The Geology of the Black Forest Mine Area,
Spruce Mountain, Nevada.

by

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A Thesis
submitted to the faculty of the
Department of Geology
in partial fulfillment of
the requirements for the degree of
Master of Science
in the Graduate College
University of Arizona
1938

Approved:  [Signature]
Major Professor
Dec. 13, 1937
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The Geology of the Black Forest Mine Area, Spruce Mountain, Nevada.

Clark L. Wilson

Abstract

This thesis is based on field work done in the Black Forest area during the summer months of 1937.

The Spruce Mountain district has been chiefly a lead-silver producer. This is also true of the Black Forest mine, which has been worked intermittently since 1870. The production of the district has been more than $1,500,000. The production of the Black Forest mine has been more than $600,000.

The sedimentary formations are dolomite and limestone of Devonian age, and limestone and quartzite of Mississippian age. Anticlinal folding and faulting of the sedimentary rocks, followed by intrusion of granite porphyry and diorite dikes, occurred probably during Laramide time. Fissures, formed during the period of faulting, were mineralized by solutions that probably emanated from an underlying magma.

The Black Forest mine is developed by six levels consisting of approximately 10,000 feet of workings.
The ore bodies are principally bed replacement deposits at the intersection of a favorable dolomite beds and N. 40° W. fissures. The original sulphide ore bodies included such minerals as pyrite, arsenopyrite, sphalerite, chalcopyrite, and galena. Oxidation and enrichment have formed a limonitic lead-silver ore, in which the principal minerals are cerussite and plumbojarosite.
Introduction

Field Work and Acknowledgements

The field work upon which this thesis is based was carried on from June, 1937, to September, 1937. The author is indebted to Drs. B. S. Butler, M. N. Short, A. A. Stoyanow, and F. W. Galbraith, of the faculty of the University of Arizona, for suggestions and assistance in field, laboratory, and office. The author is also indebted to the personnel of the Missouri Monarch Consolidated Mines Company, particularly to Mr. Duncan MacVichie for his kind offer of company maps and equipment, and to Mr. Knudsen for his help in and about the mine. Dr. W. R. Landwehr, of the American Smelting and Refining Company, gave many helpful suggestions in the field. Thanks are due Mr. P. A. Andros for assistance in the topographic mapping.

Previous Investigation

The first description of the Spruce Mountain mining district is a report by R. W. Raymond published by the

1 Raymond, R. W., - Statistics of mines and mining in the States and Territories west of the Rocky Mountains for 1872, p. 152.
United States Government. His study, made in the year 1871, dealt with the geography of the area rather than the geology. Since that time, Mineral Resources of the United States, published annually, first by the U. S. Geological Survey and later by the U. S. Bureau of Mines, has descriptions of operations in the district. Most of the articles discuss the mineral production of the district and have only meager comments on the geology.

The general geology of the mountain ranges which include the area was described in the report of the Fortieth Parallel Survey, but the mines were merely mentioned, as very little development had been completed by 1878. The first detailed study of the district was made by J. M. Hill who described the areal geology and compiled some notes on the mine workings. A second general report on the district was made by F. C. Schrader who gave detailed descriptions of some of the mines.

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and some historical and statistical data. Several private reports for mining companies have been prepared, one of which was available to the writer and is listed in the bibliography.

Geography

Location

The Spruce Mountain mining district covers Spruce Mountain, an isolated peak at the southern end of the Peoquop Range, fifty miles south of Wells, Nevada.

The area studied includes approximately one-half square mile on the north slope of Spruce Mountain. Black Forest, Nevada, is one-fourth of a mile to the east. This is the post office for the Missouri Monarch Consolidated Mines Company, operators of the Black Forest Mine.

The Black Forest Mine has two camps. The mine office and some residences form the lower camp at the Black Forest post office. The mine plant and additional residences are at the upper camp, one-half mile up Black Forest Canyon from the post office. A steep road, through the canyon, connects the two camps.

Black Forest is situated a few miles west of longitude 114° 45' and north of latitude 40° 30'.
Specifically it is in T. 31 N., R. 63 E., Mount Diablo base and meridian. The area is included in sections 13 and 14.

Accessibility

There are two good routes to the area. The lower camp is best reached as follows: U. S. Highway 93 from Wells, south fifteen miles to Tobar Junction. From this point a county road leads five miles southeast through Tobar and continues in the same general direction thirty miles to Black Forest.

The upper camp is best reached by U. S. Highway 93 to Sprucemont Junction, 36 miles south of Wells. A county road continues to the east of this point for seven miles to Sprucemont. It is five miles farther to the northeast over a mountain road to the mine.

Black Forest can also be reached from Jasper on the Western Pacific Railroad. A desert road leads from Jasper for twenty miles southwest to the mine. The mail and some of the supplies are brought in over this route.

The roads, after leaving the highway, are, for the most part, dirt. They are passable when dry but difficult during wet weather.

Topography

Eastern Nevada is characterized by typical basin
and range topography which consists of numerous parallel, north-trending mountain ranges separated by broad flat valleys.

Spruce Mountain is a somewhat isolated peak, connected with the Peoquop Range to the east by a line of low transverse hills.

The Peoquop Range, Spruce Mountain, and its northerly extension, are so placed as to resemble a small letter "j" with Spruce Mountain and its extension forming the "hook."

The mountain has a well developed system of drainage and divides and is characterized by steep slopes both wooded and barren. There are numerous gullies, small canyons, and limestone cliffs.

Johnson Gulch, extending from Black Forest Canyon up the north slope of Spruce Mountain, is a youthful canyon. The slopes are steep and the east wall is a cliff. The upper part of the gulch has evidently been localized by a fault trace.

Black Forest Canyon is also a youthful canyon but is in a more advanced stage of erosion than is Johnson Gulch. Its upper end is also along a fault trace.
The summit of the peak rises nearly 4,000 feet above the flat valleys that surround the mountain on all but the east side.

Banner Hill, to the north, is separated from Spruce Mountain by the Killie Flats and Black Forest Canyon. This hill slopes out in a northerly direction as a long ridge into Antelope Valley.

Spruce Mountain, because of its greater relief, is being eroded at a faster rate and is in a younger stage of erosion than some of the lower surrounding hills.

Climate and Vegetation

The climate is typical of the temperate zone. There is a moderate snowfall in the winter and there are numerous summer showers. The snow reaches sufficient depth to stop automobile travel for two months during the winter.

No weather records are available for this area. The nearest weather recording station is at Clover Valley, ten miles to the west and at an elevation of 5,800 feet. The average annual precipitation there is fourteen inches, the average maximum temperature 60.6°F., and the average minimum temperature 30.2°F.
The vegetation on Spruce Mountain and its greater elevation indicate that the precipitation there is considerably more than that recorded at Clover Valley.

Summer temperatures at Black Forest are never very high and the nights are comfortably cool.

Field work is limited to the months of May through October and is interrupted by frequent summer showers.

The vegetation is characteristic of mountainous areas and, in spots, is dense and varied. Some of the larger trees on the southern end of Spruce Mountain have been used as mine timber. Several varieties of pine and fir trees grow abundantly on the north slopes. Mountain mahogany is the main source of fuel. Included in the bushy plants are wild raspberries, currants, and chokecherries. There is an abundance and variety of grasses and flowers. Sagebrush is common on the lower slopes. The larger trees grow on limestone and dolomite soil and are notably absent in areas of igneous rock. The vegetation is suitable for sheep and cattle grazing.
History of Mining Activity in the Spruce Mountain Mining District

The discovery of lead-silver ores at Spruce Mountain was made in 1869 at the Latham mine. The Spruce Mountain district was organized in 1871, by the consolidation of the Latham, Johnson, and Steptoe districts, and now includes all of the mines in the vicinity.

