of the highway in the west end of the district. The rock is predominantly granodiorite, but locally where it is in contact with a massive limestone unit it is a coarse-grained hornblende gabbro.

**TERTIARY ROCKS**

**Tertiary Rhyolite Tuff (Tt)**

In the northern half of the district, distinctive light multi-colored rhyolitic air fall tuffs and tuffaceous sediments crop out as cliffs. The maximum measurable thickness is approximately 600 m, but the total thickness may exceed this, as nowhere in the district is the base of the unit exposed. Regionally, the rocks rest unconformably upon Mesozoic sediments. Within the Sand Springs district, all exposures are in fault contact with the older rocks. The tuff unit is unconformably overlain by Plio-Pleistocene olivine basalt flows.

The unit consists of both welded and non-welded air fall tuffs, ranging from rhyolite to quartz latite in composition. The color of the tuffs is variable. White is the most common color; shades of pink, green, lavender, and blue are also observed. Welded units are variegated, with vertical zones of alternating colors, where bleaching is found adjacent to fractures. The tuffs are well stratified with distinct compaction foliation of the pumic fragments. Individual units of welded tuff are as much as 30 m in thickness. Some units
are completely devitrified, while others have a glassy matrix. A prominent 5 m thick vitrophyre unit of black glass crops out in the northwest part of the district.

The average tuff unit contains 5 to 10 percent plagioclase phenocrysts, 2 to 5 percent quartz and sanidine, and 5 to 10 percent biotite. The phenocryst content of the tuffs varies, ranging from 5 to more than 30 percent; euhedral quartz phenocrysts averaging 2 mm locally constitute 30 percent of the rock.

The non-welded tuff is a rock with 2 to 5 percent biotite within a clayey matrix. Locally, the non-welded tuff is a coarse breccia containing fragments of more welded tuff as large as 20 cm.

Up to 5 percent of the welded tuffs consist of lithic fragments averaging 2 cm but ranging up to 7 cm. The fragments are light green to black argillaceous phyllite similar to outcroppings of the metasediments. Regionally, lithic fragments in the tuffaceous units increase in size near Fairview Peak, suggesting a possible vent in that area (Willden and Speed, 1974, p. 24). Reihle et al. (1972, p. 1383) suggests a source area for the tuffs approximately 25 km northeast of Sand Springs in the Clan Alpine Range.

The upper 100 to 150 m of the rhyolite tuff is more variable and regionally has been recognized as a Pliocene erosional surface (Morrison, 1964, p. 11). Deep oxidation of the tuffs is locally evident, and several thin beds of tuffaceous sediments containing water-worn clasts less than 1 cm were observed. Interbedded reddish-brown vesicular basalt flows and scoriaceous material are common and represent the initial phases of the Pliocene basalt flows which cap the tuffs.
Tertiary Hornblende Andesite Intrusive (Tai$_2$)

An unaltered intrusive (?) andesite crops out in the north­
eastern part of the Sand Springs district and forms several high
rounded hills (see Plate 1). In addition to this extensive exposure,
a texturally equivalent small plug occurs in the eastern part of the
district just north of the quartz vein. At all locations the andesite
was observed to intrude only the rhyolitic tuffs.

The rock is unaltered and generally consists of a porphyritic
hornblende andesite containing 5 to 10 percent of subparallel horn­
blende crystals up to 2 cm long. The matrix of this rock is sugary
textured, with 10 to 20 percent light colored plagioclase phenocrysts
1 mm or less in size. Equally abundant is a non-porphyritic equigran­
ular andesite of similar composition. The outcrops of both andesites
are blocky and rounded, and are light greenish-gray in color. On a
fresh surface the rock is light- to medium-gray, often shaded pink or
gray-green.

Locally, the andesite consists of a breccia containing large
subangular fragments up to 25 cm of both the porphyritic and non­
porphyrritic andesite. There is evidence of multiple episodes of
brecciation, as the larger fragments are often a numble of smaller
fragments. The small intrusive body near the Summit King vein at the
east end of the district is composed of this andesite breccia. The
age of this unit is uncertain. Based on the lack of propylitic
alteration, it may be later than the Miocene intrusive andesite (Tai$_1$).
Tertiary Intrusive Andesite and Dacite (Tai)

Dikes, sills, and small plugs of andesite, dacite, and rhyolite are exposed throughout the Sand Springs mining district. The intrusives show strong structural control and cut primarily the granitic and sedimentary rocks, although in several instances they were observed intruding the Tertiary tuffs. Similar intrusives are found elsewhere in the Sand Springs Range, as noted by geologists of the Nevada Bureau of Mines (1964, p. 27), who mapped numerous dikes cutting the Sand Springs pluton, and Abdullah (1966, p. 14), who mapped andesite and rhyolite dikes in the southern part of the range.

A large east-west trending andesite dike swarm (see geologic map, Plate 1) provides the host rock for the Summit King vein. Propylitic alteration of the andesite is pervasive and imparts a light- to dark-greenish-gray coloration. The andesite contains numerous flat plagioclase phenocrysts of andesine to labradorite composition ranging in size up to 10 mm, and locally constituting as much as 30 percent of the rock. The phenocrysts weather easily, giving the andesite a distinctive "patchy" or "mottled" appearance.

Under the microscope, the porphyritic andesite shows 50 to 60 percent plagioclase which occurs both as large phenocrysts and as fine-grained groundmass 0.1 to 0.2 mm in size. The phenocrysts are commonly rimmed with calcite and sericite. Other constituents are 20 to 30 percent chlorite, 10 to 20 percent calcite, 2 to 5 percent fine-grained quartz, and less than 2 percent epidote and apatite. Locally the andesite contains 10 to 30 percent hornblende. Pyrite varies from
1 to 5 percent, and often has hematitic rims. Sericite and clay content vary with proximity to the Summit King quartz vein.

Although the andesite intrusives are the most common, numerous dikes and sills of rhyodacitic to rhyolitic composition are also present. They are generally white to tan in color and exhibit both porphyritic and aphanitic textures. The aphanitic variety compositionally is a rhyolite and consists of an intergrowth of quartz and feldspar. The porphyritic variety locally contains up to 30 percent phenocrysts of quartz and/or feldspar, although the average is closer to 2 to 5 percent. In thin section, the phenocrysts are euhedral to anhedral and range in size from 0.5 mm to 3 mm. The groundmass is aphanitic or microphenocrystic and contains abundant sericite. Biotite is locally present and can constitute as much as 3 percent of the rock.

