Selected Mining Districts of Utah

by
Carl L. Ege

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UTAH GEOLOGICAL SURVEY
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Headframe of Centennial Eureka mine, Tintic mining district.

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STATE OF UTAH
Jon Huntsman, Jr., Governor

DEPARTMENT OF NATURAL RESOURCES
Michael Styler, Executive Director

UTAH GEOLOGICAL SURVEY
Richard G. Allis, Director

PUBLICATIONS
contact
Natural Resources Map/Bookstore
1594 W. North Temple
telephone: 801-537-3320
toll-free: 1-888-UTAH MAP
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email: geostore@utah.gov

THE UTAH GEOLOGICAL SURVEY
contact
1594 W. North Temple, Suite 3110
Salt Lake City, UT 84116
telephone: 801-537-3300
website: http://geology.utah.gov

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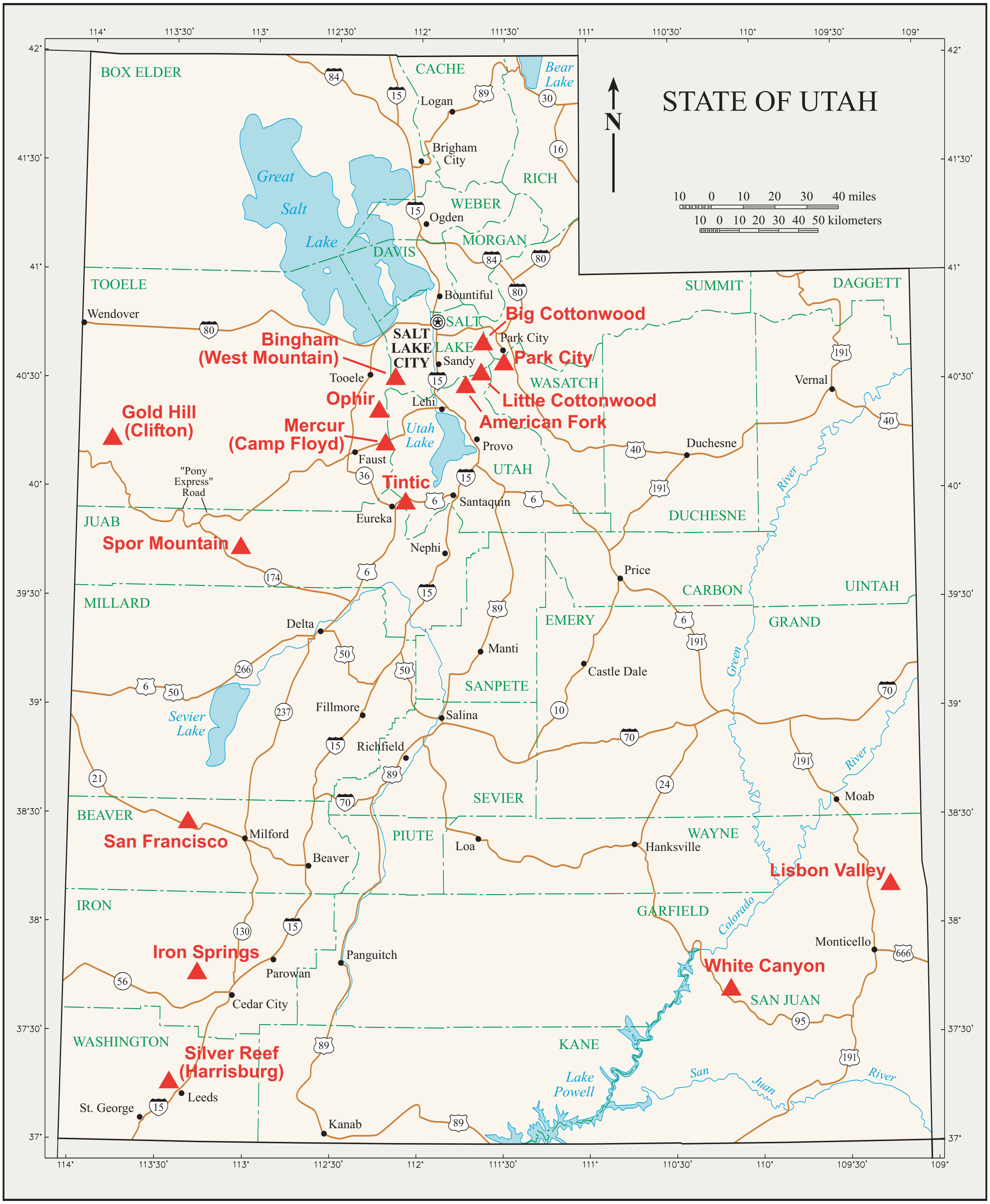