Active development in the district began in the fall of 1871, when the Ingot Mining Company acquired the Latham and several other prospects. In 1872, the company built a 4½-foot Philadelphia-type smelter at Sprucedmont to treat lead carbonate ore. The plant could treat 35 tons of ore daily, but it closed down in 1873. There was no fluxing material, the water supply was limited, and the high copper content of the ores caused contamination of the lead. The plant never re-opened and only the ruins now remain.

At this time the principal mines were the Latham, Fourth of July, Monarch, and Badger.

There is no report of production from the district for 1877 to 1900, so it is assumed that mining activity was negligible. The Black Forest Mining and Smelting
Company was organized during this interval and erected a 30-ton lead blast furnace on their property. Considerable ore from the Black Forest mine was smelted prior to 1910. During this time the mine was developed by 8,000 feet of tunnel work.

Since 1910 several mines have produced small amounts. These include the Monarch, Killie, Banner Hill, Keystone, Black Forest, Spruce, Juniper, and Fourth of July. The Black Forest mine has been the most consistent producer throughout this period.

In July, 1929, the Black Forest and Monarch mines were consolidated to form the Missouri Monarch Consolidated Mines Company. This company has continuously operated the Black Forest mine since the consolidation, but, until the spring of 1937, the Monarch had been idle for several years. Other properties in the district, which are inactive at the present time, are the Nevada Lead and Zinc, the Spruce Standard, and the Index Mining Company.

A survey for an extension of the Western Pacific Railroad to Sprucemont was completed in 1929, but production has not warranted the construction of the road.

Hill\(^5\) estimates the total production of the district.

\(^5\) Hill, J. M., - op. cit., p. 68.
to 1916 as $700,000. Following is a table of production taken from his work.

Production of the Spruce Mountain district, Elko County, Nevada.

1902-1912

Table I

<table>
<thead>
<tr>
<th>Year</th>
<th>Gold fine ounces</th>
<th>Silver fine ounces</th>
<th>Copper pounds</th>
<th>Lead pounds</th>
<th>Total value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1902</td>
<td>189,072</td>
<td>1,272,600</td>
<td>$145,440</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1903</td>
<td>29,175</td>
<td>6,000</td>
<td>451,000</td>
<td>27,063</td>
<td></td>
</tr>
<tr>
<td>1904</td>
<td>62.73</td>
<td>8,773</td>
<td>122,869</td>
<td>9,954</td>
<td></td>
</tr>
<tr>
<td>1905</td>
<td>1.16</td>
<td>10,722</td>
<td>185,257</td>
<td>16,177</td>
<td></td>
</tr>
<tr>
<td>1906</td>
<td>3,648</td>
<td>59,985</td>
<td>5,862</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1907</td>
<td>3.43</td>
<td>189,072</td>
<td>116,592</td>
<td>24,590</td>
<td></td>
</tr>
<tr>
<td>1908</td>
<td>75</td>
<td>10,977</td>
<td></td>
<td>1,489</td>
<td></td>
</tr>
<tr>
<td>1909</td>
<td>5.56</td>
<td>10,668</td>
<td>40,615</td>
<td>201,861</td>
<td>19,622</td>
</tr>
<tr>
<td>1910</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1911</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1912</td>
<td>14</td>
<td>13,277</td>
<td></td>
<td>605</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>72.88</td>
<td>253,953</td>
<td>174,184</td>
<td>2,306,829</td>
<td>$250,802</td>
</tr>
</tbody>
</table>

The following table of production for the period from 1915 to 1931, inclusive, is taken from Mineral Resources reports of the U. S. Geological Survey. The data for 1934 and 1935 is taken from the Minerals Yearbook of the U. S. Bureau of Mines.
Production of the Spruce Mountain district, Elko County, Nevada.

1913-1935

Table II

<table>
<thead>
<tr>
<th>Year</th>
<th>Short tons.</th>
<th>Gold</th>
<th>Silver fine ounces</th>
<th>Copper pounds</th>
<th>Lead pounds</th>
<th>Total value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1913</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1914</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1915</td>
<td>71</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$3,755</td>
</tr>
<tr>
<td>1916</td>
<td>288</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>13,426</td>
</tr>
<tr>
<td>1917</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1918</td>
<td>480</td>
<td>$.55</td>
<td>12,454</td>
<td>19,929</td>
<td>89,265</td>
<td>23,769</td>
</tr>
<tr>
<td>1919</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1920</td>
<td>7,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1921</td>
<td>1,897</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1922</td>
<td>1,197</td>
<td>128</td>
<td>26,791</td>
<td>3,082</td>
<td>474,421</td>
<td>53,428</td>
</tr>
<tr>
<td>1923</td>
<td>1,221</td>
<td>166</td>
<td>23,755</td>
<td>5,993</td>
<td>522,143</td>
<td>58,714</td>
</tr>
<tr>
<td>1924</td>
<td>3,333</td>
<td>210</td>
<td>46,866</td>
<td>5,904</td>
<td>1,016,927</td>
<td>113,736</td>
</tr>
<tr>
<td>1925</td>
<td>4,099</td>
<td></td>
<td>61,936</td>
<td></td>
<td></td>
<td>114,288</td>
</tr>
<tr>
<td>1926</td>
<td>6,383</td>
<td>813</td>
<td>95,150</td>
<td>50,643</td>
<td>2,197,074</td>
<td>243,043</td>
</tr>
<tr>
<td>1927</td>
<td>2,902</td>
<td>540</td>
<td>52,560</td>
<td>24,332</td>
<td>1,271,234</td>
<td>116,190</td>
</tr>
<tr>
<td>1928</td>
<td>2,430</td>
<td>235</td>
<td>30,811</td>
<td>38,464</td>
<td>1,057,570</td>
<td>85,144</td>
</tr>
<tr>
<td>1929</td>
<td>2,530</td>
<td>104</td>
<td>23,880</td>
<td>34,148</td>
<td>776,131</td>
<td>70,534</td>
</tr>
<tr>
<td>1930</td>
<td>1,122</td>
<td>43</td>
<td>6,403</td>
<td>15,193</td>
<td>404,014</td>
<td>24,684</td>
</tr>
<tr>
<td>1931</td>
<td>130</td>
<td></td>
<td>1,187</td>
<td>1,528</td>
<td>52,189</td>
<td>2,422</td>
</tr>
<tr>
<td>1932</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1933</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1934</td>
<td>152</td>
<td>730</td>
<td>65,376</td>
<td></td>
<td></td>
<td>3,567</td>
</tr>
<tr>
<td>1935</td>
<td>1,500</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>36,735</td>
<td>$2,307</td>
<td>385,511</td>
<td>199,216</td>
<td>9,069,332</td>
<td>$812,514</td>
</tr>
</tbody>
</table>
A study of the production tables indicates that the district has been chiefly a lead-silver producer with minor amounts of copper and gold. A small amount of zinc was produced in 1927 and 1929.

Using the assumed production through 1916 as $700,000, the production for the district to the present would be more than $1,500,000. The average value of the ore mined from 1915 to 1935 is $35. per ton.

Production from the Black Forest mine has been intermittent since 1870, and though no shipping records are available, the smelter records indicate that 30,000 tons were shipped between the years 1919 and 1928, with net smelter returns of $608,500, or an average of $20. per wet ton of crude ore.
13.

Sedimentary Rocks

General Statement

Rock formations present in the area include:

Mississippian
Keystone formation

Devonian
Cave limestone
Juniper limestone
Forest dolomite

The formations have been named locally as there is no definite correlation with rocks of surrounding districts. A general correlation is shown in Plate VI.