The compositionally variable dikes usually occur in groups of two to five, either in contact with one another, or with 1 to 10 m of phyllite separating them (see Figure 6). Cross cutting relationships of the different dikes is not apparent, so relative ages cannot be assigned, although observations made underground indicate the andesite to be the oldest. Localized deformation associated with the intrusives has caused the bedding of the adjacent phyllites to fold parallel to the dikes. The bedding generally changes attitude a short distance away from the intrusive. Contact metamorphism is insignificant (Figure 7).

The emplacement of the dikes and plugs was structurally controlled. The location of most of the intrusives can be attributed to a structural lineament easily traceable on the ground and on air photos.
Figure 6: (Top) Dike swarm at the east end of the Sand Springs district. Composition, left to right: dacite, rhyolite, and andesite. The prospect pit is on the eastern extension of the Summit King vein. Photo looking east.

(Bottom) Andesite dike swarm at the far eastern end of the district. The dark colored rock is phyllite. Fairview Valley and Peak in background.
The dikes intruding the northern half of the Shield Springs pluton show a consistent N-S to N-E orientation (Kneen and Moritz, 1969, p. 27) that is a reflection of the structural grain of the range. The dike system that hosts the epithermal zone is interpreted to have been displaced along the Seminoe River fault, an east-west trending structure that parallels Neocomian sediments and early Tertiary strata. The fault and associated strike can be traced through the district for over 5 km. On the southeast end of the district the late-magmatic dike is one of several with internal zones to 3 m thick of varying compositions. This differentiation along the strike is key to a general zone of scattered and conducting alteration in the uppermost 1000 ft. above the orebody and in the upper 50 ft. of the orebody. A magnetic phase relationship of the host sediments is evident in the orebody. (Jensen, 1970, p. 600, table)

Figure 7: Contact zone between a rhyolite dike and the dark gray platy phyllite. With the exception of localized disruption of bedding attitudes, the contact effects are slight.
The dikes intruding the northern half of the Sand Springs pluton show a consistent N 50° W orientation (Nevada Bureau of Mines, 1964, p. 27) that is a reflection of the structural grain of the range. The dike system that hosts the epithermal vein is interpreted to have been emplaced along the Summit King fault, an east-west trending structure that placed Mesozoic sediments against early Tertiary tuffs. The fault and associated dikes can be traced through the district for over 5 km. On the eastern end of the district the host andesite dike is one of several well defined dikes 1 to 3 m thick of varying compositions. This distinctive group of dikes gives way to a broad zone of scattered and coalescing plugs and dikes to the west which occupy an area over 1 km wide in the area of the Dan Tucker Shaft (see geologic map, Plate 1). The intrusive nature and multiple phase relationship of the host andesite is evident underground. Dobson (1940, p. 50) states:

"... the Mesozoic (?) sedimentaries have been intruded by a large body of Tertiary andesite having an east-west trend. Intruding the andesite are occasional small rhyolite and basalt dikes ..."

The larger exposures of andesite found within the district were originally mapped by Compton and Page (1951) and Page (1965) as (Jurassic) basalt flows resting unconformably upon the Triassic limestone. The present study indicates the rocks to be intrusive and of Tertiary (Miocene) age.

The age of the dikes and plugs can be approximated by the intrusive relationships and by regional comparisons. The intrusives
were most likely emplaced along a fault zone which offsets the Miocene tuff, and in several locations the andesite was observed intruding the tuff. Corvalan (1962, pp. 113-116) and Bryan (1972, p. 20) describe an east-west trending diorite porphyry dike that is intrusive into rhyolite tuffs of early Miocene age in the Westgate and Chalk Mountain mining districts. The dike was assigned an inter-tuff Miocene age by Corvalan. Dacite and andesite host epithermal precious metal mineralization in the Wonder district (Schrader, 1947, pp. 36-390), and in the Fairview district, the mineralization is confined to a dacitic intrusive body (Willden and Speed, 1974, p. 73). In the Holy Cross district (southern Terrill Mountains), mineralization occurs in tuffs along a contact with an intrusive dacite plug (Willden and Speed, 1974, p. 74). In the Wonder, Fairview, and Holy Cross districts, the dacite and andesite are intruded into early Miocene tuff. The locations of the various mining districts mentioned are shown on Figure 8.

Intrusives and related flows believed to be contemporaneous with the igneous activity identified in the previously mentioned mining districts have been dated at several locations. The ages range widely and indicate a long period of volcanic activity for the Carson Sink. Hornblende from a hornblende andesite plug intrusive into the rhyolite tuff along the northeastern side of the Terrill Mountains yields an age of 21.2 million years. Flow andesite from samples obtained near Fairview Peak provide an age of 27 million years (Willden and Speed, 1974, p. 23).

The intrusive andesite and dacite found in the Sand Springs
Figure 8
Selected Mining Districts of the West-Central Nevada Area.
district is most likely correlative with the above and can be assigned an age within the 20 to 25+ million year range. This would make the andesite late Oligocene to early Miocene, and probably contemporaneous with the inter-rhyolite tuff age assigned to the dike at Westgate by Corvalan (1962, p. 115).

Tertiary Intrusive Basalt (Tbi)

Within the intrusive andesite (Ta) unit that hosts the epithermal vein are small discontinuous dikes and irregularly shaped plugs of basalt (see Plate 1). It is often difficult to differentiate the basalt from the andesite in the field, but generally the basalt is less altered, contains more mafics, and forms dark green to black outcrops that stand out noticeably from the light to medium greenish-gray of the andesite.