Location of Selected Mining Districts of Utah

INTRODUCTION

Whether you are a geologist, history buff, or rockhound, this booklet will be a helpful guide to Utah's mining districts. The booklet is divided up into three parts: the first part provides general information on what a mining district is, how many mining districts are in Utah, types of mineral deposits found at these districts, and landownership issues. The second part includes individual mining-district discussions containing information on location, production, history, geology, mineralogy, and current/future operations. The third part includes a glossary of geologic terms and other useful resources in the appendices, such as a descriptive list of minerals found in the districts, geologic time scale, and a list of mineral resources of the mining districts.

What is a mining district?

A mining district is a collection of mines that have been located and worked under specific rules and guidelines created by the miners and mine operators. After the Mining Act of 1872, the federal government took over administration of many of the rules and regulations concerning claim staking, property ownership, and mining. Some districts have defined political boundaries, natural boundaries (rivers or ridge crests), or no specific boundaries at all. A district can contain hundreds of mines and can include a variety of different materials from building stone to metallic resources.

How many mining districts are there in Utah and are they still active?

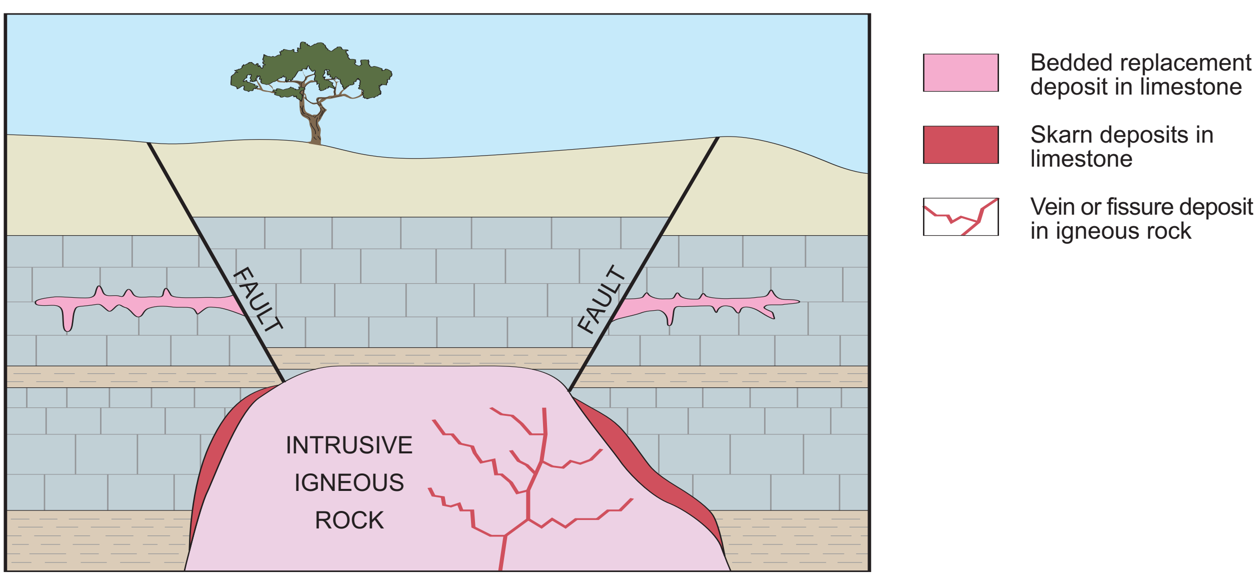
Utah has over 150 mining districts. These districts are in a variety of geographic areas, from the mountains of the Wasatch to the deserts of the Great Basin. Today, many of these districts are inactive, but they could become active again if mining occurs on any of the properties within the district. Many of the districts described here are considered active. The 15 districts in this booklet were selected because they have been the most productive districts in Utah.

What mineral resources are mined in Utah's most productive mining districts?

