MINERALIZED AREAS IN THE SAN CARLOS-SAFFORD-DUNCAN NONPOINT-SOURCE MANAGEMENT ZONE, ARIZONA

by
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This report is preliminary and has not been edited or reviewed for conformity with Arizona Geological Survey standards
INTRODUCTION

As part of a continuing study of nonpoint-source pollution in Arizona, this report identifies mineralized areas in the San Carlos-Safford-Duncan Nonpoint-Source Management Zone (Figure 1) and their potential affects on water quality. Natural processes can concentrate an element or group of elements in a particular area. Information on the location, size, and characteristics of these naturally-occurring mineralized areas may help water-quality management agencies in predicting potential nonpoint sources of pollutants and directing resources toward protection and maintenance of water quality.

METALLIC MINERAL DISTRICTS

In the early days of mining in Arizona, mines were organized into mining districts, usually based on geographic location, and sometimes on politics. Another way of organizing mines (metallic ore deposits) is by geology-based criteria, such as age, style of mineralization, and commodities produced. This geological approach commonly leads to dividing some geographically-defined mining districts into more than one metallic mineral district. The concept of metallic mineral districts (e.g. Keith and others, 1983a) has supplanted the use of mining districts (e.g. Keith, 1973) as a way of classifying metallic ore deposits in Arizona. The mineral districts in this report (Table 1) are those of Stanley B. Keith and others (1983a; 1983b), and Schnabel and Welty (1986). Non-metallic minerals, such as fluorite and barite, are not part of Keith’s classification, but can be important components of some ore deposits and are discussed in this report. Descriptions of radioactive mineral occurrences are largely from the U.S. Atomic Energy Commission (1970a, b, c, d) and Wright (1950a, b).

In this report, some mineral districts have been combined into one description. For example, the San Juan, Dos Pobres, Lone Star, Sanchez, and Sol metallic mineral districts comprise a chain of similar large porphyry copper deposits of the same age, setting, and style of mineralization (that are more commonly lumped together as the Safford district. Similarly, the mineral districts in the Dos Cabezas Mountains (Apache Pass, Mascot, and Teviston) have been described together.

Production figures for each metallic mineral district are presented in Table 2. In some cases, such as the Mascot, Stanley, and Twin Peaks districts, production from the district came largely from mines outside the Management Zone but is included in the totals. A tabulation of those mines and prospects in Cochise County (Keith, 1973) that are within the Management Zone are given in Appendix A. (Tabulations were not made for Pinal, Graham, or Greenlee Counties). A list of names and formulas for minerals mentioned in this report is given in Appendix B.

References are given in each section for sources of information that pertain specifically to mines and mineralization. Articles and maps that describe only geology are not included. A comprehensive list of geological references for the San Carlos-Safford-Duncan Nonpoint-Source Management Zone has been published in Trapp and Harris (1996), and geologic mapping is indexed in Harris (1996).
Figure 1. Location of San Carlos-Safford-Duncan Nonpoint-Source Management Zone.
Table 2. Production from metallic mineral districts within the Management Zone.

<table>
<thead>
<tr>
<th>District</th>
<th>Years</th>
<th>Cu (lbs)</th>
<th>Pb (lbs)</th>
<th>Zn (lbs)</th>
<th>Mo (lbs)</th>
<th>Au (oz)</th>
<th>Ag (oz)</th>
<th>Mn (lbs)</th>
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<td>10,500</td>
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</table>

Data to 1981 from Keith and others, 1983
NA - data not available; ** - Partial estimate for five years production.
Table 1. Metallic mineral districts in the San Carlos-Safford-Duncan Nonpoint-Source Management Zone.

<table>
<thead>
<tr>
<th>District</th>
<th>District</th>
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<tr>
<td>Apache Pass</td>
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<td>Blue River</td>
</tr>
<tr>
<td>California</td>
<td>Clark</td>
<td>Copper Mountain (Morenci)</td>
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<tr>
<td>Day Mine Wash</td>
<td>Dos Pobres (Safford)</td>
<td>Fisher Hills</td>
</tr>
<tr>
<td>Gila Hot Springs</td>
<td>Goat Camp</td>
<td>Golandrina</td>
</tr>
<tr>
<td>Kimball</td>
<td>Lone Star (Safford)</td>
<td>Mascot</td>
</tr>
<tr>
<td>111 Ranch</td>
<td>Peloncillo</td>
<td>Saddle Mountain</td>
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<td>San Carlos</td>
<td>San Juan (Safford)</td>
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<td>Sol (Safford)</td>
<td>Stanley</td>
<td>Teviston</td>
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<td>Twin Peaks</td>
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METALLIC MINERAL DISTRICT DESCRIPTIONS

Dos Cabezas Mountains (Apache Pass, Mascot, Teviston Districts)

Basement rocks in the Dos Cabezas are composed of Precambrian Pinal Schist (1.7 Ga) intruded by Precambrian granite (1.4 Ga), a combination found in almost all mountain ranges in southeast Arizona. Paleozoic to Cretaceous sedimentary rocks, mostly limestone and sandstone, are deposited on the Precambrian rocks. Late Cretaceous-Early Tertiary (59-64 Ma) granodiorite and mid-Tertiary (20-34 Ma) granite and associated rhyolite dikes intrude the older rocks throughout the Dos Cabezas Mountains. Passing through the region is the northwest-trending Apache Pass fault zone, which juxtaposes many of the different rock types and provides a major control on the locus of igneous intrusions, which in turn are responsible for mineralization in the Dos Cabezas Mountains.

Base- and precious-metal mineralization is widespread in the Dos Cabezas Mountains. Deposits include plug-like masses, veins, replacements, and disseminated mineralization. Mineralization includes occurrences of Bi, Cu, Pb, Mo, Ag, and Zn minerals (mostly sulfides) and areas of higher than background levels of these elements. In general, gold and silver are more prevalent in the south (Apache Pass), while copper, lead, and zinc are dominant to the north (Mascot, Teviston).

Within the Management Zone, the Elma Mine (T14S, R27E, section 9) in the Mascot District had the largest production. Ore in the Mascot district formed in pipe-like volcanic breccia bodies and included sulfides of iron, copper, and lead, with minor gold, tungsten, and beryllium.

Fluorite mineralization is reported from the Buckeye Canyon prospect (T13S, R27E, sec 34, NE). Fluorite occurs as purple and green veinlets in Precambrian granite cut by Tertiary rhyolite dikes.

Slight radioactivity was noted at two prospects in the Teviston district. At the Sturgess property (T13S, R26E, sec 25/36) a trace amount of a uranium mineral (possibly uraninite) was associated with pyrite, galena, and limonite in dikes in Precambrian granite. Mild radioactivity was reported in altered gray rock containing pods of dolomite and surrounded by granite at the Valley View claims (T13S, R26E, sec 22, SE). The altered rock also contains pyrite, chalcopyrite, galena, and magnetite.