The basalt is dark greenish-gray to dark black in color, dense, fine-grained, and microphenocrystic. Commonly it contains abundant labradorite phenocrysts up to 10 mm. In thin section, the rock consists of 20 to 30 percent plagioclase phenocrysts (An$_{40-55}$) in a groundmass of 50 to 60 percent of plagioclase, augite, usually chloritized, constituting to 5 to 10 percent, and pyrite 1 to 2 percent. Propylitization is more apparent in thin section than in outcrop, with the alteration minerals consisting of 5 to 10 percent calcite, 20 to 30 percent chlorite, and 2 to 3 percent quartz. Trachytic texture is readily seen in both thin section and in outcrop. Within the dikes, flat plagioclase phenocrysts commonly show orientation of their long axis parallel to the trend of the dike.
A basalt dike (Tbi) that crops out as a prominent ridge in the vicinity of the Dan Tucker shaft (Plate 1) is near the hanging wall of the Summit King vein. Elsewhere in the district, outcrops of this unit are not as prominent. Small, irregular plugs and discontinuous dikes are more common and because of alteration often appear to grade into the andesite (Tai) unit.

Small, thin basalt flows (?) cap the rhyolite tuff locally north of the Summit King vein. Texturally the basalt flows are similar to the dikes and plugs and probably are an extrusive equivalent. The flow remnants suggest that erosion has not cut deeply since the intrusion and eruption of the basalt.

The basalt is clearly younger than the andesite it intrudes and younger than the erosional surface developed on the tuff onto which the basalt locally erupted. The basalt may have been associated with the early phases of the basaltic and andesitic eruptive event that commenced at least 17.6 million years ago. This age is based on K-Ar dates on hornblende from an andesitic flow in the Cocoon Mountains (Willden and Speed, 1974, p. 28) located approximately 10 km southwest of Sand Springs.

Spatial relationships suggest the basalt intrusives in the Sand Springs district may be temporally related to the alteration and mineralization of the andesite. The prominent basalt dike which is near the vein hanging wall of the Dan Tucker and Summit King Mines and the andesite surrounding the dike and vein have been extensively altered. The basalt dike becomes less distinct to the east of this area, and in the vicinity of Quartz Hill, it is nearly indistinguishable from the
andesite. The extent of alteration tends to diminish in this area. Elsewhere in the district small plugs and dikes of basalt are centers for increased alteration in the andesite.

The writer believes that the basalt represents one of the latest stages of intrusive activity recognized in the mineralized area, and the basalts were emplaced into the andesite along structurally weak zones. It is also plausible that the basaltic magma may have been a geothermal heat source for the hydrothermal activity responsible for the alteration of the andesite and the formation of the vein with associated mineralization found in fractured zones adjacent to and sometimes within the basalt dikes. The age date of 19.5 ± 0.5 million years on vein adularia from the Summit King vein would fit this scenario since the age of intrusion of the basalt is believed to be relatively close, based on regional correlation. Similar spatial relationships of mineralization with basalt intrusives was noted in the Bodie district (Chesterman, et al., 1969, pp. 10-11) and by Schrader (1947, pp. 36-37) in the Wonder district. No relationship of the basalt to the mineralizing event was suggested by Schrader.

Quaternary (?)-Tertiary Flow Basalt (Q-Tb)

Basalt flows cap the mesas along the northern boundary of the Sand Springs district. Numerous dikes and one volcanic vent were also mapped (Plate 1). The near horizontal basalt flows rest unconformably upon the Miocene rhyolite tuffaceous units with an angular discordance of 15 to 20 degrees with the tuffs dipping to the northwest. The thickness of the basalt varies from 30 to over 100 m, with individual
flows ranging from 3 to 15 m. The variable thickness of the flows is a function of the irregular topographic surface upon which they erupted and because of significant inter-eruption faulting. The bottom part of the basalt is interbedded with a 5 to 7 m zone of red scoriaceous rock that rests directly upon the tuffs.

The basalt is generally vesicular and pyroclastic bombs are common atop the flows. It weathers dark reddish-gray to brown and is dark-gray to black on a fresh surface. It is fine-to-medium-grained with olivine and plagioclase phenocrysts in an aphanitic groundmass of feldspar, pyroxene, and mafic minerals. The olivine is generally partially or entirely altered to iddingsite.

Basalt feeder dikes several meters thick are common in the northwestern part of the district. They intrude the tuffs and tuffaceous sediments and can be traced upward to the base of the basalt flows at which point they become indistinguishable from the extrusive rocks. The dikes are most abundant near a volcanic vent area which, in addition to the dikes, is typified by an agglomeration of basaltic breccia and red scoriaceous material. The vent area is approximately 300 m in diameter.

The basalts correlate with the Bunejug Formation of Morrison (1964, p. 14), which has its type location 25 km west of the Sand Springs district in the Bunejug Mountains. It is also correlative with the Plio-Pleistocene basalts and basaltic andesites mapped by Page (1965) as capping the Stillwater Range where their thicknesses exceed 500 m. The age of the earliest basalt flows is most likely Pliocene. Radiometric dating of hornblende from the Cocoon Mountains
(10 km southwest of Sand Springs) yielded 17.6 million years (Willden and Speed, 1974, pp. 23, 28). Basalt eruptions continued intermittently and the uppermost flows may be as young as Early Pleistocene.

**QUATERNARY ROCKS**

**Quaternary Deposits (Qal)**

Alluvial fans consisting of poorly sorted, sub-angular, boulder to coarse gravel are found in the washes and pediment areas of the district. Colluvial deposits 1 to 10 m thick of dark colored basalt scree are found on the slopes beneath the Plio-Pleistocene flows that cap the ridges on the north side of the Sand Springs district. The alluvial fan and basaltic scree deposits are common throughout the region and were mapped and described as the Quaternary Piute Formation by Morrison (1964, p. 23).

The shoreline of Pleistocene Lake Lahontan is evident on the hills in the western part of the district. The lake inundated most of the intermontane valleys of interior drainage in northwestern Nevada. In the district, gravel terraces and tufa deposits common to the Lahontan shoreline are found to an elevation of approximately 1,300 m.

**STRUCTURE**

**Faults**

Faults in the Sand Springs mining district have three major trends: (1) east-west, (2) north 50° to 60° west, and (3) north 10°
to 20° east (Plate 1). The east-west and northwest faults are the oldest and have influenced the emplacement of Tertiary intrusives. The northeast faults are the youngest and are most likely associated with recent Basin and Range tectonics.