Economically, the most important mineral resources mined in Utah are copper, gold, silver, lead, zinc, and iron. Other mineral resources mined include beryllium, fluorspar, uranium, vanadium, molybdenum, manganese, tungsten, antimony, bismuth, cobalt, arsenic, and mercury (see appendix C for more information).

What are the most common types of ore deposits found in Utah's mining districts?

The most common types of ore deposits found in Utah's mining districts include (1) bedded replacement deposits, (2) vein or fissure deposits, and (3) skarn deposits. These deposits are found in many of the mining districts throughout the state and represent some of the most productive deposits for their mineral value.



Most Common Types of Ore Deposits in Utah's Mining Districts

Bedded replacement ore deposits result when rising hydrothermal (hot) fluids from a cooling magma body come into contact with favorable carbonate rocks, such as limestone or dolomite. These fluids are generally rich in dissolved metals (gold, silver, lead, copper, or iron) and move upward along breaks or faults in the Earth's crust. Chemical reactions between the fluids and the carbonate rock cause the metals to be brought out of solution, which replace the mineral composition of the original rock.

Vein or fissure ore deposits have clearly defined, abrupt margins and are roughly tabular in shape. They are considered the product of deposition from fluids in open fractures or fissures. These deposits also contain crystallized pockets of the vein minerals.

Skarn ore deposits form when cooling magma deep under the surface contacts limestone. The heat of the magma and fluids from the magma cause recrystallization of the limestone and the formation of new minerals such as garnet, diopside, and wollastonite. Later, metal-bearing fluids from the intrusion deposit ore minerals.

What about landownership and safety issues?

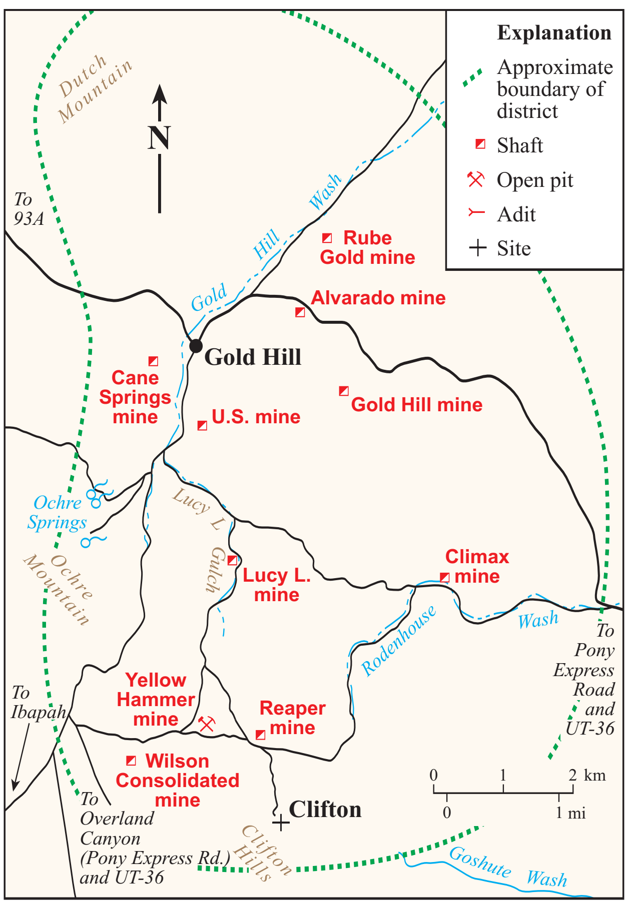
If you venture out to any of Utah's mining districts, please remember to respect private property and mining claims. Seek permission from the present landowner or mine operator before planning a visit to any mining district.

When exploring any mining district, remember to stay out of abandoned mines. There are an estimated 20,000 abandoned mine openings in Utah that pose a variety of dangers to the unsuspecting explorer: cave-ins, falls, undetonated explosives, pockets of deadly air and gases, radioactivity, hazardous waste, water hazards, and animals. The explorer should also be familiar with mine-dump toxicity before visiting a mining district. Some mine dumps contain elevated levels of toxic chemicals, such as uranium, arsenic, and mercury that can be harmful if digested or inhaled.

Selected Mining Districts

Gold Hill Mining District (Clifton)

The Gold Hill mine is one of the largest mines in the Gold Hill district.