Tungsten mineralization has been prospected at the Ram prospect, Section 21, T14S, R28E (Apache Pass district). Scheelite occurs in quartz-calcite veins in contact-metamorphic zones of limestone and schist cut by felsic dikes. Tungsten also occurs at the Comstock Lode
claim, in section 22, T13S, R26E (Teviston District). Mineralization consists of scheelite in quartz veins associated with felsic dikes in altered diorite, and minor placer concentrations of scheelite in drainages. Along with the scheelite is minor galena and iron oxide.

Gold placers are a notable feature of the Teviston district. Gold has been produced from the Gold Gulch, California Gulch and Cowboy Canyon areas.


Ash Peak

Ash Peak is a mid-Tertiary silver district. Rocks in the district include andesite lava flows, silicic pyroclastic flows and tuffs, rhyolite, and diabase dikes. At Ash Peak, two thick andesite flows (21-23 Ma) are separated by rhyolite pyroclastic flows. Mineralization is restricted to the lower andesite flows and consists of quartz-calcite veins with silver and gold. Silver ore is dominantly argentiferous tetrahedrite in a chalcedonic quartz matrix, associated with fine-grained sulfides including pyrite, chalcopyrite, covellite, galena, and sphalerite.

Manganese is found in two NW-trending shear zones about 1,200 feet apart. Psilomelane and pyrolusite are with calcite in veinlets and lenses up to two feet wide. Tungsten is reported to occur with the manganese.

The Ash Peak Mine was active from 1981 to late 1990, so additional silver and gold have been mine since the figures in Table 2. Total production from the mine from 1899 to when it shut down in 1990 was at least 3,883,023 ounces silver and 14,224 ounces of gold (Sims, 1993).


Black Hawk

The Black Hawk district lies at the northwest end of the Pinaleno Mountains near Eagle Pass. A large low-angle normal (detachment) fault traverses the Eagle Pass area. Bedrock of the lower plate consists of Precambrian quartz monzonite and diabase intruding Pinal schist, with scattered mid-Tertiary (25 Ma) rhyolite dikes cutting the older rocks. Upper plate rocks are composed of Miocene andesite overlain by rhyolite (probably equivalent to the Galiuro volcanics), and coarse-grained sedimentary rocks (fanglomerate and mud-flow breccia) of the Hell Hole Conglomerate.

Manganese mineralization occurs as ENE-trending quartz veins along a fracture zone in Precambrian granite. The entire production from this district consisted of one shipment of Mn-oxide ore to a government purchasing depot in 1955.

References: Farnham and others, 1961; Blacet and others, 1978; Brown, 1993a; Davis and Hardy, 1981.
**Blue River**

The Blue River district is an unclassified mineral district underlain by mid-Tertiary volcanic and intrusive rocks. The district has areas of hydrothermal alteration, but no known mines or prospects and no production. Altered rocks are silicified, argillized, or hematite stained. A mineral resource evaluation of the Blue Range Primitive Area failed to discover any mineral deposits. Hydrothermal alteration and low-level geochemical anomalies may indicate mineral potential at depth.

References: Ratté and others, 1969.

**California**

The California district is a mid-Tertiary lead-zinc-silver district situated on the northeast flanks of the Chiricahua Mountains. Basement rocks consist of Precambrian schist about 1700 Ma old, intruded by 1400 Ma granite. A thick sequence of Paleozoic and Mesozoic sedimentary rocks is deposited on the basement. Widespread mid-Tertiary (24-35 Ma) igneous activity occurred across southeast Arizona. Granitic bodies intruded the older rocks and volcanic rocks covered the region. The California district lies on the northeast edge of a large volcanic center, dominated by the Turkey Creek caldera. A major northwest-trending structure, the Apache Pass Fault Zone, passes through the area, and is a locus for intrusions responsible for mineralization in the district.

Mineralization occurs as base metal carbonates and sulfides in veins associated with shear zones. Most ore deposits are in limestone at or near intrusive dikes and bodies of granites. Common ore minerals include galena, sphalerite, chalcopyrite, scheelite, fluorite, wulfenite, silver, and gold. The Hilltop lead-zinc mine was the district's largest producer, yielding 5,000,000 pounds of lead between 1924-1928. The mine was closed by 1973.

Fluorite mineralization occurs at the Prague prospect (T16S, R30E, sec 17, E1/2) and at an unnamed prospect near Paradise. Fluorite is found as coarse crystalline filling in veins up to four feet wide in limestone in fault contact with a Tertiary granitic intrusion.

Uranium concentrations in the dump rocks at the Hill Top, Scanlon, and King Ainsworth mines were found to be at background levels.


**Clark**

The Clark district is situated on the northwest flank of the Pinaleño Mountains. Bedrock is Precambrian granitic gneiss, with minor schist and amphibolite. Keith and others (1983) classify the Clark district as a mid-Tertiary lead-zinc-silver district. Gold is found in quartz veins that follow chloritized dikes cutting Precambrian granite. Cobalt and nickel are reported in the form of smaltite (CoNiAs₂) in a silver-gold-bearing vein at the Bluebird mine.

References: Blacet and Miller, 1978; Moore, 1969a;1969b; Wilson and others, 1934.
Copper Mountain (Morenci)

Copper Mountain is more commonly known as the Morenci or Morenci-Metcalf district. The Morenci Mine, the second largest copper mine in the world, is by far the most prolific mine in the Management Zone, and since 1991 is the only active metal mine.

Bedrock is composed of Precambrian schist and granite, upon which Paleozoic and Mesozoic sediments were deposited. During Laramide time (53-65 Ma), dikes and stocks of diorite, quartz monzonite, and granite porphyry intruded the older rocks. Copper mineralization resulted from this igneous activity. During the mid-Tertiary, volcanic rocks covered the region.

Primary mineralization at Morenci consists of pyrite, chalcopyrite, molybdenite, sphalerite, and minor galena in veinlets and disseminations. Weathering and oxidation has produced secondary sulfides (chalcolite, covellite), oxides (chrysocolla, malachite, azurite, brochantite, chalcocite, turquoise), and native copper.

Skarn mineralization is developed in shale and limestone near intrusive margins. Unlike most porphyry-related skarns, those at Morenci rarely have grades greater than 1% copper.

Sulfide copper ore is processed by traditional methods of milling, floatation concentration, and smelting. Increasingly, copper production is from leaching process.

Gold and silver are byproducts of the copper mining. Placer gold is found in many of the streams around the district.


Day Mine Wash

The Day Mine Wash district is classified as a mid-Tertiary silver vein and replacement district. A thick sequence of Tertiary lava flows, tuffs, and tuff breccias ranging from basalt to rhyolite underlie the district. A series of rhyolite plugs intrudes the volcanic rocks.