Sand Springs Pass, a dominant east-west linear feature, reflects the Summit King fault. This fault strikes approximately east-west and dips 35° to 55° to the south, this attitude being determined by the inclination of the mine workings downward to the 150 m level. In the eastern two-thirds of the district, the Summit King fault has placed the Triassic phyllites adjacent to Miocene rhyolitic tuffs. The total vertical displacement cannot be determined, but probably is in excess of 100 m.

In the western third of the district, the Summit King fault becomes much less distinct. Vertical movement on the northwest trending Red Top Canyon fault, which intersects the Summit King fault just west of the main mining area, has raised the Triassic sediments on the west and has either offset or truncated the older east-west structure. It is possible that the east-west trending andesite dike west of the main mining area (Sections 10 and 11) may be an extension of the Summit King fault. The narrow andesite dike, which can be traced for about 1 km, has intruded the metasediments along an apparent south dipping fault zone similar in orientation to the Summit King fault. A weakly mineralized quartz-calcite vein is within the dike and may represent a deeper exposure of the main vein.

The Summit King fault may be part of a significant east-west structure that can be traced topographically and geologically to the
east for many kilometers. In the Westgate and Chalk Mountain mining districts, located approximately 20 km east, a similar structure was noted by Corvalan (1962, pp. 113-115) and Bryan (1972, p. 20).

A second group of subparallel faults in the district strikes north 50° to 60° west. These faults are most noticeable on the south side of the mining district within the Sand Springs pluton (Plate 1). A majority of the andesite dikes mapped by geologists of the Nevada Bureau of Mines (1964, p. 27) intruded faults along this trend. Movement on these faults was largely vertical. Of the northwest group, the Red Top Canyon fault (southwest part of the district, see Plate 1) had the greatest lateral displacement and significantly offset the contact between the Triassic metasediments and the Sand Springs pluton. This cluster of faults is interpreted to have been active intermittently from shortly after the intrusion of the granite until recently (Nevada Bureau of Mines, p. 32).

Bingler (1971, p. 83) recognized a similar northwest trend of normal faults associated with the Yerington-Nevada Scheelite east-west lineament which is located about 40 km south of Sand Springs. He attributed these faults as being the result of strain created during a late history of right-handed strike-slip movement along the major fault. The northwest trending faults in the Sand Springs district may be associated with the same structure or with similar movement along the Summit King fault.

The faults trending northeast appear to be the youngest major fault set in the district. Most prominent faults of this trend are Basin and Range structures flanking either side of the ranges.
Displacements are large: 1,500 m or more on the east side and 600 m or more on the west side of the range (Nevada Bureau of Mines, 1964, pp. 45-46).

Basin and Range faults have affected the Tertiary volcanics exposed in the northern part of the mapped area, breaking these rocks into a series of tilted fault blocks. Smaller-scale displacements are noted in the metamorphic and granitic rocks, and the dikes intruded into these rocks are commonly offset as much as several tens of meters. The Summit King vein is also locally offset minor distances by faulting along this trend.

The greatest displacement on the Basin and Range faults occurred after the eruption of the Plio-Pleistocene olivine basalts. Pre-eruption and inter-eruption faulting also occurred, significantly thickening the basalt locally, and in many instances it may account for the strong angular discordance between the basalt and the older rhyolitic tuffs.

**Thrusting**

Page (1965) interprets the thick limestone which forms the prominent east-west ridge across the southern part of the district (Sections 7, 11, and 12) as a thrust fault klippen. He named it the Sand Springs thrust and considered movement on it to be large, suggesting it to be an extension of the La Plata thrust he identified 25 km north of Sand Springs in the Stillwater Range. This interpretation of overthrust limestones was presumably based on the brecciation that locally occurs between the limestone and the underlying phyllites.
This study indicates the limestones to be autochthonous, or nearly so, and to form a continuous depositional sequence with the underlying phyllite. The limestone ridge is bounded on all sides by high-angle faults, movement along which has caused local brecciation of the limestones. The phyllite is locally folded in the direction of the fault movement or parallel to the dike that often occupies the fault zone, and this folding has created an apparent angular discordance between the limestone and phyllite. In numerous locations, however, bedding attitudes of the same orientation were observed in both the limestone and phyllite.

Imbricate thrusting of sediments adjacent to the Sand Springs pluton was probably a result of the Cretaceous intrusive activity. Imbricate thrusting occurs in the quartzite and quartzite conglomerate unit in the western part of the district (Section 11, see Plate 1). Another thrust occurs on the eastern end of the limestone ridge (Section 7), this perhaps due to rotation resulting from movement on the bordering high-angle faults. In both of these instances, the thrusts are recognized by fault brecciation and a strong angular discordance in bedding within the upper and lower plate blocks. The small, isolated limestone outcrops in the southeast corner of Section 7 are likely fault-bound klippen that have been thrust only short distances.

**Folding**

The Triassic sediments are poorly exposed and complexly faulted in the Sand Springs mining district making recognition of
large-scale folds difficult. The intrusion of the Cretaceous pluton may have folded the sediments near its contact and could account for the small, shallow synclinal folds which occur in the limestone ridges of the southern part of the district (Sections 11 and 12). These folds may also be due to vertical movement along the bordering faults.

Cenozoic rocks are notably unaffected by folding.

ALTERATION

The predominant alteration type exposed in the Sand Springs mining district is propylitization of the andesite. In nearly all exposures, whether in the main mining area or in small outlying bodies, the andesite is propylitized, imparting a distinctive light green color to the rocks. The later stage basalt which intrudes the andesite is also propylitized, but generally less extensively than the andesite.