Location: The Gold Hill mining district is in the northern part of the Deep Creek Mountains of western Utah in Tooele County. The district can be reached by driving west from Salt Lake City along I-80 to Wendover, Nevada, then southwest on U.S. Highway 93A for approximately 27 miles. The town of Gold Hill is to the east via paved and gravel roads. Many mines are visible in the immediate area of the town. The district can also be reached by traveling south from Tooele along Utah State Highway 36 to the Pony Express Road (which is a dirt road out of Faust). Turn west onto the Pony Express Road; several miles past the town of Callao, turn right onto a gravel road heading north to Gold Hill.

Production: From 1892 to 1961, the district produced approximately 25,900 ounces of gold, 832,000 ounces of silver, 10.9 million pounds of lead, 3.47 million pounds of copper, and 20,000 pounds of zinc (Stowe, 1975). Values after 1961 are largely unknown and too small to warrant a mineral evaluation. Arsenic production (between 1923 and 1925) is estimated to be valued at $2.5 million, most originating from the Gold Hill and U.S. mines (Nolan, 1935). Only small-scale mining operations were present between 1926 and 1940 and no production numbers were recorded. Large-scale mining began during World War II with the production of 98,800 tons of ore yielding 15.2 percent arsenic (El-Shatoury and Whelan, 1970). Most of the arsenic production came from the U.S. mine. The district was also the largest producer of tungsten in the state. Tungsten production is estimated to be valued between $100,000 and $120,000 with most of the ore coming from the Reaper and Yellow Hammer mines (Everett, 1961). Bismuth was never recorded from the district, but bismuth minerals are found at several of the mines, notably the Wilson Consolidated and Lucy L mines.

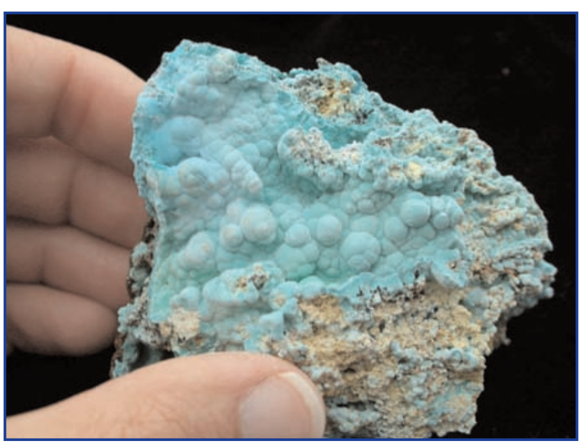
History: The Gold Hill mining district is one of the oldest in Utah. It was discovered around 1857 by travelers heading to California through Overland Canyon, located just 6 miles south of the town of Gold Hill (Nolan, 1935). Rich lead-silver surface deposits were discovered and the area was inundated with prospectors and miners. Mining began in 1869 and continued until 1875. Following a brief period of inactivity, mining renewed in 1892, when the first mills began operating. Production lasted until 1904. Over 50 mines were developed, but fewer than half shipped any substantial ore (Nolan, 1935). The towns of Gold Hill and Clifton grew in 1917 with the development of the Deep Creek Railroad, a branch line of the Western Pacific Railroad. During this year, production was greater than in any previous year. In 1920, production of arsenic became important, as significant amounts were mined from the Gold Hill and U.S. mines. Arsenic ore was in great demand for the manufacture of an insect repellant used in the cotton fields of the South. Because of foreign competition, the U.S. arsenic market collapsed in 1925, which caused the area to become a virtual ghost town. From 1926 to 1940, only small-scale mining operations continued, mainly exploration and rehabilitation. The district became important during World War II with the production of arsenic ore from the U.S. mine. The district also produced tungsten used in electric filaments and as a strengthening agent in steel during and after World War II. Most of the tungsten production came from the Reaper, Lucy L, and Yellow Hammer mines.

Geology: Sedimentary rocks in the district consist of limestone, dolomite, shale, and sandstone ranging in age from Cambrian (540 million years old) to Pennsylvanian (300 million years old). These sedimentary rocks formed from sediments that were deposited in a warm, shallow sea that covered much of the present-day western United States. Mineralization began at Gold Hill approximately 152 million years ago, with the intrusion of magma into the overlying marine sedimentary rocks (Robinson, 1993). This event created three different types of ore deposits in the district: skarn deposits, replacement-type bodies, and vein deposits. In the Gold Hill mining district, skarns are small deposits but contain a rich suite of metals that includes copper, iron, tungsten, gold, and silver. The Cane Springs and Alvarado mines are examples of skarn deposits (El-Shatoury and Whelan, 1970).