Devonian Formations

Forest dolomite

The Forest dolomite, named after the Forest claim, is exposed on the slopes of Black Forest canyon above E level.

The formation is composed essentially of dolomite with a gradation to limestone near the top. The dolomite is massively bedded, uniform in character, and is commonly gray to black in color. A section of
approximately 400 feet is exposed without reaching the base of the formation.

The lower 280 feet consists of alternating gray and blue beds that have a "sandy" weathered surface. Near the top of this section is a series of banded, light and dark blue dolomites. The banding varies from one inch to a foot in width. Ten feet from the top is a dark blue dolomite containing white dolomite bodies that are probably replaced fossils and act as a good marker in prospecting. The section contains a fossiliferous horizon, but the fossils are poorly preserved and identification was impossible.

The "ore horizon" or so-called "favorable" bed of the Black Forest mine is above this series. The favorable bed is approximately ten feet thick, and, being quite brittle, breaks into small pieces (one-half to one inch square) when subjected to stress. The bed is light blue in color and also has a "sandy" surface on weathered outcrops and on exposures underground in stopes and fissures.

The favorable bed is overlain by a black, thin-bedded dolomite that is relatively insoluble in dilute hydrochloric acid as compared with the other rocks. The ore rarely replaces this rock, which acted as a dam to the mineralizing solutions.
Near the top of the formation are intercalated limestone beds. One of these is fossiliferous and contains a coral identified by Stoyanow as a *Cyathophyllum* sp., commonly found in the Devonian.

A similar occurrence of dolomite, containing the white dolomite bodies mentioned above, is reported in the Silverhorn dolomite at Pioche by Westgate.6

"One rock type is "white-spotted" or "spaghetti" dolomite, a striking variety of brown dolomite which originally contained small branching corals (Cladopora?). These have been replaced by white crystalline dolomite, so that the rock is crowded with small curving stems, 2 to 3 centimeters long by 1 to 3 millimeters in cross section. This distinctive texture seems to be confined to the Devonian."

A second occurrence of this type is reported in the Guilmette formation at Gold Hill, Utah, by Nolan.7

"The most abundant (rock) is a fine-grained dolomite, dark to medium gray ------, that contains numerous vugs almost completely filled with white coarsely crystalline dolomite."

From the correlation in Plate VI it is observed that dolomitic formations are common in the Devonian rocks of several mining districts in the vicinity of Spruce Mountain. Hill8 has reported Devonian rocks in


the Hunter district which is twenty miles north of Ely, Nevada. He described them as dark, massive-bedded, dolomitic limestones containing Cyathophyllum sp., which also occur in the Nevada limestone of Devonian age.

On the basis of lithology the Forest dolomite is tentatively correlated with the Silverhorn dolomite (Pioche), the Nevada limestone (Ely), and the Guilmette formation (Gold Hill).

**Juniper limestone**

The Juniper limestone, named after the Juniper claim, is exposed on both slopes of Johnson Gulch and on the south slope of Black Forest Canyon below E level.

The formation is composed essentially of limestone, with some intercalated shaly beds, and is approximately 400 feet thick.

There are several limestone beds, ten to fifty feet in thickness, that are relatively resistant to weathering, and form ledges on the south slope of Johnson Gulch. These are separated by thin-bedded limestones and shaly limestones that form talus slopes with few outcrops.

The limestones are generally gray to blue, with
bedding planes at several horizons stained red and yellow, probably by iron oxides.

Some of the rocks have a "hummocky" weathered surface; others have fissured surfaces that are characteristic of certain horizons and aid in correlation and mapping.

Throughout the formation there are numerous gastropod horizons, but identification was not possible due to the poor preservation of the fossils.

The Juniper limestone is included in the Devonian period, since Devonian fossils are recognized in overlying limestone beds.

Cave limestone

The Cave limestone, named after the Cave claim, is exposed on the south slope of Black Forest Canyon above F level, in the Spence cliffs, and in the vicinity of the Index tunnel.

This formation includes all the rocks above the Juniper limestone and below the Keystone formation; however, only the lower part of the section is exposed in the mapped area.
The lower 350 feet of the formation is composed of massive limestones with some intercalated thin-bedded limestones. The rocks are various shades of blue.

The Forest cliffs are formed by a series of re-crystallized limestones located 125 feet above the base of the formation.

A complete section of the Cave limestone is not exposed; however, in the upper portion is included a series of dark blue cherty limestone beds with some overlying yellowish shaly and thin-bedded limestone beds.

The lower part of this formation contains fossils, but the recrystallization of the limestone has destroyed most of them. Several coral specimens were obtained and identified by Stoyanow as a Cladopora sp. of Devonian age. This dates the lower part of the section, but the age of the upper part is not known as no fossils were found.

The chert beds and yellow shale beds correspond in a general way with the descriptions of the West Range limestone, Bristol Pass limestone, and Peers...
Spring formation of Pioche as given by Westgate. 9

From a comparison of lithology of the Cave limestone with formations in other districts it seems possible that the upper part of the limestone is Mississippian in age.

Keystone formation

The Keystone formation, named after the Keystone tunnel and claim, is exposed on the east flank of Spruce Mountain, one-half mile east of Black Forest, and on the west flank of Spruce Mountain, a mile to the west of the Black Forest mine. Within the Black Forest area, exposures are located above the Index tunnel and also north of the porphyry dike.

The basal portion of the Keystone formation consists of a coarse-grained, well-cemented quartzite, usually light brown in color. Above this is a quartzite conglomerate, also well cemented, that contains pebbles ranging up to two inches in diameter. This is overlain by a thin-bedded, limy shale that is black, weathering to dark brown.

9 Westgate, L. G., - op. cit., p. 20.
A series of limestones, capped by a limestone conglomerate, is above the shale.

The section was not measured because of complications by faulting.

The shale contains numerous fossils that are well preserved, and were identified by Stoyanow as *Spirifer ex. aff. pelleensis* Weller and *Productus sp.* of Mississippian age.

The Scotty Wash quartzite (Pioche) and the Diomand Peak quartzite (Eureka) have been tentatively correlated as the same formation by Westgate.\(^\text{10}\) The quartzites are upper Mississippian in age, and it may be that the Keystone formation is the equivalent of these in the Black Forest area.

**Pennsylvanian formation**

Above the Keystone formation is a series of yellow limestones exposed to the east of the Black Forest area. This formation contains numerous crinoid stems and fusulina identified as *Triticites* sp. of Pennsylvanian age.

\(^{10}\) Westgate, L. G., - op. cit., p. 21.
Igneous Rocks

General Statement

The occurrence of igneous rocks in the district has been described by Schrader\(^\text{11}\) as follows:

"Igneous rocks are only sparingly present. They consist chiefly of granite porphyry, diorite porphyry, and ------ are intrusive into the sedimentary rocks. They are in general highly altered and are not well exposed."

Granite porphyry

The largest exposure of granite porphyry is the dike that strikes to the east, across the area north of the mine. A branch of this dike extends south to the vicinity of the Index tunnel. Small porphyry dikes are exposed in the mine workings.

In hand specimen this rock is light gray, and consists of abundant phenocrysts of quartz and orthoclase, up to six millimeters in diameter, in a fine-grained groundmass. Ferro-magnesium minerals were not abundant and are now weathered beyond recognition.

A thin section shows that the average composition

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\(^{11}\) Schrader, F. C., - op. cit., p. 8.
of the rock before alteration was quartz 35 percent, orthoclase 55 percent, oligoclase less than five percent, and biotite and apatite less than five percent. The phenocrysts of orthoclase and quartz are in the ratio of approximately three to one, constituting about 25 percent of the rock. The orthoclase is untwinned. Some of the orthoclase crystals have been completely altered to sericite and kaolin, and others exhibit alteration only along the borders. The orthoclase phenocrysts have euhedral outlines, but the quartz phenocrysts occur as irregular grains.