Propylitic alteration products, as observed under the microscope, consist of 20 to 30 percent chlorite, 10 to 20 percent vein and pervasive calcite, 2 to 5 percent fine-grained quartz, minor adularia and epidote, variable amounts of sericite, and minor zeolites (?). Pyrite (2 to 10 percent) occurs as fine-grained disseminations and as aggregates along the margins of calcite and quartz veinlets. Microscopically, pyrite locally constitutes 20 percent of the altered andesite, and occurs both along open fractures and as disseminations throughout the rock. Chalcedony was found in some samples, and in one area chalcedony forms tear-shaped globules up to 5 cm long.
Argillic alteration of the andesite is locally extensive adjacent to the Summit King vein and along the margins of most of the basaltic intrusions (Tbi unit) where it forms large, irregularly shaped bleached areas. These areas are generally light yellowish-gray to white in color and consist largely of clays of the kaolinite and montmorillonite groups. The bleached areas are often iron-stained, and may contain abundant quartz veining in close proximity to the main vein. Gypsum plates and veinlets are common in the argillic zones. The argillic alteration could be related to supergene weathering of the pyrite. A comparison of the dumps from the deeper workings to those of the more shallow workings indicates the clay zone is most extensive above what is interpreted to be the 90 m level. The andesite from the deeper levels is propylitized, but bleaching is minor.

Bleaching of the phyllite is extensive in one area located in the eastern end of the district (southeastern part of Section 7). The phyllite is altered to a moderately soft, clay-rich, grayish-white colored rock in an area that has been intruded by a number of andesite and basalt dikes. Thin, braided pegmatitic quartz veins and iron staining are locally abundant along fractures in the phyllite. Samples of the altered phyllite were anomalous in copper, lead, zinc, and silver (see Appendix).

Other than the area mentioned above, no extensive hydrothermal alteration of the sediments was observed. Minor bleaching of the phyllite and silicification of small breccia zones in the limestone are locally present adjacent to the Summit King vein.
GEOLOGIC HISTORY

The Upper Triassic rocks of west-central Nevada are shallow marine sediments deposited on and around a large westwardly prograding deltaic complex (Burke and Silberling, 1973, p. E13). The sediments consist of over 7,500 m of largely argillaceous and silty terrigenous clastics with lesser amounts of shallow-water limestone and dolomite precipitated during periods of a reduced influx of clastics. The rivers transporting the sediments are postulated to have drained the eastern Great Basin, Colorado Plateau, and the Rocky Mountains (Silberling and Wallace, 1969, pp. 30-49; Burke and Silberling, 1973, p. E13). The deposition of the sediments lasted at least into the Early Jurassic.

The delta was situated in a basin marginal to the west coast of the North American continent and was part of an arc-trench complex that persisted during the Upper Paleozoic through the Lower Mesozoic (Silberling, 1973, p. 345). The basin was bordered by a volcanic arc on the west and by the continent on the east. The arc-trench resulted from the subduction of the oceanic plate, and the collapse and expansion of the basin recorded a complex history of submarine volcanism, on-continent thrusting, and subsequent terrigenous sedimentation.

In Late Cretaceous time, the granitic rocks of the Sand Springs pluton were emplaced. Extensive metamorphism of the adjacent sediments produced phyllites and schists and small skarn scheelite deposits locally within the limestone. Minor folding and imbricate thrusting resulted from the stresses connected with the intrusion.
The Mesozoic rocks of the region were subject to Paleogene erosion resulting in a topographic lowland (Van Houten, 1956, p. 2820). Beginning in Late Oligocene and Early Miocene, widespread volcanism, principally rhyolitic flows and ash-fall tuffs, covered the Mesozoic rocks. Major east-west and northwest faulting commenced during the eruptions of the tuffs, and at some point during this time dikes and plugs of andesitic to rhyolitic composition were intruded along these trends. The andesite host rock for the Summit King vein was emplaced during this intrusive epoch.

The tuffs were eroded during the Late Miocene and Early Pliocene. This was followed by the start of Basin and Range tectonic activity which faulted and tilted the tuffs. Large outpourings of basalt covered the tuffs and overlie them in strong angular unconformity. The basalt eruptions and Basin and Range faulting continued through the Pliocene and possibly into the Early Plesitocene.

During the initial stages of basaltic activity, dikes and plugs of labradorite basalt were intruded along previously developed faults in the Miocene andesite intrusives of the Summit King mine area. Some basalts erupted onto the surface forming thin, localized flows.

At about this time, the epithermal silver-gold veins were developed within open fractures in the intrusive andesite and basalt. The hydrothermal activity propylitically altered the host rock, introduced calcite, quartz, and adularia vein gangue, and, in some areas of the vein, silver and gold minerals. The intrusive basalt phase could have temporally and spatially been associated with the vein and ore
deposition. The basaltic magma may have provided a geothermal heat source for the hydrothermal activity.

Basin and Range faulting continued, uplifting the Stillwater and Sand Springs Ranges. The region remains tectonically active, as evidenced by the July 6 and August 23, 1954, magnitude 6.8 earthquakes which occurred 10 to 20 km northeast of Sand Springs in Dixie Valley (Slemmons, 1956, pp. 4-9). Erosion of the fault block mountains and the Sand Springs Pass area has given rise to the present topography. Coalescing alluvial fans consisting of coarse gravels flank the mountain ranges and extend out to the playas found on Fourmile Flat and Fairview Valley.
ORE DEPOSITS

Introduction

Several periods of mineralization are recognized in the Sand Springs mining district. Small, contact metasomatic skarn-tungsten deposits represent the oldest mineralization and are associated with the intrusion of the 75 to 80 million year old Cretaceous granite into the Triassic sediments. Some of the thinner limestone units interbedded with the phyllite were locally altered to skarns and host minor tungsten and sulfide mineralization. Quartz-tourmaline veins (northwest part of Section 3), locally anomalous in silver and gold, represent a later stage of mineralization, and may be associated with the intrusion of a small, late-stage porphyritic granodiorite stock. The granodiorite is altered and contains disseminated sulfides, and has been prospected for porphyry-type copper.

The youngest stage of ore deposition in the district resulted in the formation of the epithermal Summit King silver-gold vein. This mineralization accounts for the significant production of the district, and is typical of many other Tertiary age epithermal mining districts within volcanics found in western Nevada. The vein is hosted in Tertiary andesite, shows strong structural control, exhibits extensive propylitic alteration of the host rock, and has many other characteristics of this type of ore deposit such as open space filling.
Contact Metasomatic Tungsten Mineralization

During the 1950's there was minor production of tungsten concentrate milled from ores mined from the Jones and Red Top scheelite mines located within the limestone units along the northern contact margin of the Sand Springs pluton. Total production from the mines is unrecorded, but a small mill was constructed to process the ore near Highway 50 immediately west of Fourmile Flat (southwest corner of Section 4). The extent of development work at the mines suggests total production was small.