Manganese is found in or near the district at the Voelckel claims. Calcite veins containing Mn-oxide minerals occur in shear zones in andesite.


Dos Pobres (see Safford)
Fisher Hills

Situated southeast of the Pinaleño Mountains, the Fisher Hills district is classified as a mid-Tertiary manganese vein district. Tertiary volcanic rocks ranging from andesite to rhyolite are deposited on or are in fault contact with Precambrian granite.

Manganese is present as psilomelane and pyrolusite in seams and veinlets along fractures and shears in Precambrian granite. Minor copper staining is noted in some of the prospects.

Slight radioactivity in veins with fluorite and hematite were noted during reconnaissance investigations for uranium in the region. The source of the radioactivity is unknown; no uranium minerals were evident.


Gila Hot Springs

Low-grade manganese ore at the Pyrolusite claims, one mile east of Gillard Hot Springs, is found in lenses along fractures in the Tertiary basin fill (“Gila Conglomerate”). Ore consists of the Mn minerals psilomelane, pyrolusite and manganite, along with calcite, barite and fluorite in an iron-stained siliceous matrix. Mineralization appears to be related to mid-Tertiary volcanic activity.

References: Potter and others, 1946; Farnham and others, 1961; Spencer and Welty, 1989.

Goat Camp

The Goat Camp district (more commonly known as the Steeple Rock mining district) is on the Arizona-New Mexico border northeast of Duncan. Mid- to late-Tertiary volcanic rocks of the Mogollon-Datil volcanic field cover the region. The volcanic rocks include andesite flows, rhyolite ash-flow tuffs, and rhyolite plugs and dikes. Beneath the volcanic rocks, and exposed in a few areas in the Steeple Rock mining district are Precambrian granites overlain by Paleozoic and Mesozoic sedimentary rocks.

Most of the district is in New Mexico, and the overwhelming bulk of the production from the Steeple Rock mining district came from mines in that state. Keith and others (1983) classify Goat Camp as a mid-Tertiary manganese district, whereas the nearby Twin Peaks district is a lead-zinc-silver producer. Historically, the Goat Camp (or Duncan) subdistrict of Steeple Rock mining district was Arizona’s largest fluorite producer. (Fluorite is a non-metallic mineral and so does not enter into Keith’s metallic mineral district classification, even though the Steeple Rock mining district is best known as a world-class fluorite district.)

The geology of the Arizona portion of the Goat Camp district is composed of at least 1500 feet of Tertiary lava flows ranging from andesitic basalt to rhyolite. Rhyolite and diorite dikes and plugs intrude the flows, commonly along faults and joints.

Hydrothermal alteration has affected large areas of the Goat Camp district, although some rock units are much more altered than others. Alteration has left some of the volcanic rocks bleached and iron-stained, leaving quartz and alunite. Propylitic, argillic, and silicic alteration are common.

Faults were sites of deposition of quartz veins which also carry fluorite, calcite, and MnO. At the Black Cat mine (T6S, R32E, section 33), MnO minerals occur in lenses along two parallel, north-trending veins, 800 feet apart. The veins are mostly quartz, with calcite and fluorite. The
beryllium mineral bertrandite is reported in the veins of the district. Production figures for the district in Table 2 are from this mine.


Golandrina

The Golandrina district occupies the lower hills at the southeast end of the Pinaleño Mountains. Tertiary volcanic flows, tuff, breccias, and dikes ranging from andesite to rhyolite are in fault contact with Precambrian granite.

Galena, sphalerite, pyrite, and smithsonite are found in sheared and hydrothermally altered volcanic rocks and in quartz veins and shear zones in Precambrian granite. Secondary lead and copper minerals occur in fractures in the volcanic rocks. Uranium-bearing pyromorphite is reported from several localities in the district. Veins in the district with anomalous radioactivity commonly contain fluorite, hematite, and chlorite. Tungsten-bearing MnO in veins is reported.


Kimball

Unclassified district with no known mineralization. Schnabel and Welty (1986) list a USGS geologic map (I-442, Morrison, 1965) as the only reference for this district. This map indicates no mines, prospects, or alteration. [Note: this is not the Kimball district of Lindgren and others (1910), Young (1982), or Enders (1981). Their Kimball mining district is Keith’s Peloncillo metallic mineral district.]

References: none

Lone Star (see Safford)

Mascot (see Dos Cabezas)

111 Ranch

The 111 Ranch district wraps around the north and west part of Dry Mountain, at the north end of the Whitlock Mountains. The Whitlock Mountains are composed of a thick sequence of mid-Tertiary lava flow, tuffs, and eruptive centers. Post-volcanic lacustrine deposits of limestone, marl, diatomite, and clay host uranium mineralization in the district.

Uranium is found in highest concentrations in beds of diatomite. Levels up to 444 ppm uranium are reported. Within the diatomite, lenses of chert commonly carry the most uranium. The yellow uranium mineral carnotite is present in outcrop and in stockpiles.

The source of the uranium may be from the weathering of volcanic rocks in the Whitlock Mountains. Although extensively prospected, grades and tonnages of uranium and diatomite have not been high enough to warrant commercial mining of either.
Uranium concentrations in the bedrock of the Whitlock Mountains are higher than the average concentrations in the basin fill alluvium surrounding the mountains (neglecting the U deposits of 111 Ranch). Airborne radioactivity anomalies are reported over the Whitlock Mountains (Burgett and Zollinger, 1976a, 1976b, reported in Carlisle, 1978). Bedrock levels of 6-27 ppm U were measured), compared to an average basin-fill concentration of 3.6 ppm (Harris, 1994).


Peloncillo

The Peloncillo district of Keith and others (1983) corresponds to the Kimball (Steins Pass) mining district of Lindgren and others (1910), Enders (1981), and Young (1982). Mineralization developed along faults and dikes associated with a mid-Tertiary volcanic center dominated by the Steins Caldera. Volcanic rocks underlie the region and consist of flows, tuffs, breccias, and plugs of rhyolite, dacite, and andesite. Production from the district was largely from mines in New Mexico.

Silver was mined in the district, with the Volcano Mine (just inside New Mexico) being the largest producer. At that mine, silver ore was found in quartz-pyrite veins along a fault contact between an andesite megabreccia and rhyolite ash flow tuff. To the north, the Federal Mine (also just in New Mexico) produced gold and silver from a north-trending silicified shear zone or vein 5 to 20 feet wide. A yellow mineral thought to be vanadinite accompanied the gold. The Beck (National) mine, southwest of the Federal Mine, was developed in quartz-calcite veins along ENE-trending dikes in chloritized volcanic rocks. The ore contained sulfides of iron, copper, lead, and zinc, along with high values of silver and some gold.