Replacement deposits occur along the contact between the cooled magma (granodiorite) and limestone. The host rock for the ore deposits are Mississippian to Pennsylvanian (360 to 330 million years old) limestone from the Ochre Mountain Limestone (Robinson, 1993). The Gold Hill and U.S. mines are examples of mines in replacement deposits (El-Shatoury and Whelan, 1970). These deposits are rich in silver, gold, arsenic, copper, and lead.

Vein deposits are found within the granodiorite in the Lucy L and Climax mines. All of the veins are small and represent only a small portion of the ore mined from the district.

In the Gold Hill district, a second stage of mineralization began in the early to middle Tertiary (approximately 38 million years ago) with the intrusion of magma into overlying sedimentary rock. This resulted in the creation of replacement and vein deposits rich in silver, lead, copper, gold, and other metals. The host rocks for the ore deposits are Mississippian to Pennsylvanian (360 to 330 million years old) limestone, shale, and quartzite from the Prospect Mountain Quartzite, Abercrombie Formation, and Ochre

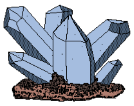


Malachite from the 760-foot level of the Gold Hill mine.

Adamite from the 80-foot level of the Gold Hill mine. U.S. dime for scale.

Mountain Limestone (Robinson, 1993). Most of these ore deposits are restricted to the area of Dutch Mountain, north of the town of Gold Hill.

The final stage of mineralization in late Tertiary time, approximately 8 million years ago, was associated with volcanic activity in the region that created low-grade beryllium mineralization in Rodenhouse Wash (Robinson, 1993). The beryllium occurs in quartz-adularia-carbonate veins within granodiorite.



Mineralogy: The primary ore-bearing minerals found at Gold Hill are copper, chalcopyrite, bornite, stibnite, tetrahedrite, tennantite, arsenopyrite, molybdenite, powellite, and galena. Secondary ore-bearing minerals include scorodite, malachite, cuprite, smithsonite, azurite, and cerussite. Common associated minerals include calcite, quartz, gypsum, barite, and conichalcite. The Gold Hill mining district is known worldwide for its rare and unusual minerals. At the Gold Hill mine, world-class specimens of adamite, austinite, beudanite, carminite, chalcophanite, conichalcite, juanitaite, cornwallite, mixite, olivenite, scorodite, pharmacosiderite, philipsburgite, and tyrolite can be collected on the mine dumps. Austinite and juanitaite were first found and identified at the Gold Hill mine. At the U.S. mine, specimens of pyrrhotite, stibnite, arsenopyrite, cobaltite, erythrite, azurite, and tooeleite have been collected. Tooeleite was first found and identified from the U.S. mine. The Rube Gold mine produced small quantities of gold in the form of well-developed crystals. Tourmaline, the black schorl variety, is widespread throughout the district, generally as black, thin, needle-like crystals several inches long.