The Jones scheelite mine (south central part of Section 11) consists of several small prospect pits and a 40 m adit driven to intersect a limestone in contact with the granite. The coarse-grained, generally recrystallized limestone is 3 to 10 m thick and is intercalated with the thicker metamorphosed phyllites. Small pods of tungsten-bearing diopside-garnet-quartz skarn have been developed locally within the limestone, and quartz veining is locally pervasive.

The Red Top scheelite mine (southwest corner of Section 12) consists of several shafts, adits, and prospect pits in two limestone units that are within 150 m of the contact with the Sand Springs pluton. The limestone units are 10 to 20 m thick, are near vertical or dip steeply to the south, and can be traced for 700 meters parallel to the contact. Dense, fine-grained diopside-garnet-quartz skarn zones one meter or less in thickness are locally present along the margin of the limestone units at their contact with the phyllites. Sulfides are locally abundant within the skarns. At the Red Top mine, a
vertical shaft approximately 20 m deep followed one of these tungsten-bearing skarns.

Tungsten-bearing skarn is also exposed in the southeastern part of Section 7 in the eastern end of the district. The skarn occurs at the base of a flat-lying limestone unit at its contact with the phyllite. Prospect work consists of several bulldozer trenches, but no significant production is evidenced.

Numerous other small skarns are present in the limestone units throughout the district and most of them were prospected in the 1950's. Many of them were ultraviolet lamped as part of this study, but no scheelite was observed.

Minor sulfide (pyrite, arsenopyrite, galena, and chalcopyrite) mineralization is locally associated with the skarns, particularly in Section 3 in the northwestern part of the district. The sulfides are generally oxidized, and the small gossans have all been prospected for gold. Several gossans were sampled as part of this study and gold values up to 7 g/mt were obtained.

Quartz-Tourmaline Veins and Porphyry Copper Mineralization

Tourmaline-bearing quartz veins are abundant in Section 3 in the northwestern part of the area mapped. The veins are associated with north-south to north 20° east trending high angle structures that cut both granitic and sedimentary rocks. The veins average 50 cm in thickness and usually occupy a fault that may contain up to 2 m of gouge. The veins can often be traced for several hundred meters. The quartz is milky white to clear with black tourmaline
crystals up to 2 cm in length. The veins have been prospected, and at one location an adit at least 30 m long was driven to intersect the veins at depth. Samples gathered from the veins for this study contained minor amounts of gold and silver (up to 3 g/mt Au and 5 g/mt Ag). The age of the quartz veins cannot be determined, although they are clearly younger than the intrusion of the Sand Springs pluton.

Later stage copper mineralization is associated with a small altered porphyritic granodiorite intrusive located in the northwestern part of the district (southeastern corner of Section 3). The granodiorite exhibits moderate quartz-sericite alteration, and contains minor amounts of pyrite and chalcopyrite. Copper carbonate is locally present along open fractures. The area was explored for porphyry copper potential in the early 1960's. The age of the intrusive and related mineralization is not certain, but is included within the Kg map unit.

**Epithermal Vein Silver-Gold Mineralization**

The intrusive andesite hosted Summit King vein can be traced approximately 4.5 km east-west across the district. It has been extensively prospected, but only a segment about 1 km in length on the western end of the vein has been of economic importance. In this area, Summit King Mines, Ltd. sank the Dan Tucker and Getchell inclined shafts to 150 m and mined by open stoping the vein on five levels along strike for over 300 m. Figure 9 is a plan map of the underground workings. The vein averages 1 to 3 m in width and dips 35° to 50° to the
Figure 9:
UNDERGROUND PLAN MAP
SUMMIT KING MINES
SAND SPRINGS MINING DISTRICT
CHURCHILL COUNTY, NEVADA

Excerpted from an Army Plan Map by R.S. Bozey, Summit King Mines, Ltd., 1919
south. Workings on the vein produced approximately 90,000 mt of ore, which, through selective mining, averaged 640 g/mt silver and 7.0 g/mt gold (Dobson, 1940, pp. 51-52).

Away from the main mining area, the vein has been explored by numerous small prospect pits and inclined shafts. Most recently, Sand Springs Silver Company worked the area near Quartz Hill by open pit, mining approximately 10,000 mt of low grade silver-gold ore from a zone as wide as 30 m. The rock consisted of both vein material and argillized andesite in the foot wall zone of the vein which locally contains numerous thin, braided quartz veins and abundant iron staining (Figure 10). The ore was treated by heap leaching, and the grade averaged 70 g/mt silver and 1 g/mt gold (John Whitney, 1978, personal communication). It is estimated that metallurgical recovery was between 50 and 60 percent.

Caving of the underground workings prohibited access, so information on the character of the vein for this study is based on surface exposure, an underground plan map, several company reports, and interpretation of dump material. In the main mining area, the ore was apparently concentrated in one or two ore shoots developed at points where the east-west Summit King fault, host fissure for the vein, was intersected by cross cutting structures. The fracturing associated with the fault intersections allowed the development of thicker mineralized zones. The cross cutting structures are shown on the plan map, Figure 9.

The mineralized portion of the Summit King vein branches and locally becomes a parallel set of veins. Two major parallel veins
were mined underground, the "hanging wall" and "foot wall" veins, which branch and rejoin each other at several locations. Braided quartz veining is common for a short distance away from the primary veins with quartz filling small, near parallel fractures in both the andesite and basalt. To the east of the main mining area, the Summit King vein becomes tighter, mineralization is less, and the mapping showed that the cross-cutting structures and associated fracturing are not as abundant.

Throughout its entire length, the vein averages 2 m wide, and in one location, a width of over 6 m was noted. It exhibits many textures typical of epithermal veins. On the eastern end of the district, the vein is restricted to a single propylitized andesite dike and consists of a vuggy and coxcomb quartz cemented andesite breccia. The quartz gangue will occasionally give way to exposures of massive calcite, and locally calcite forms separate 1 m thick veins that parallel the through-going quartz vein.