References: Calder, 1982f; Enders, 1981; Richter and others, 1990; Lindgren and others, 1910; Young, 1982.

Saddle Mountain

Mineralization in the Saddle Mountain district consists predominantly of lead-silver veins. Bedrock consists of Precambrian granite and schist, younger Precambrian sediments of the Apache Group, Paleozoic sedimentary rocks, older Cretaceous sediments and volcanic rocks, Cretaceous-Tertiary volcanic and intrusive rocks, and mid-Tertiary volcanic and sedimentary rocks.

Silver-bearing sulfides of iron, copper, and lead occur in quartz-calcite-barite veins in the district. These deposits are found in Cretaceous andesite and diorite porphyry.

In the Ash Creek area, deposits of gold-bearing pyrite occur, principally in Cretaceous volcanic rocks. The gold is most commonly found in shear zones where the rocks have been brecciated. Pyrite is accompanied by quartz, calcite, chlorite, magnetite and hematite. A few gold-bearing pyrite deposits are found in rocks that are not sheared.

Contact-metamorphic deposits are found where limestone has been intruded by igneous bodies. During formation of these deposits, calcium silicate minerals (epidote, garnet, diopside) replace limestone. Silver- and gold-bearing sulfides of copper and lead are mined from these deposits.
Safford (Dos Pobres, Lone Star, San Juan, Sanchez, Sol)

The Safford district comprises several large porphyry copper deposits along the southern flanks of the Gila Mountains, northeast of Safford. Together, these deposits form one of the largest porphyry copper districts in the world. The district is also known as the Lone Star mining district in many references.

Igneous rocks of Laramide age (early Tertiary, 53-58 Ma) are the oldest rocks exposed in the district. These include andesite lava flows and agglomerates that have been intruded by latite dikes, quartz diorite stocks, and quartz monzonite porphyry stocks. Copper mineralization is associated with the porphyry intrusions. Post-mineral volcanic rocks of mid-Tertiary age cover most of the Gila Mountains. These younger rocks include andesite and basalt flows, and rhyolite tuffs and plugs.

Along the range front through the district is the Butte Fault, with as much as 2000 feet of down-to-the-southwest displacement. The large copper deposits are north of the fault. Although this and other young Basin and Range faults are responsible for the present topography of the mountains, structures related to mineralization are older (Laramide age) and northeast-trending. The porphyry stocks related to copper deposits are associated with NE-trending shears. The Sol deposit is considered to be sub-economic because it is relatively small and is deeply buried (Yarter, 1981).

Important ore minerals include the primary sulfides pyrite, chalcopyrite, bornite, molybdenite, tetrahedrite, galena, and sphalerite. Weathering and oxidation of the primary sulfides generates secondary sulfides such as calcocite and covellite, and oxide minerals such as chrysocolla, malachite, brochantite, cuprite, limonite, and jarosite.

Minor gold is found in the district as fine to visible flakes in fractures north of the San Juan mine, north of the Lone Star mine, and in the Walnut Springs area. The gold is commonly associated with iron and manganese oxides, especially where copper-stained.


San Carlos

The San Carlos district, about nine miles southeast of the town of San Carlos, is a mid-Tertiary manganese district. Tertiary andesite and basalt flows make up the bedrock in this area. Mineralization is associated with fracture zones in andesite flows. Manganese occurs as stringers and seams of psilomelane and pyrolusite mixed with calcite and brecciated wall rock.

References: Farnham and others, 1961; Bromfield and Shride, 1956; Spencer and Welty, 1989.

San Juan (see Safford)
Sanchez (see Safford)

Sol (see Safford)

Stanley

Stanley is classified as a mid-Tertiary lead-zinc-silver vein and replacement district. The geology of the Stanley district is much like that of the Saddle Mountain district immediately to the west. Bedrock is composed of Precambrian schist and granite overlain by Paleozoic sedimentary rocks, Cretaceous volcanic and sedimentary rocks, Cretaceous-Tertiary igneous rocks, and mid-Tertiary igneous and sedimentary rocks.

Vein mineralization has developed along shear zones and dikes in much of the district. Quartz-calcite veins typically carry copper, lead, zinc, manganese, and silver.

Contact metamorphism is common where limestone has been intruded by igneous rocks. Alteration of the limestone to garnet, actinolite, magnetite, and hematite is accompanied by mineralization including sulfides of copper, lead, zinc, and antimony, along with minor gold and silver.

Manganese mineralization occurs at the Black Rock (Davis group of claims, T4S, R19E, section 18. Irregular replacement beds in limestone contain iron and manganese oxides in coarsely crystalline calcite.

Barite-fluorite mineralization is noted at the Barium King prospect, T4S, R20E, section 24. Veins up to 18 feet wide containing fine-grained fluorite and barite occur in brecciated trachyte. Fluorite is found with quartz and barite in the Coronado Group prospects, T4S, R19E, sec28/29, in veins along bedding planes in limestone. Silver-bearing barite in copper-stained veins and stringers occurs in volcanic rocks near the top of Stanley Butte, in the Little Mule group of claims, T5S, R19E, sections 2, 11, and 12.

References: Bromfield and Shride, 1956; Brown, 1993c; Elevatorski, 1971; Farnham and others, 1961; Ross, 1925a; Stewart and Pfister, 1960; Wilson, 1950b.

Teviston (see Dos Cabezas)

Twin Peaks

The Twin Peaks metallic mineral district (known more commonly as the Steeple Rock mining district) straddles the Arizona-New Mexico border east of Duncan, and is mostly in New Mexico. Mid-to late-Tertiary volcanic rocks of the Mogollon-Datil volcanic field cover the region. The volcanic rocks include andesite flows, rhyolite ash-flow tuffs, and rhyolite plugs and dikes. Beneath the volcanic rocks, and exposed in a few areas in the Steeple Rock mining district are Precambrian granites overlain by Paleozoic and Mesozoic sedimentary rocks.

Most of the district is in New Mexico, and the overwhelming bulk of the production from the Steeple Rock mining district came from mines in that state. Keith and others (1983) classify the Twin Peaks district as a lead-zinc-silver producer whereas the nearby Goat Camp is a mid-Tertiary manganese district.

Hydrothermal alteration has affected large areas of the Twin Peaks district, although some rock units are much more altered than others. Alteration has left some of the volcanic rocks bleached and iron-stained, leaving quartz and alunite. Propylitic, argillic, and silicic alteration are common.
Quartz is the major vein mineral, along with minor calcite. Ore minerals include pyrite, sphalerite, chalcopyrite, and galena. Tungsten-bearing psilomelane (MnO) veins are present in many fractures. Beryllium mineralization in the form of bertrandite in veins is reported in the district.