The groundmass consists of orthoclase, quartz, oligoclase, and biotite. None show euhedral outlines. The texture is even-grained and the average diameter is about 0.1 millimeter. The plagioclase is untwinned and was determined as oligoclase by the immersion method.

Apatite is an accessory mineral, that is, later than biotite, and follows the biotite cleavage.

The plagioclase has been altered to sericite and kaolin. The biotite is almost completely altered to chlorite, iron oxide, and leucoxene.

A thin section of altered granite porphyry from D level shows the rock altered to sericite and mineralized with a small amount of pyrite.
**Porphyritic diorite**

This rock is exposed as a sill in Black Forest Canyon above the junction with Johnson Gulch. The sill is near the top of the Juniper limestone and is found only to the north of the Mud fault.

Rocks of similar composition but different textures are exposed as small dikes in the mine workings.

In hand specimen the rock is made up of fifty percent dark green phenocrysts of hornblende in a light green to white groundmass which is too fine grained to permit determination of the minerals. The phenocrysts are euhedral crystals up to eight millimeters in length. Alteration of the rock, forming a light green groundmass, has caused the dark hornblende crystals to stand out strongly in the altered groundmass.

The average composition of a typical thin section, omitting alteration minerals, is hornblende 75 percent, oligoclase twenty percent, and apatite less than five percent.

In thin section, the phenocrysts of hornblende make up about fifty percent of the rock. The ground-
mass is composed of small subhedral hornblende crystals, and irregular grains of oligoclase one millimeter in diameter, the whole displaying a "mottled" texture. Apatite is an accessory mineral later than hornblende. The hornblende has been altered to chlorite and epidote; the feldspar to sericite and kaolin.
General Geology of Spruce Mountain

Hill\textsuperscript{12} summarizes the general structure as follows:

"Spruce Mountain seems to have been formed as an anticlinal fold but to have been much modified, in the vicinity of the mines, by the intrusion of the igneous rocks and by two nearly parallel normal faults, striking approximately N. 20° E.

"West of the west fault, between Old Sprucemont, (abandoned) and the divide in which the mines are located, the limestones lie essentially horizontal, though showing some minor breaks. Between the two major faults the beds, owing to minor faults and the intrusion of the igneous rocks, show considerable diversity in dip, inclining NE., E., or SE. at low angles. Eastward from the east fault the limestone dips E., at first steeply, but within a short distance, only moderately."

The anticlinal nature of Spruce Mountain is quite evident, but it now appears that at least five large faults have modified the anticline.

General features of the Black Forest area

The Black Forest mine is located on the east flank of the Spruce Mountain anticline. The strike of the rocks is N. 15° E. to N. 30° E., and the dip averages 30° to the southeast. The structure, in detail, is rather complex due to faulting. All of the faults appear

\textsuperscript{12} Hill, J. M., - op. cit.: p. 70.
to be normal and most of them have a small throw.

A granite porphyry dike with easterly strike crosses the area north of the mine. A branch of this dike extends south to the vicinity of the Index tunnel.

Several small granite porphyry and diorite dikes are exposed in the mine occupying faults and fissures that strike northwest. These dikes are from one to ten feet thick.

The structural disturbance is believed to be mainly pre-intrusion, as the intrusive rocks occupy faults and fissures.

The age relationships of folding, faulting, and intrusion, have been summed up by Ferguson\(^\text{13}\) as follows:

"There is another belt of intense folding, accompanied by major thrusting, which parallels the eastern border of the state (Nevada) in western Utah, extends southwestward through Clark County, and enters California west of Goodsprings. Granitic intrusions also accompanied this folding. This folding and intrusion is considered to be of early Tertiary age. Butler considers that the granitic rocks of the plateau region and the eastern part of the Great Basin in Utah were intruded during the early Tertiary. Nolan has found in the Gold Hill

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district, Utah, close to the Nevada line, monzonite intrusions which are younger than folded sediments of probable Eocene age, and Hewett has likewise concluded that the granitic intrusives in the vicinity of the Goodsprings district are of Tertiary age. The intrusion of granitic rocks, therefore, appears to be not later than late Jurassic or early Cretaceous in the western part of the state and not earlier than the Eocene in the eastern and southern parts."

The probable sequence of structures is:

1. Anticlinal folding with a general north-south strike.
2. Modification of the structure by faulting.
3. Intrusion of granite porphyry and diorite.

Folding

The anticlinal structure of Spruce Mountain is well shown by the outcrops of the Keystone formation. As plotted on Plate III the members of this formation have been found near the summit and on both the east and west flanks of the mountain.

On the east flank of the Mountain the quartzite strikes N. 15° E. and dips 30° to the east. The strike is west of north on Banner Hill. The change of strike suggests a dome, but it is not as distinct as the anticline.

The folding was asymmetrical with the axial plane dipping to the east. This is shown in Plate IV, a reconstruction of the fold as it may have appeared before faulting.
Faulting

The fold has been displaced by a series of nearly parallel northeast normal faults. The Monarch, Thelma, and Great Faults, are on the west flank of the mountain and, with the exception of the Monarch, dip steeply to the west. This fault zone seems to have had a larger throw than the faults to the east and is marked by a rather prominent scarp, and several springs emerge along its strike.

The eastern major faults are shown in two saddles east of the summit of Spruce Mountain. The Spruce fault, the more westerly of these two, strikes to the north across the mine area and continues across Banner Hill to the west of its summit. The Banner Hill fault, east of the Spruce fault, strikes N. 20° E. across the slope of Spruce Mountain, east of F level, and continues across the east slope of Banner Hill.

The Spruce and Banner Hill faults also dip to the west, but the angle of dip is not known.

The granite porphyry dike that crosses the area is along a fault of several hundred feet throw. The Keystone formation, as shown in Plate I, outcrops in the bottom of Black Forest Canyon to the north of the granite porphyry dike. South of the fault it outcrops
above the Juniper shaft. This indicates an east-west break across the strike of the anticline.

**Number 1 fault**

Number 1 fault strikes N. 55° E. and dips 45 to fifty degrees to the northwest. An easterly strand of the fault, branching from the main fault in the vicinity of the junction of the Dutch fissure and Number 1 fault, extends to the south. It strikes N. 30° E. and dips 45° northwest. This is a pre-mineral normal fault that drops the beds forty to sixty feet vertically and 45 feet to the southwest horizontally. Most of the movement is on the main branch of the fault; the east strand shows displacement of only a few feet.

The fault has been located on the surface in several places but has little topographic expression.

Both strands strike into Johnson Gulch and merge with Number 2 fault below the Index tunnel.

Number 1 fault is exposed on B, C, D, and E levels.

**Number 2 fault**

Number 2 fault strikes N. 10° to N. 45° E and
dips 70° to 80° east. It roughly parallels the curving contact of the porphyry intrusion to the southeast and evidently joins the dike above the Spence cliffs.

The fault is pre-mineral but appears to have had a slight post-mineral movement as indicated by a thin brown streak of gouge, apparently drag ore in the fault near the ore. In unmineralized areas, the fault walls have a polished slickensided surface.

Number 2 fault terminates the Spence cliffs to the west and can be followed south into Johnson Gulch. To the north of the cliffs, a small depression or gully marks the fault trace down the slope to Black Forest Canyon.

This fault marks the western limit of the mine workings. Exposures in the mine are on A, D, and E levels.