In the main mining area, the gangue consists largely of white porcellaneous quartz, generally lamellar pseudomorphs after calcite (Figure 11), with adularia, calcite, and minor dolomite and barite. No fluorite was observed or detected in spectrographic analysis of the vein material. The presence of manganese oxide in the weathered portion of the vein suggests rhodocrosite may be a gangue mineral. In this area, the vein exhibits abundant open space textures and well formed quartz crystals up to 4 cm long are common. The gangue, for the most part, has been cataclastically shattered by late-stage fault movement.
Figure 10: View of the Summit King vein in the Quartz Hill area. The vein workings are the day-lighted stopes of Summit King Mines, Ltd. The open pitting of the vein and foot wall zones was done by Sand Springs Silver, Inc. Photo looking east.

Figure 11: Detail of lamellar quartz pseudomorphic after calcite. Specimen from vein in the Quartz Hill area.
Vein adularia associated with the mineralized quartz vein in the Quartz Hill area yields a potassium-argon date of 19.5 ± 0.5 million years (McKee and Garside, 1978, personal communication). This corresponds with the ages of other western Nevada epithermal veins studied by Silberman and McKee (1974, p. 71).

The understanding of the ore mineralogy associated with the Summit King vein is hindered by the fine-grained nature of the ore minerals, and by the inaccessibility of the underground workings which may have provided a look at the nature of the vertical distribution of ore minerals. No polished sections were made as part of this study.

The better grade of ore mined consisted mostly of the supergene enriched near-surface portion of the vein. Generally, the grade of ore diminished in the lower levels of the mine where the hypogene ore was encountered, although some high grade ore was reported by Dobson (1940, p. 50) on the 150 m level. Hypogene mineralization consists mostly of pyrite. The chloritized wallrock contains abundant brassy colored, euhedral coarse-grained pyrite crystals along open fractures and as finer-grained disseminations throughout the rock. Pyrite in the vein material is generally not as abundant as in the wallrock; it is finer-grained, and it appears to be disseminated throughout the quartz-carbonate gangue. Pyrite also occurs along secondary quartz veinlets that cut the vein. Hypogene ore minerals associated with the pyrite are argentite, free gold and electrum.

Based on field observations and the similarity of Sand Springs to other epithermal districts, minor amounts of galena, chalcopyrite, bornite, sphalerite, and enargite are probably present.
Supergene ore mineralogy in the near-surface portion of the vein consists of free gold, electrum, argentite, and the secondary silver minerals cerargyrite and bromargyrite. Detailed sampling of surface exposures indicated the better grade of ore is associated with a dark brownish-gray to grayish-black manganese wad which occurs mostly as staining along open spaces in the quartz vein; it is locally more massive in the larger fractures. Minor silver values may be associated with jarosite staining along fractures in the altered wallrock, and jarosite probably accounts for some of the low grade silver-gold ore mined adjacent to the vein by Sand Springs Mining Company.

Spectrographic analysis on samples of vein material rotary drill cuttings indicate trace metal associations of copper (60 ppm), manganese (640 ppm), lead (150 ppm), and zinc (220 ppm) (John Whitney, 1978, personal communication).

The importance of supergene enrichment of silver is apparent in the gold and silver mining assay results taken during mining through the vertical extent of the orebody. The gold values remain more or less consistent through all working levels, while the silver values increase markedly between the 30 m and 90 m levels. On the 150 m level, below the zone of oxidation, the average grade of silver drops significantly.

The nature of vein and ore at depth can only be speculative. The grade drops significantly, and ore milled from the 150 m level was minor compared to the upper levels. Material on the dumps presumed to be from the lowermost level indicates the vein material shows an
increase in the amount of gangue calcite and a decrease in the amount of quartz. The relationship of this to ore grade is not known.

The potential for future production of gold and silver from the district is probably best from the leachable surface ores such as mined by Sand Springs Silver Company. International Nickel Company was interested in this potential and in 1977 undertook a detailed mapping and drilling program to determine the extent of mineralization. About ten holes approximately 100 m deep were drilled in the Quartz Hill area. The results were not made available to the writer.
SUMMARY AND RECOMMENDATIONS FOR FURTHER WORK

The Summit King vein in the Sand Springs mining district yielded approximately 39,000 kg of silver and 650 kg of gold during the years 1937 through 1951. The deposit is a classic epithermal vein system with gangue, texture, and mineralogy similar to other western Nevada Tertiary age epithermal occurrences. The Summit King vein trends east-west, is over 4 km long, averages 2 m wide, and consists largely of coxcomb quartz, calcite, adularia with minor barite and dolomite. The vein is locally mineralized with the main ore minerals being argentite, gold, electrum, and secondary silver chlorides and bromides.

The vein was formed approximately 20 million years ago in an intrusive andesite and basalt dike swarm. The dikes are part of a Mid-to-Late Tertiary intrusive event that emplaced numerous dikes and plugs of various compositions along east-west and northwest trending structures that cut all older rocks. Other Tertiary volcanic rocks in the district consist of thick accumulations of air fall tuffs and flow basalt.

The largest intrusive exposed in the Sand Springs area is the Cretaceous Sand Springs Pluton of granitic to granodioritic composition. The pluton intruded into Triassic sediments consisting of regionally and locally contact metamorphosed phyllite, limestone, conglomerate, sandstone, and quartzite. These sedimentary rocks are probably correlative to the Upper Triassic Grass Valley Formation which is
a thick sequence of deltaic sediments now exposed over a large area of west-central Nevada. The delta is interpreted to have been located in a marginal basin developed in an arc-trench system.

The inaccessibility of the underground workings prohibits a detailed three-dimensional geochemical and petrographic study of the Sand Springs epithermal vein. The surface, however, might provide adequate exposures of the vein and wallrock to allow a study of vein characteristics and wallrock alteration. The dumps might provide sufficient samples for petrographic analysis to determine the nature of the deeper portions of the vein. A detailed trace element geochemical study along the 4 km strike length of the vein might provide clues to the lateral zonation within the hydrothermal system.
REFERENCES


Dobson, P.G., 1940, Summit King mills 70 tons of silver-gold ore daily: Engineering and Mining Jour., v. 141, no. 8, pp. 50-52.