PRODUCTION

Total known production for metallic mineral districts in the Management Zone is given in Table 2. The figures to 1981 are from Keith and others (1983). Data after 1981 for Morenci were compiled from US Bureau of Mines, US Geological Survey, and Arizona Department of Mines and Mineral Resources publications, and Ash Peak figures are from Sims (1993). Other sources of information on production from mineral districts or individual mines include Long (1995), and Welty and others (1985).

Virtually all mining activity (in terms of the number of locations being mined) in the Management Zone took place before 1969. Only two districts, Copper Mountain and Ash Peak, have recorded production of metallic minerals since 1981.

Morenci Mine (Copper Mountain district) copper production figures for 1988, 1993, and 1994 were interpolated from incomplete BOM and ADMMR data and so the total for 1982-1997 (Table 2) is only a close estimate. Similarly, molybdenum production from Morenci was mentioned each year in the Bureau of Mines Minerals Yearbooks, but actual figures were given only for 1982, 1986, 1989, 1990, and 1992. Gold, silver, and other metals are also extracted as a byproduct of copper mining. Morenci was ranked first, second, or third for silver output in Arizona for many of the years 1982-1991, but no data were published on the actual amount of silver or other commodities produced.

For the Safford and Morenci deposits, data on the known reserves and grades are published in Long (1995). These figures indicate that the known reserves of the Copper Mountain district (Morenci-Metcalf Mine) are far from exhausted. Of the reported 60+ billion pounds of copper contained in the Morenci-Metcalf deposits, about 20 billion pounds has been extracted from 1873 to 1997.

Silver was mined in the Ash Peak district from 1918 to late 1990. Virtually the entire production from the district came from the Ash Peak Mine, which produced at least 3,883,023 ounces of silver and 14,224 ounces of gold (Sims, 1993). According to the US Bureau of Mines Minerals Yearbook for 1987, the Ash Peak mine produced about 200 tons of ore per day containing 5 to 6 troy ounces of silver per ton. After Ash Peak shut down, Morenci was the only active metal mine in the Management Zone.
MINERAL RESOURCE EVALUATIONS

Various mineral resource assessments have been performed for 1° X 2° quadrangles by agencies such as the US Geological Survey, US Bureau of Mines, US Department of Energy, and Atomic Energy Commission. References for these studies are:

Silver City 1° X 2° quadrangle: McDanal and others, 1983; O'Neill and Thiede, 1982; Raines, 1984; Richter and Lawrence, 1983; Richter and Sharp, 1984a-m; Richter and others, 1986; Watts and others, 1986a-k; Watts and Hassemer, 1988, US Department of Energy, 1981b;

Mesa 1° X 2° quadrangle: Koller, 1980; Cook and Koller, 1980;

Douglas 1° X 2° quadrangle: US Department of Energy, 1981a;

Clifton 1° X 2° quadrangle: White and Foster, 1982;

Primitive and roadless areas have been assessed for suitability as wilderness. Mineral resource assessments of wilderness study areas not in mineral districts include:

Black Rock: Harms and others, 1985; Calder, 1982c; Ryan, 1985a; Simons and others, 1987c;
Chiricahua: Drewes and Williams, 1973
Fishhook: Harms and others, 1985; Calder, 1982e; Ryan, 1985b; Simons and others, 1987a;
San Francisco: Ratté and others, 1982b; Klein, 1984; Lane, 1982
Hells Hole: Briggs, 1982; Hassemer and others, 1981, 1983; Ratté and others, 1982a;
Needles Eye: Harms and others, 1985; Simons and others, 1987b; Ryan, 1985c;
North End: Bigsby, 1983; Drewes and Bigsby, 1984; Drewes and others, 1983; Moss and Abrams, 1985; Watts and others, 1985;
Vanar Hills-Peloncillo: Calder, 1982f;
Turtle Mountains-Gila Box: Calder, 1982a;
Whitlock Mountains: Calder, 1982d

Mineral resource assessments of the Coronado National Forest were performed simultaneously by the US Bureau of Mines and US Geological Survey (Brown, 1993a-c; Nowlan and Chaffee, 1995; duBray, 1996). The USGS study was a look at mineral resource potential, relying largely on geophysics, remote-sensing data, computer-based models, and calculations. The Bureau of Mines study was based on field examinations of mines and prospects, with extensive mapping and sampling of mineralized areas.

The entire state was surveyed for uranium by the US Atomic Energy Commission and US Department of Energy by county (US Atomic Energy Commission, 1970a-d), and by 1° X 2° quadrangle (O'Neill and Thiede, 1982; White and Foster, 1982; US Department of Energy, 1980, 1981a, 1981b). A few uranium occurrences were found within the Management Zone and are discussed under the appropriate districts.
POTENTIAL IMPACTS ON WATER QUALITY

Mining activities can provide a potential source of TDS to surface and groundwater. The nature and magnitude of potential water quality impacts associated with mining are controlled by a number of factors (Frisch-Gleason, 1995), including:

- type and size of mine
- type and volume of waste
- hydrology, geology, topography, and climate of mine site
- exposure to air and water
- distribution of sulfide minerals

In southeast Arizona, most mineralized zones and virtually all large ore bodies contain abundant sulfide minerals. These sulfides weather naturally by oxidation to form sulfate or sulfuric acid, and metals contained in the minerals may be released. Acid mine drainage is generally considered to be the major environmental impact of mining. In Arizona, however, this potential problem is not as severe as in other parts of the country, for several reasons. First, the climate is arid, so abundant water, the main ingredient in acid mine drainage, is not available. Second, the abundance of carbonates in and around mining areas allows for prevention or rapid neutralization of any potential acid generation (see references on acid mine drainage neutralization in Frisch-Gleason, 1995). Carbonates are present in the following forms:

- limestone and dolomite bedrock
- limestone and dolomite clasts in alluvial basin fill
- ubiquitous soil caliche (pedogenic carbonate)
- secondary calcite formed by weathering of rocks
- lacustrine and evaporitic limestones and marls in basin fill

Another potential problem is sediment loading of streams by runoff from mining areas. A study of this potential problem at Morenci by the US Bureau of Mines (Jessey and others, 1981) found that sediment runoff is controlled by dams along Chase Creek and so is not a factor in the sediment load of the San Francisco River. Further, acid mine drainage corresponds only with periods of heavy rain. The dams on Chase Creek contain the acid drainage, and any that could conceivably get beyond the dams would be quickly diluted in the river to negligible levels.

"Seepage of water from the open pit into the ground water aquifers is not a problem", according to the Bureau of Mines report because the pit bottom is below the groundwater table. Leaching of metals from the tailings piles is another potential problem but has apparently not occurred. From the limited sampling of the study, the chemistry of San Francisco river water one kilometer below the tailings shows "no appreciable increase in copper content" from that of the river at its confluence with Chase Creek, well upstream of the tailings. An EPA study (referred to in Jessey and others, 1981) showed that a mercury violation in 1977 was probably not related to mining, but was more likely the result of municipal pollution.