**Number 3 fault**

Number 3 fault is best shown in the Forest cliffs which it crosses as a brecciated zone directly to the south of triangulation point F. It can be traced down to the bottom of Johnson Gulch to the west, and down the east slope to the east of point F.
It is a normal fault striking N. 55° W. and dipping 65° to 70° to the northeast. The throw is approximately 300 feet vertically. No horizontal displacement was determined.

No fault with this throw has been found in the mine workings. Absence of a large movement may be due to: 1, a rotational fault pivoting at Number 1 fault, 2, a block fault.

The first suggestion does not seem feasible. If there had been rotation sufficient to produce a fault of 300 feet throw at the Forest cliffs, the dip of the rocks on the north and south of the fault should differ by fifteen to twenty degrees. Actually the dip of the limestone bedding to the north and south of the fault is quite similar.

The second possibility seems more reasonable, but none of the mine workings have prospected the area through which a fault in Johnson Gulch would pass. Such a fault would complete the block, and a fault must be there to account for the repetition of the Juniper limestone on the south slope of Johnson Gulch. Some evidence of displacement is seen in the gulch, but it is not conclusive.

The presence of the Forest dolomite in contact with
the Juniper limestone near the bottom of the gulch and the offset of a fossiliferous horizon at the top of the Juniper limestone are facts that do prove the presence of a southerly continuation of Number 4 fault.

Thus it appears that a block of the upper Forest cliffs is elevated with respect to the surrounding rocks.

**Number 4 fault**

Another fault block in the northwestern part of the area is bounded on the south and east by Number 4 fault. This is a concealed fault that trends with Black Forest Canyon from the porphyry dike crossing to E level. The other section strikes N. 15° W. up the south slope of Banner Hill from E level. This block is depressed in relation to the surrounding rocks.

**Mud fault**

The Mud fault strikes approximately N. 20° W across the northern edge of the developed area. The dip varies between 60° to 80° to the northeast.

The fault can be traced from a point above and fifty feet to the south of E level portal, through Johnson Gulch and across the Forest cliffs. The fault is marked by a small depression on the north slope of Black Forest Canyon.
Exposures in the mine on E and F levels are marked by a zone of breccia about five feet wide. This is rather loose and required timbering on E level. The zone is wet and muddy. On F level a part of the gouge is granite porphyry that has been altered.

The fault does not show mineralization.

Index Fault Zone

One hundred feet north of the Index tunnel is a fault breccia zone approximately 100 feet wide and 800 feet long. The breccia zone, mineralized with hematite and limonite, weathers into relief with respect to the surrounding igneous and sedimentary rocks. The zone is limited to the east by Number 2 fault and diminishes to the west until it disappears at the Juniper shaft. The fault has offset the porphyry dike that extends up towards the Index tunnel.

Fissure system

There are four main sets of fissures that have the following general trends:

Strike N. 40° W., dip 50°-70° northeast
Strike N. 40°-50° E., dip 50°-90° northwest and southeast
Strike N. 15° E., dip 80° northwest
Strike N. 80° W., dip 50° southwest.

Some fissures have a movement of a few feet and should be classed as fault fissures. All the fissures seem to have been formed during the same structural period and are pre-mineral.

The N. 40° W. fissures drop the rocks on the north-east side from zero to three feet. They appear to be tension fissures. Diorite and granite porphyry dikes were intruded into some. Mineralizing solutions circulated through others. The greater part of the mineralization is associated with the N. 40° E. fissures. The Dutch fissure is a notable example.

The N. 50° E. fissures are second in importance. They contain some mineralization, but as a rule are rather tight and do not contain dikes. Movement is slight, being five feet or less. In a few places the ore has been deposited between the N. 40° W. fissures on the N. 50° E. fissures.

The N. 15° E. fissures, which rarely carry any mineral, have a throw varying from one to ten feet. They are tight fault fissures that usually cannot be recognized underground in the massive dolomite.

The N. 80° W. fissures are of minor importance, and are the most poorly developed. Several of these
fissures were noted in the Spence and Forest cliffs. Movement on the fissure is slight.

The N. 40° W. fissures generally offset the three other sets. The N. 40° E. fissures in turn offset the remaining two.

Granite porphyry intrusion

Subsequent to most of the folding and faulting, there was intrusion in the area, probably in Tertiary time. The granite porphyry dike, which is the largest exposed intrusion, has a general strike of N. 65° E. but in the vicinity of the mine is nearly east.

The porphyry generally occupies faults or fault zones, and no folding or faulting was observed to be definitely associated in time of formation with the intrusion.

The source of the intrusive material is problematical, as no stock or other large igneous body is exposed.

Diorite intrusion

Several diorite dikes and sills are exposed. The dikes which occupy faults are one or two feet thick, being thinner than the granite porphyry dikes.

No notable structural disturbance accompanied the intrusion of these dikes.
Metamorphism

The metamorphism in the district consists mainly of recrystallization of the limestones and dolomites along the porphyry dikes, with the addition of some silicates.

The zone of recrystallization extends several hundred feet from the granite porphyry exposures, but the silicate minerals are generally confined to a zone a few feet in width which borders the intrusive. Schrader\textsuperscript{14} has reported metamorphism, in the vicinity of Spruce-mont, 500 feet from any exposed intrusive rock, which consists of replacement of limestone by garnet and subordinate quantities of actinolite, diopside, and other pyroxenes. Hill\textsuperscript{15} has reported garnet and diopside in a contact zone near a diorite dike on Banner Hill.

The rocks included in the area between the granite porphyry dike, north of the mine, and the Mud fault have been recrystallized. Any fossils that were present have been destroyed and it is difficult to correlate the formations to the north and south of the fault.

\textsuperscript{14} Schrader, F. C., - op. cit., p. 9
\textsuperscript{15} Hill, J. M., - op. cit., p. 70.
F-3 drift was run towards the granite porphyry contact but had not reached it in 1937. The dolomite near the end of the drift has been recrystallized, probably indicating that the porphyry is not a great distance away. The dolomite, ordinarily black, is bleached, forming veins and splotches of white dolomite which, in thin section, show twinning and recrystallization with respect to the original black dolomite. Numerous marbleized beds are exposed in F-1 drift near F level portal.

No metamorphism is noted accompanying the diorite dikes and the small porphyry dikes.
Geomorphology

General Statement

Eastern Nevada is in the Basin and Range Province, and also within the Great Basin.

The maximum relief in the Black Forest area is about 4,000 feet. Spruce Mountain, the highest point, reaches 10,400 feet.

The physiographic development has been controlled by climate, structure, and lithology.

Development of Topography in the Area

Streams: The area has a moderate snowfall in winter but there are no perennial streams. Several springs issue at various points along the base of the mountain, flow a few feet, and sink back into the ground. The snow run-off forms small streams that run for short distances and also disappear below the surface. Some of the summer rains are torrential, and the surface is eroded rapidly for a short period.

The water supply is sufficient for the growth of considerable vegetation which covers most of the slopes and aids in retaining the moisture.
Structure: The fissuring and faulting of the area has an important control over the development of drainage. Black Forest Canyon and Johnson Gulch follow faults through part of their courses, and several small gullies also follow faults.

Water seldom flows in Black Forest Canyon or Johnson Gulch for any great distance, as the numerous fissures in the area act as channels to carry the water underground.

That part of the drainage which is controlled by the fault system has developed a trellised pattern, but in the upper parts of the canyons, where the drainage is controlled by the homogeneous character of the rocks, a dendritic pattern has resulted.

The beds on the east slope of the Spruce Mountain anticline dip 40° to 50° southeast. This is steeper than the general slope of the mountain, but, in places, dip slopes have been formed.