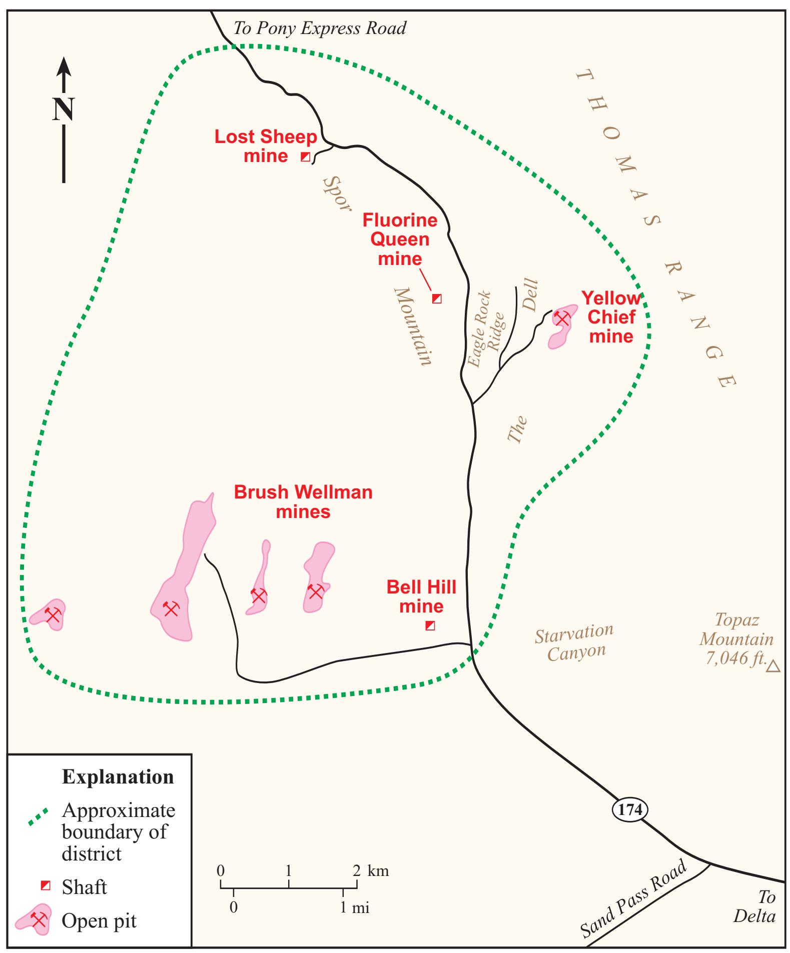
Current/Future Operations: The Clifton Mining Company has explored in the district and has announced plans to rework and develop several mines, such as the Cane Spring and Yellow Hammer mines, for gold and silver. Most of the known reserves are small and could support only small operations. Other, larger resources are low grade and currently uneconomic. No effort has been made, to date, to develop the beryllium in Rodenhouse Wash (Robinson, 1993). Today (2005), the town of Gold Hill has only a few year-round residents. Clifton is now a ghost town, and many of the buildings and structures present during the town's glory days are gone.

Spor Mountain Mining District

The Bell Hill mine with Brush Wellman mine dumps in the background, Spor Mountain mining district.

Location: The Spor Mountain mining district is about 35 miles northwest of the town of Delta in central Juab County. It can be reached from Delta by traveling northeast on U.S. Route 6 to State Route 174. Turn west on State Route 174 and continue northwest on the paved road for approximately 50 miles. The road becomes a well-groomed gravel road and immediately forks when it enters the district. The fluorspar and uranium mines are located to the north and the beryllium mines are located directly to the west at the fork.

Production: From 1944 to 1980, the district yielded 350,000 tons of fluorspar ore (Bullock, 1981a). Park (in preparation) reports total production of 260,000 tons of fluorspar ore from the Lost Sheep mine, the district's largest producer. Uranium production for Juab County from 1948 to 1970 was approximately 105,000 tons of uranium ore (Chenoweth, 1990a), and over 95 percent originated from the Yellow Chief mine. Beryllium ore production from 1970 to the end of 1992 was approximately 2 million tons (Valiquette, 1993). In 2000, over 100,000 tons of beryllium ore was mined, but in the past few years, production has been significantly less due



to lack of demand and the processing of stockpiled ore (Bon and Gloyn, 2002).

History: The Spor Mountain district experienced three mining booms for three different commodities: fluorite, uranium, and beryllium. The fluorite boom began in the late 1930s and continues today. The uranium boom began in the early 1950s and lasted until the early 1960s. The beryllium boom began in the 1960s and continues today.

Chad and Ray Spor discovered the district's first fluorspar (fluorite ore) in 1936 at Spor Mountain (Staatz and Carr, 1964). Composed of fluoride and calcium, fluorite is chiefly used as flux in the manufacture of steel and in making hydrofluoric acid. In 1941, George Spor and his sons staked the Floride claim at Spor Mountain. Ore shipments began in 1944. Other claims were located (Fluorine Queen, Bell Hill, and Lost Sheep mines) and produced ore. Albert and Earl Willden staked the Lost Sheep claim in 1948 and began production that year. The Lost Sheep mine is still active in 2005; it is the largest fluorite deposit in Utah and has been mined to a depth of 372 feet.

In 1953, prospectors using hand-held Geiger counters discovered uranium on the east side of Spor Mountain. The Yellow Chief group claims were immediately located and shallow prospects dug. No more work was done for several years until the Topaz Uranium Company leased the claims. In 1959, the company began developing an open pit to uncover mineable ore. When mining ended in 1962, the overall size of the pit was 1200 feet long, between 300 to 500 feet wide, and 150 feet deep.