Given that Morenci is the world's second largest copper mine, it is significant that the operations there have had apparently little impact on the water quality of the San Francisco or Gila Rivers.

The total acreage of land used for mining may increase in the future as new copper deposits are brought into production. Mining operations at Morenci have steadily increased in size since open pit mining started in 1937, and new ore deposits adjacent to the existing open pit are expected to be put into production in coming decades. New open pit operations are also planned in the Safford District.
In some areas, land once used for mining is rapidly being converted to rural residential use. In the Portal area of the Chiricahua Mountains, for example, patented mining claims are being sold to individuals who are building houses on the land. Even though the area is heavily mineralized, there is little possibility of any new mining taking place there.

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US Bureau of Land Management, undated b, [Copper King, San Jose, and Standard Copper mines, Copper Mountain district, Greenlee County]: U.S. Bureau of Land Management Mining District Sheet 839 [available for inspection at BLM State Office and Field Offices, filed by Township and Range].

US Bureau of Land Management, undated c, [Shannon mine, Copper Mountain district, Greenlee County]: U.S. Bureau of Land Management Mining District Sheet 840 [available for inspection at BLM State Office and Field Offices, filed by Township and Range].
US Bureau of Land Management, undated d, [Mammoth and Brunswick mines, Copper Mountain district, Greenlee County]: U.S. Bureau of Land Management Mining District Sheet 837 [available for inspection at BLM State Office and Field Offices, filed by Township and Range].

US Bureau of Land Management, undated e, [Iolanthe prospect, Copper Mountain district, Greenlee County]: U.S. Bureau of Land Management Mining District Sheet 838 [available for inspection at BLM State Office and Field Offices, filed by Township and Range].

US Bureau of Land Management, undated f, [Stargo mines, Copper Mountain district, Greenlee County]: U.S. Bureau of Land Management Mining District Sheet 841 [available for inspection at BLM State Office and Field Offices, filed by Township and Range].


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World Mining, 1974, Phelps Dodge accelerates Safford underground development: World Mining, v. 27, no. 5, p. 76.

World Mining, 1976, Arizona - 'Don't neglect Safford as major future porphyry copper district': World Mining, v. 29, no. 4, p. 139.


APPENDIX A

Mines and prospects within the Management Zone (from Keith, 1973).
<table>
<thead>
<tr>
<th>MINING DISTRICT AND MINES</th>
<th>LOCATION</th>
<th>T. R. Sec.</th>
<th>MINERAL PRODUCTS</th>
<th>GEOLOGY</th>
<th>TYPE OF OPERATION AND PRODUCTION</th>
<th>REFERENCES</th>
</tr>
</thead>
</table>
| Dos Cabezas District                                          | 13-26    | Cu, Pb, Zn | 1. Erratic gold with minor silver values and partly oxidized base metal sulfides in irregular quartz-filled veins along fault and fracture zones containing spotty oxidized and disseminated magnetite, pyrite, and chlorite in irregular contact metamorphic rocks in epi-
                                                                                      |          | Au, W, Fe, P  |                  | dotes of Precambrian granite intrusives are cut by biotite, diabase and basaltic dikes, and he-
                                                                                      |          | (Mo)         |                  | nally disseminated magnetite, pyrite, and chlorite in irregular contact metamorphic rocks in epi-
                                                                                      |          |              |                  | dotes of Precambrian granite intrusives. | Numerous small deposits, mostly relatively small. Close to 100,000 tons of ore, mostly of
copper and gold, produced since the late 1890's. Small placer operations produced large but | Tenny, 1927-1929, p. 226-227 |
| Elkina mine                                                   | 146 TNE  | Au, Cu, Ag | Irregular quartz veins containing spotty free gold, copper oxides, pyrite and chlorite in epidiom and chloritized Laramide veins intruded by Laramide granite plug. | Shaft workings. At least 5000 tons of ore produced intermittently from the late 1890's to the | Mines Handbook, 1931, p. 224 |
| Mineral Park mines                                            | 146 TNE  | Au, Cu, Ag | 2. Weathered quartz veins containing erratic gold and silver values in Precambrian granite and schistose rocks. | late 1960's.                                                                                   | USGS Min. Resources, 1985-1986, p. 226-227 |
| II Tewaessa District (Tewa, Dos Cabezas Mountains)            | 13-26    | Au, Ag, Pb, | Numerous small deposits from tunnel and shaft. Worked during the late 1890's mainly and a few hundred tons of ore produced intermittently from the | Tunnel workings. Sporadic production of about 4000 tons from late 1890's to late 1940's. | USGS Min. Resources, 1985-1986, p. 226-227 |
| Apache Pass mine                                              | 135 22E  | Au, Pb, Ag, | Spotty gold and silver values with minor oxidized base metal sulfides in irregular quartz-filled fissure veins cutting Precambrian granite. |               | Wilson et al., 1924 (1967), p. 117 |
| Beryl Hill and Live Oak prospects                            | 145 2ME  | Au, Ag, Pb, | Lenticular quartz veins in Precambrian granite with porphyritic grano- | Open cut workings. Some 5000 tons of ore produced since 1937. Some 11,000 tons of ore produced | Merry, 1969, p. 14, 16 |
| Buena Vista Apache mine                                       | 146 TNE  | Au, Ag, Pb | Aurora pyrite and argentiferous galena in quartz veins along fracture zones in Precambrian granite. | intermittently between 1937 and 1946.                                                                 | Artz, Dept. Min. Resources file data |
| Comstock Lode mine                                            | 133 2EE  | W, Pb, Ag, | Spotty scheelite with minor galena and oxidized base metal sulfides in quartz veins and veinlets in Laramide granite rock. | Open cut, pila, short adits, and shallow shafts. A few tons of ore mined in the 1960's. | Dale et al., 1960, p. 26-28 |
| Cowboy mine                                                   | 135 2HE  | Au, Ag, Cu, | Spotty gold values with minor oxidized base metal sulfides in irregular quartz veins in Precambrian Pinal Schist. | Shallow workings. Some 75 tons of ore produced intermittently from 1933 to 1946. | Artz, Dept. Min. Resources file data |
| Golden Eagle mine                                             | 135 2HE  | Pb, Cu, Ag, | Spotty oxidized base metal sulfides in irregular quartz veins in Precambrian Pinal Schist. | Tunnel workings. About 120 tons of ore produced from 1937 to 1939. | ABM file data |
| Gold Gulch placer                                             | 135 2HE  | Au            | Place gold in shallow alluvium and gravel covering a granitic pediment in a mountain basin. | Mainly a dry placer operation. Estimated that over 18,000 cubic yards treated during various periods from early 1900's to 1940. | U.S.G.S. Min. Resources, 1912, p. 68 |
| Hillside mine                                                 | 146 2EE  | Au, Ag      | Spotty argentiferous galena in quartz veins in Precambrian Pinal Schist. | Limited tunnel and shaft workings. Some 77 tons of ore produced in 1936. | ABM file data |
| Silver Strike mine                                            | 145 2EE  | Ag, Cu, W, Zn, Cu, Ag | Spotty argentiferous galena with minor chalcopyrite and sphalerite in quartz plug along a fissure vein cutting Precambrian and Cretaceous rocks close to a Laramide granite intrusive. Spotty scheelite occurs in shear zones and quartz bodies in porphyritic Precambrian granite. | Adit and shaft workings. A few hundred tons of lead-silver ore produced intermittently between the 1900's and 1919. | Dale et al., 1960, p. 18-22 |
California district