Lithology: The quartzite and conglomerate of the Keystone formation form ridges and ledges, whereas the shale above the quartzite weathers to slopes and canyons.

The Cave and Juniper limestones have some resistant members that characteristically form cliffs and ledges. The Forest and Spence cliffs have been formed along fissures that cut through these resistant beds.
The Forest dolomite has formed even slopes with no cliffs or ledges.

**Effect of temperature change:** The drop in temperature from day to night causes rapid decomposition of the granite porphyry, which weathers to topographic lows, leaving the surface covered with fine granitic gravel. The limestone members, more resistant to temperature change, form the higher areas.
Mineral Deposits

Character and distribution in district

The mineral deposits in the district consist mainly of oxidized lead-silver ore bodies occurring as replacement of limestone and dolomite. Some of the deposits also carry copper, gold, and small amounts of zinc.

The lead-silver ores contain cerussite, anglesite, and residual galena kernels, together with abundant limonite. The copper ores contain malachite, chrysocolla, and chalcopyrite, with subordinate quantities of bornite, chalcocite, and covellite. The zinc ores contain smithsonite and hemimorphite.

There is a suggestion of a general zonal arrangement of the ore minerals with respect to the granite porphyry dike that crosses the area. A large part of the copper mineralization has been in the border of the intrusive. The balance of the copper is in metamorphosed sediments associated with silicate minerals of contact metamorphic origin.

The zinc deposits are few and are located in the sediments near the porphyry.

The lead-silver deposits are in approximately the
same zone as the zinc, but range to greater distances from the porphyry.

There is also a possible center of mineralization one-half mile to the west of the mapped area. A siliceous, copper mineralized zone forms the central core. Grouped around this, to the north and west, are the deposits containing zinc. The lead-silver deposits are located farther from the center.

The ores mined are practically all oxidized, and no large sulphide bodies have been located.

**Description of Black Forest mine**

The Missouri Monarch Consolidated Mines Company, operators of the Black Forest mine, own 71 contiguous lode mining claims (1,150 acres) in the Spruce Mountain mining district. Forty-eight claims are held by patent from the United States Government, and 23 by annual assessment work. The company owns all the water having its source on the property.

The property consists of two separate mines: the Black Forest mine, and the Monarch mine. The Monarch mine is located on the western section, and the Black Forest mine on the eastern section of the claims.
The Black Forest mine workings consist of six levels, connected by winzes and raises. The levels have surface connections at various points in Black Forest Canyon, and for convenience have been lettered alphabetically, "A" being at the top. The vertical distance between levels varies from 300 feet between E and F levels to fifty feet between B and C levels.

The mine has about 10,000 feet of underground work, the ore zone being developed through a horizontal area approximately 700 by 900 feet, and through a vertical range of 400 feet.

The Diesel compressor plant, warehouse, and blacksmith shop are located on E level dump. The company bunkhouse and several houses are also in this vicinity.

Ore from the upper workings is transferred to F level by means of ore-passes and chutes. It is then trammed to a surface orebin and trucked to Jasper.

Very little timber is required in the mine as the dolomite wall-rock stands well.

Occurrence of Black Forest ore

The ore deposits are replacements in dolomite, closely associated with fractures, faults, and with intrusive igneous rocks. The replacement deposits are of two types, bed replacement and fissure. The fissure
deposits are the most numerous, but most of the production from the Black Forest mine and from the district has been from bed deposits.

A ten-foot dolomite bed that is brittle and shatters when faulted has been especially favorable to replacement. The bed ore occurs as pipes at the intersection of the N. 40° W. and N. 50° W. fissures with this bed; the pipes follow the intersection for as much as several hundred feet. The Dutch fissure, which has produced considerable ore, is an example of this type of deposit. This fissure has been followed for 1,000 feet on the dip of the beds.

Most of the fissure deposits have replaced the dolomite for a foot or two from the fissure walls. The ore has formed in the favorable ore horizon.

Several deposits formed along the intersection of Number 1 and Number 2 faults with the ore horizon.

Character of Black Forest ore

The Black Forest ore is an oxidized lead-silver ore containing on the average twenty percent lead, twenty ounces of silver per ton, twenty to forty percent iron, and a small percentage of lime and "insoluble," but no appreciable gold, copper, or zinc. Some of the ore contains small amounts of arsenic. The minerals are
carbonates, sulphates, and oxides.

The ore has a variety of colors, with red and yellow predominating, and is easily mined because of its soft, earthy character.

The ore bodies are encased by a ferruginous material, exhibiting a crude banding parallel to the dolomite walls, and in places containing some copper and zinc minerals. The casing material is helpful in prospecting since it indicates mineralization and is usually a guide to ore.
Mineralogy of the Ore Deposits

General Statement

The principal ore minerals are cerussite and plumbotjarosite, cerussite being the more abundant. Silver is in some unidentified combination. The minor minerals include anglesite, galena, sphalerite, pyrrhotite, chalcopyrite, pyrite, and arsenopyrite. Most of the gangue is unreplaced dolomite.

Detailed description of minerals

In this section the minerals are described in the order followed by Dana.

Elements

Sulphur (S) - Small quantities of elemental sulphur were recognized on C level. The sulphur was intermixed with both sulphides and oxidized minerals, and according to the miners it did not have any particular zoned positions, but was scattered through the ore.

Sulphides, sulphosalts

Galena (PbS) - Galena and the sulphides in general, are in small amounts throughout the mine. The only sulphide ore body reported to the writer was on B level.
Elsewhere the sulphide is in tight fissures where it has been protected from oxidation. Galena is the most abundant sulphide and usually has good cubic cleavage. Specimens from the Monarch mine, to the west of Black Forest, have the "steel galena" texture. Alteration to anglesite, cerussite, and plumbojarosite, is general.

**Chalcocite (Cu₂S)** - Small quantities of chalcocite were found in prospect holes to the west of the Black Forest mine. The chalcocite is formed as a supergene replacement of bornite and chalcopyrite.

**Sphalerite (ZnS)** - The distribution of sphalerite is similar to that of galena, but in smaller amounts. It replaces arsenopyrite and pyrite and is generally replaced by the other sulphides. Most specimens contain tiny rounded inclusions of chalcopyrite.

**Pyrrhotite (FeS₁⁻)** - Pyrrhotite was observed in one specimen as tiny inclusions associated with chalcopyrite in sphalerite. The pyrrhotite appears to have been deposited simultaneously with chalcopyrite.

**Covellite (CuS)** - Covellite occurs at the Black Forest mine in small amounts as supergene replacements of chalcopyrite and tetrahedrite and around kernels of galena. In some of the prospect pits to the west of the Black Forest mine, covellite occurs as a supergene replacement of bornite and chalcopyrite.
**Bornite** \((\text{Cu}_5\text{FeS}_4)\) - Bornite was not found in the Black Forest mine but specimens were collected from the copper prospects to the west. The bornite was considerably altered to chalcocite and covellite.

**Chalcopyrite** \((\text{CuFeS}_2)\) - Most of the polished sections contain chalcopyrite, but in small percentages as compared with galena. It occurs both interstitial to other sulphides and as tiny rounded inclusions in sphalerite.

**Pyrite** \((\text{FeS}_2)\) - Pyrite occurs both in sulphide mineral deposits and disseminated through the altered granite porphyry. In the polished sections examined, pyrite is second in abundance to galena. Most of the pyrite is granular and thus difficult to polish.

**Marcasite** \((\text{FeS}_2)\) - Marcasite was noted in several specimens. It has replaced pyrite, from which it may readily be distinguished in polished specimens by its anisotropism in polarized light.