# APPENDIX

Sample Analytical Data

<table>
<thead>
<tr>
<th>Sample</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
<th>Value 4</th>
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<tr>
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<td>456</td>
<td>789</td>
<td>012</td>
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<td>654</td>
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<td>Sample 4</td>
<td>210</td>
<td>789</td>
<td>456</td>
<td>123</td>
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## Appendix: Analytical Data, Sand Springs Mining District

**Note:** Samples analyzed by atomic absorption, Monitor Geochemical Laboratory, Elko, Nevada.

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Location</th>
<th>Description</th>
<th>Au</th>
<th>Ag</th>
<th>Cu</th>
<th>Pb</th>
<th>Zn</th>
<th>Mo</th>
<th>Sb</th>
</tr>
</thead>
<tbody>
<tr>
<td>4084</td>
<td>West end of district, north of Highway 50. T.A. Brackney's claim.</td>
<td>Prospect pit on gossan, visible sulfides and oxides of copper. Minor skarn.</td>
<td>-.01</td>
<td>2.9</td>
<td>1150</td>
<td>10</td>
<td>155</td>
<td>5</td>
<td>--</td>
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<tr>
<td>4085</td>
<td>Same area as 4084.</td>
<td>Dump sample from shaft on quartz tourmaline vein.</td>
<td>.41</td>
<td>-.01</td>
<td>125</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>-5</td>
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<tr>
<td>4086</td>
<td>Same area as 4084.</td>
<td>Dump sample of limonitic gossan from small limestone replacement.</td>
<td>7.05</td>
<td>3.5</td>
<td>670</td>
<td>45</td>
<td>15</td>
<td>17.5</td>
<td>--</td>
</tr>
<tr>
<td>4089</td>
<td>Same area as 4084. Brackney's working prospect.</td>
<td>Dump sample from gossan in limestone.</td>
<td>.92</td>
<td>4.2</td>
<td>860</td>
<td>300</td>
<td>730</td>
<td>20</td>
<td>--</td>
</tr>
<tr>
<td>4090</td>
<td>Same area as 4084.</td>
<td>Dump sample from 10 m shaft in limestone replacement gossan. Minor skarn.</td>
<td>.92</td>
<td>1.8</td>
<td>185</td>
<td>60</td>
<td>310</td>
<td>10</td>
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</table>
Appendix: Analytical Data, Sand Springs Mining District

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<th>Pb</th>
<th>Zn</th>
<th>Mo</th>
<th>Sb</th>
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<tbody>
<tr>
<td>4096</td>
<td>West end of district, approximately 1 km south of Highway 50.</td>
<td>Dump sample from prospect pits in iron stained shears in white phyllites.</td>
<td>-.01</td>
<td>4.8</td>
<td>135</td>
<td>10</td>
<td>45</td>
<td>30</td>
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<tr>
<td>4093</td>
<td>East end of district, approximately 1 km south of Highway 50.</td>
<td>Channel sample of braided limonite stained quartz veins adjacent to andesitic dike which intrudes argillically altered phyllites.</td>
<td>-.01</td>
<td>4.8</td>
<td>780</td>
<td>620</td>
<td>675</td>
<td>70</td>
<td>--</td>
</tr>
<tr>
<td>4095</td>
<td>Same area as 4093.</td>
<td>Bulk sample of fractured and argillized phyllites. Iron staining and quartz veining locally abundant.</td>
<td>-.01</td>
<td>0.2</td>
<td>60</td>
<td>10</td>
<td>15</td>
<td>7.5</td>
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</tbody>
</table>
## Appendix: Analytical Data, Sand Springs Mining District

Note: Samples fire assayed by Monitor Geochemical Laboratory, Elko, Nevada

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Location</th>
<th>Description</th>
<th>Gold (g/mt)</th>
<th>Silver (g/mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3998</td>
<td>In open stope east of Dan Tucker Shaft.</td>
<td>One meter channel sample across three pillars in stope. Friable, bone white quartz vein material. Sparse manganese oxides.</td>
<td>3.95</td>
<td>123.77</td>
</tr>
<tr>
<td>4099</td>
<td>Same area as 3998.</td>
<td>Selected vein rock. Friable quartz with abundant manganese oxide, dull gray to black in color.</td>
<td>4.11</td>
<td>284.20</td>
</tr>
<tr>
<td>3997</td>
<td>Near open stope east of Dan Tucker Shaft.</td>
<td>Slightly argillized basaltic wallrock adjacent to main vein. Minor manganese oxide along fractures. No visible quartz veining.</td>
<td>.17</td>
<td>4.11</td>
</tr>
<tr>
<td>3999</td>
<td>Near open stope east of Dan Tucker Shaft.</td>
<td>Channel sample in argillized andesitic wallrock. Abundant braided quartz veining, iron stained, minor manganese oxide.</td>
<td>.70</td>
<td>17.14</td>
</tr>
<tr>
<td>4098</td>
<td>Dan Tucker Dump.</td>
<td>Select dump sample of propylitically altered andesite with 2 to 3% fine-grained brassy colored pyrite.</td>
<td>tr</td>
<td>1.71</td>
</tr>
</tbody>
</table>
Appendix: Analytical Data, Sand Springs Mining District

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<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Location</th>
<th>Description</th>
<th>Gold (g/mt)</th>
<th>Silver (g/mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3996</td>
<td>On hill approximately 500 m south of Dan Tucker Shaft.</td>
<td>Channel sample of argillized andesite. Abundant iron stained braided quartz veining.</td>
<td>.17</td>
<td>.34</td>
</tr>
<tr>
<td>4092</td>
<td>West end of district, approximately 1 km north of Highway 50.</td>
<td>15 m channel sample of highly argillized andesite.</td>
<td>tr</td>
<td>2.40</td>
</tr>
<tr>
<td>4094</td>
<td>East end of district, south of Summit King vein system.</td>
<td>Rock chip sample from 15 m wide silicified breccia zone in limestone. Visible pyrite.</td>
<td>.17</td>
<td>4.46</td>
</tr>
<tr>
<td>4097</td>
<td>East end of Summit King vein system.</td>
<td>Dump sample from prospect pits in argillically altered andesite dikes. Quartz and calcite veining abundant.</td>
<td>.17</td>
<td>4.80</td>
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</table>