<table>
<thead>
<tr>
<th>MINING DISTRICT AND MINES</th>
<th>LOCATION</th>
<th>MINERAL PRODUCTS</th>
<th>GEOLOGY</th>
<th>TYPE OF OPERATION AND PRODUCTION</th>
<th>REFERENCES</th>
</tr>
</thead>
<tbody>
<tr>
<td>California District (Chiricahua Mts.)</td>
<td>15-29 SE 17S 31E</td>
<td>Pb, Zn, Cu, Ag, Au, W, Mo</td>
<td>1. Base metal sulfides, oxides, and carbonates along strong silified fault zones, in replacement pipes and lenses along quartz dikes, and in disseminated deposits in strongly folded, faulted, and often pyro-metamorphosed Paleozoic limestone and Cretaceous sedimentary and volcanic formations that have been invaded by Laramide or Tertiary intrusives. 2. Spotty scheelite mineralization in pyro-metamorphosed Paleozoic limestones.</td>
<td>Numerous scattered mines and prospects, mostly with limited workings from tunnel, adit, and relatively shallow shafts. District has produced at least 38,000 tons of base metal sulfides and minor tungsten ore from the late 1900's through 1970.</td>
<td>Coll, 1910; Bainger, 1923; Bahnas, 1915, 1927, 197b; Dale et al., 1952; ABM file data</td>
</tr>
<tr>
<td>Bernoudy Mine (Bernoudy Mng. &amp; Milling Co., Bernoudy-Turkey Creek Co.)</td>
<td>17S 31E No.</td>
<td>Cu, Ag, Zn,</td>
<td>Base metal carbonates and sulfides in irregular replacement bodies in Mississippian to Permian limestones along strong thrust faulting.</td>
<td>Tunnel workings. A few tens of tons of high grade ore shipped between 1909 and 1911.</td>
<td>Copper Handbook 1908, 1909, 1910-1913; ABM file data</td>
</tr>
<tr>
<td>Blue Mountain Mine (Doran)</td>
<td>16S 31E No.</td>
<td>Cu, Ag, Zn,</td>
<td>Spotty lead and minor copper carbonates in leasing replacement deposits in a folded band of Mississippian Espanola Limestone.</td>
<td>Relatively shallow shafts and adits. Some 50 tons of ore shipped in 1942.</td>
<td>ABM file data</td>
</tr>
<tr>
<td>Chiricahua Mine (Cape, Theo., Burns, Lake Superior Mining Co., Chiricahua Development Co., San Simon Copper Co.)</td>
<td>17S 30E SE 11 W 12</td>
<td>Cu, Ag, Zn, W</td>
<td>Base metal carbonates and sulfides with spotty, fine-grained, disseminated scheelite in folded and sheared, shaly, and slaty Pennsylvanian-Permian Naco Group limestones intruded by Laramide or Tertiary granitic rock.</td>
<td>Shaft and adit workings. Some spotty production of ore in the late 1900's and early 1900's.</td>
<td>Copper Handbook, 1905; Mines Handbook, 1919; Dale et al., 1960, p. 14-17; ABM file data</td>
</tr>
<tr>
<td>Columbia mine</td>
<td>17S 30E SE 12 W 10-12</td>
<td>Cu, Ag, Cu, Zn,</td>
<td>Base metal carbonates and sulfides with local economy scheelite in sheared tectite and along faults and fractures in affiliated Pennsylvanian Collins Limestone.</td>
<td>Tunnel workings. Small shipments of about 50 tons of high grade, base metal ore made intermittently from 1922 to 1941. Some tungsten ore shipped in 1933</td>
<td>USGS Min. Res. of U.S., 1906; USBM Min. Res. of U.S., 1921; USGS Min Yearbook, 1939, 1941; Dale et al., 1960, p. 12-12; ABM file data</td>
</tr>
<tr>
<td>Coyleville Mines (Monte Carlo Conservative Mining Co., Tyrone Mng. Co.)</td>
<td>17S 30E SE 13 W 12</td>
<td>Pb, Ag, Cu, Au,</td>
<td>Base metal carbonates and sulfides with spotty scheelite in sheared and faulted tectite and in irregular replacement bodies in Pennsylvanian-Permian Naco Group limestones.</td>
<td>Shallow workings. Produced about 27 tons of ore in 1933.</td>
<td>Dale et al., 1960, p. 12-12; ABM file data</td>
</tr>
<tr>
<td>Grace mine</td>
<td>17S 31E SW 13 E 11</td>
<td>Cu, Ag, W</td>
<td>Spotty galena and minor chalcopyrite, largely hosted in lead and copper carbonates, along a contact zone between Pennsylvanian Collins Limestone and an intrusive porphyry.</td>
<td>Shaft and surface workings. 100 or more tons of lead-copper-silver ore produced in the late 1900's and about 100 tons of tungsten ore produced in 1945.</td>
<td>ABM file data</td>
</tr>
<tr>
<td>Harris Mountain mine group (Blue Ribbon, Rima, Harris, Malachi groups)</td>
<td>16S 31E SE 14 W 30 E 13-20</td>
<td>Cu, Zn, Ag, Au,</td>
<td>Numerous small replacement cratellites of base metal carbonates and sulfides in silified, fractured, and folded Mississippian and Pennsylvanian limestones.</td>
<td>Many shaft and tunnel workings. A total of some 100 tons of ore shipped from the groups during 1911, 1929, and 1946 to 1949.</td>
<td>USGS Min. Res. of U.S., 1923; ABM file data</td>
</tr>
</tbody>
</table>
Honestake mine (Boekler Mag. Co.)

Savage Rabbit (McClidan)

Horse mine (Dodge & Cross, McManus)

Bembooki mine (Bradenham, Arizona, May, Reid & South Bradenham, Arizona, Mag. Co.)