**Arsenopyrite** \((\text{FeAsS})\) - Arsenopyrite was found in small amounts in several polished sections.

**Tetrahedrite** \((5\text{Cu}_2\text{S}\cdot2(\text{Cu,Fe})\text{S}\cdot2\text{Sb}_2\text{S}_3)\) - A small amount of tetrahedrite, altering to covellite, was recognized in one polished section. A grayish, isotropic mineral was noted as small inclusions in galena. The inclusions are so small that no chemical test could be
made, but the general appearance suggests tetrahedrite. The tetrahedrite may have been the source of the silver, as no silver sulphide mineral was recognized.

**Oxides**

Quartz ($\text{SiO}_2$) - Quartz occurs in places as a gangue mineral but is lacking in most specimens of ore.

Hematite ($\text{Fe}_2\text{O}_3$) - Hematite is intermixed with altered sulphides and in the ferruginous casing that surrounds the oxidized ore bodies.

Some of the hematite is a filling of open spaces and has a somewhat botryoidal structure. It is also a replacement mineral and has preserved casts of pyrite. The hematite is generally black, but some is earthy red. The occurrence indicates that the mineral is all supergene.

Limonite (Hydrated oxides of iron) - Limonite as used here includes all the hydrous iron oxides. The limonite is associated with sulphides that are oxidizing, with the oxidized ores, and in altered igneous rocks. It has a yellowish, ocher appearance and fills vugs and fissures in the ore. There is probably an intermixture of jarosite and goethite in some of the ores, but the individual minerals cannot be recognized megascopically.
**Carbonates**

**Smithsonite (ZnCO₃)** - Small amounts of smithsonite are present in the ferruginous casing, surrounding the ore in the Black Forest mine. Some of the zinc producing mines to the west of Black Forest had large amounts of the mineral.

**Cerussite (PbCO₃)** - Cerussite is one of the principal ore minerals and is usually found as coarse-grained, gray masses. It also occurs as "sand carbonate." Occasionally the cerussite occurs as colorless and milky crystals imbedded in hematite. The formation of cerussite from galena, with anglesite as an intermediate step, is well shown in polished sections.

**Malachite (CuCO₃·Cu(OH)₂)** - Malchite is a rare mineral in the Black Forest mine, but it forms a stain on the dolomite walls of stopes.

**Azurite (2CuCO₃·Cu(OH)₂)** - Azurite is also a rare mineral in the Black Forest mine and has an occurrence similar to that of malachite.

**Aurichalcite (2(Zn,Cu)CO₃·3(Zn,Cu)(OH)₂)** - Aurichalcite, a supergene mineral, occurs as needle-like incrustations on the dolomite walls of stopes. It is quite abundant in some places, but is absent in many of the stopes.
Allophane(?) (Al₂SiO₅.nH₂O) - A mineral questionably identified as allophane(?) was collected from a prospect pit below the Juniper shaft.

The mineral is granular with a sub-conchoidal shining fracture. It is brittle, vitreous, and sky-blue. Chemical tests were obtained for aluminum, silica, and a trace of zinc. The mineral is isotropic and the index of refraction is 1.47. These properties correspond with the description of allophane as given in Dana's Textbook of Mineralogy, but the physical appearance differs from that of specimens in the University of Arizona collection. The mineral is of very minor importance.
Anglesite ($\text{PbSO}_4$) - Anglesite is a supergene mineral formed by the oxidation of galena. It is usually in earthy masses, forming concentric layers about a nucleus of unaltered galena. This mineral is formed as an intermediate product between galena and cerussite, and is too scarce to be classed as an important ore mineral.

Gypsum ($\text{CaS}_4\cdot2\text{H}_2\text{O}$) - Gypsum is rarely seen in the ore deposit, but several large crystals were collected. The gypsum is probably formed by the reaction of sulphuric acid, derived from the oxidation of pyrite, with the dolomite.

Jarosite ($K_2\text{Fe}_6\text{(OH)}_12\text{(SO}_4)_4$) - Because of the difficulty in distinguishing the members of the jarosite group from one another, except by chemical tests, it is uncertain how widespread the occurrence of pure jarosite is in the ores of the Black Forest mine. Some of the material tested was lead-free and gave a potassium flame test.

Plumbojarosite ($\text{PbFe}_6\text{(OH)}_12\text{(SO}_4)_4$) - Plumbojarosite constitutes an important part of the Black Forest ore. The brownish color of the ore is probably caused, to a large extent, by the presence of plumbojarosite as well as limonite. An assay of some of this mineral showed lead 20.1 percent per ton, iron 29.3 percent, and silver
61 ounces per ton. The lead and iron check fairly well with the respective percentages by formula. The silver may be due to some included argentojarosite.

**Unknown mineral** - A lead-arsenic mineral, that is associated with cerussite, occurs in the ore-bodies of the Black Forest mine. The mineral is not recognized as any species described in Dana's Textbook of Mineralogy.

It is soft, chalky-white, and soluble in hydrochloric acid. The mineral is isotropic, with an index of refraction above 1.855, and under high magnification appears as small euhedral crystals.

Microchemical tests were obtained for iron, lead, and arsenic. An assay of the material showed 0.010 ounces of gold, 13.8 ounces of silver per ton, thirty percent lead, and nineteen percent iron.

In places, the mineral comprises an important part of the ore, but it is not found in all the ore-bodies.
Paragenesis

The hypogene sulphides were deposited in the following order: Pyrite, arsenopyrite, sphalerite, pyrrhotite and chalcopyrite, galena and tetrahedrite, and marcasite.

Polished section study indicates that arsenopyrite replaces pyrite. In several sections, arsenopyrite shows a tendency to surround and form "pyrite islands" of some of the pyrite crystals. In some sections the pyrite is replaced by sphalerite and in others the pyrite forms veins cutting the sphalerite. This indicates two periods of pyrite mineralization; however it is possible that the pyrite was deposited as veins in an ore or gangue mineral that was later replaced by sphalerite, thereby indicating only one period of pyrite mineralization.

Pyrrhotite associated with chalcopyrite occurs as small inclusions in sphalerite. The pyrrhotite and chalcopyrite have a mutual boundary relation indicating simultaneous deposition. The chalcopyrite replaces sphalerite as veinlets following sphalerite cleavage.

Galena is later than sphalerite and contains tiny inclusions of tetrahedrite. The tetrahedrite does not occur in any other mineral, so it seems probable that it was deposited simultaneously with the galena.
Marcasite was the last hypogene sulphide deposited.

Bornite is also a hypogene mineral but is not associated with the sulphides in the Black Forest mine. The relation of bornite to the other sulphides in the sequence was not determined.

Chalcocite and covellite are supergene sulphides formed from bornite. Covellite is later than chalcocite. Chalcocite is also an alteration product of chalcopyrite. Some chalcocite has been deposited as borders around galena centers.
Mineralizing Solutions

It is generally recognized that ore deposits are formed from solutions that were derived from the same source as that of igneous rocks. This relation seems to be true for the Black Forest mine, as shown by the close association of granite porphyry and diorite dikes with the ore.

According to Bowen, acid aqueous solutions, which are a distillate from a salic magma, are the principal ore bringers. The procedure of deposition of minerals is as follows:

"The solutions deposit their load as a result of reaction with the rocks through which they are forced as a consequence of the formation of vapor at the boiling source. They thus become neutral and finally alkaline, which is the eventual fate of hot waters in contact with rock minerals."

On the basis of the above statements, the mineralizing solutions of the Black Forest mine are assumed to have been acid and to have come from an igneous mass that was also the source of the exposed igneous rocks.

Carbonate rocks are strongly attacked by acid solutions.\textsuperscript{17} Thus, the solutions, in passing through the limestone and dolomite, take material into solution and deposit other material, eventually becoming neutral or alkaline.

Bowen also states that:\textsuperscript{18}

"----- among the substances deposited are those whose transport depends upon the solutions remaining acid. Sulphides and certain oxides are therefore among the substances deposited, -----"

As the mineralizing solutions approached the favorable dolomite bed in the Black Forest mine, they must have had such a chemical nature that deposition of sulphides was about to take place. The broken nature of this bed due to its brittleness, and the presence of an overlying, relatively insoluble, dolomite bed, are factors that also controlled mineral deposition. The sulphide minerals were deposited in the form of pipes, at the intersection of a mineralized fissure and the favorable bed.

\textsuperscript{17} Bowen, N. L., - op. cit., p. 125.

\textsuperscript{18} Bowen, N. L., - op. cit., p. 127.
Oxidation and Enrichment

The sulphides were deposited in brecciated ground, indicative of shallow depth, but the minerals were probably at greater depths below the surface than the ore bodies are now. Due to erosion, the sulphides were brought closer to the surface, and were subjected to oxidizing conditions.

The oxidation of pyrite yields sulphuric acid and iron sulphate. The sulphuric acid solutions formed from pyrite, react with the other sulphide minerals. Lead sulphide oxidizes slowly to form sulphates, carbonates, and oxides, and, since these minerals are not highly soluble, lead tends to remain in the oxidized zone. Zinc sulphide is easily oxidized and dissolved and zinc is carried downward in large amounts. The zinc is easily precipitated by carbonate rocks. The copper sulphides are generally soluble and are leached from the upper parts of the oxidized zone and concentrated in the lower parts.

The iron sulphate, formed from pyrite, is oxidized

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to ferric sulphate, then hydrolyzed and precipitated as limonite. Lead sulphate, formed from galena, reacts with carbonate to produce cerussite. Zinc sulphate, formed from sphalerite, moves downward, together with iron sulphate and sulphuric acid. In passing through the carbonate rocks below the ore body, the zinc in the sulphate solutions is precipitated as smithsonite or monheimite.

Plumbojarosite, usually intermixed with the ore, is also found as larger deposits on the borders of cerussite ore bodies. These occurrences indicate that plumbojarosite was probably formed by the reaction of ferric sulphate solutions with cerussite.

Since lead sulphide oxidizes slowly to form difficultly soluble products, it is likely to remain near the site of the original ore, but, since zinc and iron are removed, the original ore body shrinks, and galena, anglesite, and cerussite, are found in the bottom of a cave.

These relations are well shown in the ore bodies of the Black Forest mine. The original zinc and copper content of the hypogene ores was small, but the zinc and copper present was leached, and is now found as small deposits on the walls of stopes. The oxidized lead ores
usually have an overlying shrinkage cave and occupy the site of original sulphide replacement deposits. In some of the near surface ore bodies, deposits of stratified, fine sand are above the ore, indicating that surface solutions have been active in the oxidation process.

It has been shown by Butler\textsuperscript{20} that the result of oxidation of a lead-silver-zinc ore body is the production of a porous mass occupying practically the same space as the original ores and containing essentially the same amount of iron, lead, and silver, but much less zinc, and possibly slightly less copper.

This process is applicable to the Black Forest mine and constitutes ore enrichment, as equal volumes of sulphide and oxidized ore contain essentially the same amount of iron, lead, and silver, but it is apparent that in percentage of weight, these metals have gained in the oxidized ore.

\textsuperscript{20} Butler, B. S., "Geology and ore deposits of the San Francisco and adjacent districts, Utah: U. S. Geol. Survey Prof. Paper 80, p. 143, 1913."
Bibliography


Raymond, R. W. and others, - Statistics on mines and mining in the States and Territories west of the Rocky Mountains: 1872 through 1904.


PLATE VII - A

Part of north slope of Spruce Mountain.
Offset of Cave limestone caused by Number 3 fault is shown in center.

PLATE VII - B

North slope of Spruce Mountain from top of Banner Hill. Black Forest Canyon is parallel to and below the picture. Johnson Gulch trends up the mountain slope.
PLATE VIII - A

Mine plant on E level dump in foreground.
D level dump at the upper right.

PLATE VIII - B

Number 1 fault, exposed on B level, showing gouge zone associated with the fault.
Surface of Juniper limestone showing fracture system. Shadows caused by trees.
Limestone in A strikes N. 52° E. and dips 53° SE.; that in B strikes N. 10° E. and dips 35° SE.
POLISHED SECTIONS OF ORES

PLATE XI - A
Sphalerite apparently cut by pyrite vein; however sphalerite appears to replace pyrite. Pyrite probably veined some pre-existing mineral that has been completely replaced by sphalerite. Plain light.

X 70

PLATE XI - B

X 70

py - pyrite
sl - sphalerite
gn - galena
cp - chalcopyrite
POLISHED SECTIONS OF ORES

PLATE XII - A

Pyrite cube surrounded by chalcopyrite. Chalcopyrite replaces sphalerite which is bounded by crystal forms (center of picture). Plain light.

X 123

PLATE XII - B

Pyrite crystals surrounded by marcasite. Plain light.

X 70

py - pyrite
sl - sphalerite
mr - marcasite
POLISHED SECTIONS OF ORES

PLATE XIII - A

A small mass of pyrite is surrounded by galena. Tetrahedrite appears to be contemporaneous with galena. Covellite (not shown in picture) is contained in fine cracks that cut tetrahedrite. Plain light.

X 123

PLATE XIII - B

Small inclusions of tetrahedrite in galena. Plain light.

X 280

PLATE XIII - C

Chalcopyrite and pyrrhotite inclusions in sphalerite. Chalcopyrite and pyrrhotite exhibit mutual boundary texture indicative of simultaneous deposition. Plain light.

X 315

py - pyrite
gn - galena
cp - chalcopyrite
td - tetrahedrite
po - pyrrhotite
sl - sphalerite
PLATE XIV - A

Pyrite, arsenopyrite, chalcopyrite, and sphalerite. Arsenopyrite has replaced the pyrite and has been replaced by sphalerite. Chalcopyrite replaces the sphalerite. Plain light.

X 80

PLATE XIV - B

Chalcopyrite veins in sphalerite. Alignment of veins in two general directions, suggests replacement of chalcopyrite along crystallographic directions in sphalerite. Plain light.

X 80

py - pyrite
cp - chalcopyrite
sl - sphalerite
asp - arsenopyrite
POLISHED SECTIONS OF ORES

PLATE XV - A


X 123

PLATE XV - B

Chalcopyrite gash veins in bornite. Black spots are pits in the section. Plain light.

X 123

bn - bornite
cc - chalcocite
cp - chalcopyrite
Surface Geological Map
BLACK FOREST MINE

Owned By
MISSOURI MONARCH CONS'D. MINES CO.
Spruce Mountain Mining District,
ELKO COUNTY, NEVADA.

Scale: 1 inch = 200 feet
November 1937
Contour Interval = 50 feet
GENERALIZED STRUCTURE SECTION THROUGH SPRUCE MTN.

Along course N. 85° W. - through Index Tunnel - & looking Northerly

Horizontal and Vertical Scale: 1 inch = 1000 feet

For explanation of colors & letter symbols see legend on Surface Map, Plate 1
STRUCTURE SECTION ALONG LINE A-A'

Looking Northeasterly

Horizontal and Vertical Scale: 1 inch = 200 feet

For explanation of colors & letter symbols see legend on Surface Map, Plate 1
Diagrammatic Section of Spruce Mountain Anticline
Before Faulting
Scale: 1 inch = 1000 Feet