King Alsworth mine group (Alsworth, Cochise, Cochise-Bullion, Oregon group: King Copper Co., Alsworth Copper Co., Cochise Consolidated Copper Co., Portal Mines Development Co., Coconino Consolidated Metal Producers Corp.)

Leadville mine group (Chamberlain & Morrow, California & Paradise Consolidated Mag. Co., Nebraska & Arizona Copper Co.)

Manhattan mine group (Manhattan Development Co.)


Ran-Zinc mine (Parisey)

Baboon claim group (Batter Sprite's, Providence Copper Co.)

Savage mine (Porfil, Savage Gold and Copper Co.)

Scadding mine

Silver Hill mine group (Black Ben, Nevada, Half mine group, Arizona; Scott & Crawford, New Vail Mag. Co.)

Sullivans mine group (Cerrus group, Blue Bell, Copperopolis, Dolley & Christian Development Co., Sullivan Copper Development Co., Sullivan Copper Development Co.)

Sunset mine group (Thompson, Black Prince; Duran, Whitehall Copper, Co., Felipe Dodge Corp., Sunset Mag. Co., Four X Mag. Co.)

Texas mine group (Kennedy Belle, Boston Belle, Texas Consolidated Mining & Smelting Co.)

Willie Rose mine (Willie Rose Copper Mag. Co.)

Silliman copper oxide and sulfide ore along a fault zone separating Pennsylvania-Pennsylvanian-Permian Rock Group limestones from Cretaceous volcanics, near a peritectic pyrophyllite stock.

Lead and copper carbonates and oxides in irregular replacement breccia in folded and faulted, silicified Mississippian to Pennsylvanian limestones.

Spotty silver chlorides and silver values associated with albitized and minor base metal sulfides in a shear zone and in pyrometamorphosed Pennsylvanian-Cretaceous limestone bordering an intrusive pyrophyllite dyke.

Shaft and adit workings. Some 160 tons of ore produced intermittently between 1899 and 1920.

Shaft and tunnel workings. A total of at least 1150 tons of ore produced intermittently from the 1899's to 1920.

Shaft and tunnel workings. A total of some 65 tons of ore produced during 1943 and 1944.

Shaft workings. A total of about 565 tons of ore produced intermittently between 1904 and 1951.

Relatively shallow workings. A small amount of ore produced during 1925 and 1927.

Tunnel and shaft workings. A total of some 65 tons of ore produced during 1914 and 1948.

Shaft and adit workings. A total of about 180 tons of base metal ore and minor amounts of tungsten produced intermittently from 1889's to 1952.

Shallow workings. About 350 tons of ore produced during 1892 to 1949.

Shaft and tunnel workings. Some minor production in the late 1889's and early 1900's.

Relatively shallow workings. Some 100 tons of ore produced during 1917 to 1918 and a small amount in 1949.

Tunnel workings. A small tonnage produced in the late 1890's.

Shaft and adit workings. A total of about 180 tons of base metal ore and minor amounts of tungsten produced intermittently from 1889's to 1952.

Open cut, tunnel, and shafts. About 10 tons produced in 1935 and some 2160 tons of ore between 1943 and 1946.

Shaft and tunnel workings. A total of over 1000 tons of ore produced intermittently during 1910 to 1915, 1927 to 1930, and 1949 and 1951.

Open cut, adit, and shaft workings. Some 56 or more tons of ore produced in the 1890's and one small lot mined in 1897.

Shaft workings. A total of about 160 tons of ore produced intermittently between 1913 and 1953.
APPENDIX B

Minerals referred to in this report
APPENDIX B

Minerals referred to in this report:

actinolite: $\text{Ca}_2(\text{Mg,Fe})_3(\text{Si}_4\text{O}_{11})_2(\text{OH})_2$

alunite: $\text{KAI}_3(\text{SO}_4)_2(\text{OH})_6$

azurite: $\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$

barite: $\text{BaSO}_4$

bertrandite: $\text{Be}_2\text{Si}_2\text{O}_7(\text{OH})_2$

bornite: $\text{Cu}_9\text{FeS}_4$

brochantite: $\text{Cu}_4\text{SO}_4(\text{OH})_6$

calcite: $\text{CaCO}_3$

chalcocite: $\text{Cu}_2\text{S}$

carnotite: $\text{K}_2(\text{UO}_2)_2(\text{VO}_4)_2 \cdot 7\text{H}_2\text{O}$

chalcanthite: $\text{Cu}_5\text{SO}_4 \cdot 5\text{H}_2\text{O}$

chalcopyrite: $\text{CuFeS}_2$

chert: $\text{SiO}_2$

chlorite: $(\text{Mg,Fe,Al})_6(\text{Si,Al})_4\text{O}_{10}(\text{OH})_8$

chrysocolla: $\text{Cu}_2\text{H}_2\text{Si}_2\text{O}_6(\text{OH})_4$

covellite: $\text{CuS}$

cuprite: $\text{Cu}_2\text{O}$

epidote: $\text{Ca}_2(\text{Al,Fe})_3\text{Si}_3\text{O}_{12}(\text{OH})$

fluorite: $\text{CaF}_2$

hematite: $\text{Fe}_2\text{O}_3$

galena: $\text{PbS}$

garnet: $(\text{Ca,Fe})_3(\text{Al,Fe})_2(\text{Si}_4\text{O}_4)_3$

jarosite: $\text{KFe}_3(\text{SO}_4)_2(\text{OH})_6$

limonite: $\text{FeO}(\text{OH}) \cdot n\text{H}_2\text{O}$

magnetite: $\text{Fe}_3\text{O}_4$

malachite: $\text{Cu}_2\text{CO}_3(\text{OH})_2$

manganite: $\text{MnO}(\text{OH})$

molybdenite: $\text{MoS}_2$

psilomelane: $(\text{Ba,Mn})_3(\text{O,OH})_8\text{Mn}_8\text{O}_{16}$

pyrite: $\text{FeS}_2$

pyrolusite: $\text{MnO}_2$

pyromorphite: $\text{Pb}_5(\text{PO}_4)_3\text{Cl}$

scheelite: $\text{CaWO}_4$

smaltite (skutterudite): $\text{CoNiAs}_2$

smithsonite: $\text{ZnCO}_3$

sphalerite: $\text{ZnS}$

tetrahedrite: $\text{Cu}_{12}\text{Sb}_4\text{S}_{13}$

turquoise: $\text{CuAl}_6(\text{PO}_4)_4(\text{OH})_8 \cdot 5\text{H}_2\text{O}$

uraninite: $\text{UO}_2$

vanadinite: $\text{Pb}_4(\text{VO}_4)_3\text{Cl}$

wulfenite: $\text{PbMoO}_4$

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