In 1959, Dr. Norman William, a University of Utah geology professor, discovered beryllium in mineralized volcanic tuffs at Spor Mountain. This discovery was made by accident; a fluorspar sample was unintentionally placed near a beryllometer, a new instrument designed to detect trace amounts of beryllium. Unexpectedly, the beryllometer started clicking, indicating the presence of beryllium. News of the discovery spread throughout the west and many individuals as well as companies flocked to the area to file mining claims. The Brush Wellman Company was one of these companies. Brush Wellman, determined to be a major player in beryllium production, began acquiring properties, such as the Vitro claims in 1964. Mining began in 1968 and the construction of an offsite mill in Millard County was completed in 1969. In 1980, Brush Wellman bought the Anaconda claims and became the lone producer of beryllium in the Spor Mountain district. Today, Brush Wellman still remains the only producer of beryllium in Utah.

Geology: The Spor Mountain district consists of faulted and tilted Paleozoic (500 to 360 million years old) marine sedimentary rocks overlain by Tertiary (42 to 21 million years old) volcanic flows and volcanic tuffs. For millions of years, large volcanic eruptions deposited ash flow tuffs (fused volcanic ash), volcanic breccias (angular volcanic fragments fused together), and lava flows. Then, approximately 21 million years ago, volcanic eruptions and erosion of the older volcanic material deposited the Spor Mountain Formation (mainly composed of tuff, rhyolite, sandstone, and conglomerate). Mineralized fluids from an underlying magma body migrated up preexisting faults, encountered a favorable host rock (the Beryllium Tuff Member of the Spor Mountain Formation), and deposited the beryllium ore. The Beryllium Tuff is a perfect host rock because it is

Close-up view of a fluorspar deposit at the Bell Hill mine. Rock hammer for scale.

Nodule containing bertrandite, fluorite, and opal from Brush Wellman property.

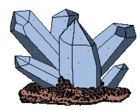
Bixbyite from the Topaz Mountain area.

porous and contains carbonate fragments, which react with the mineralizing fluids to precipitate beryllium. Many of the carbonate fragments were replaced by other minerals, forming nodules having an outer rind rich in beryllium and a core containing fluorite, opal, chalcedony, manganese oxides, and other minerals (Staatz, 1963).

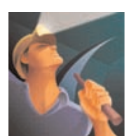
The fluorspar deposits of Spor Mountain also formed from mineralized fluids from an underlying magma source that moved up pre-existing faults. The host rocks are the Ordovician Fish Haven and Fluoride Dolomites and the Silurian Bell Hill, Harrisite, Lost Sheep and Thursday Dolomites. Many of these deposits are pipe-like in form and contain 60 to 95 percent fluorite (Bullock, 1981a).

The uranium deposits on the east side of Spor Mountain were deposited in the volcanic tuff, sandstone, and conglomerate of the Spor Mountain Formation. These deposits were formed either by the erosion of a uranium-rich fluorite body and later concentration of uranium by ground water, or by precipitation from hydrothermal fluids rich in uranium rising up along faults and fractures.

Relatively recent volcanic eruptions (8 to 6 million years ago) deposited the Topaz Mountain Rhyolite in the nearby Thomas Range. Topaz, pseudobrookite, bixbyite, red beryl, hematite, and garnet are found in this rhyolite at Topaz Mountain in the southern Thomas Range.



Mineralogy: Primary ore minerals include bertrandite, fluorite, uranophane, and weeksite. Bertrandite is the primary beryllium-bearing mineral found in the Beryllium Tuff. Bertrandite cannot be seen with the naked eye and can only be identified with the aid of an x-ray microscope. The fluorite is rarely crystallized and tends to occur in earthy masses at many of the fluorspar mines. Small purple fluorite crystals have been found in some of the nodules at the Brush Wellman mines. Uranium ore from the Yellow Chief mine contains the minerals uranophane and weeksite. Uranophane is a pale to orange-yellow uranium mineral that fills pore spaces in the sandstone and coats individual sand grains. Weeksite is a yellow mineral that occurs in a limestone conglomerate above the uranophane mineralization. The Spor Mountain district is near Topaz Mountain, a wonderful area for the mineral collector where topaz, red beryl, bixbyite, pseudobrookite, garnet, and other minerals can be found.



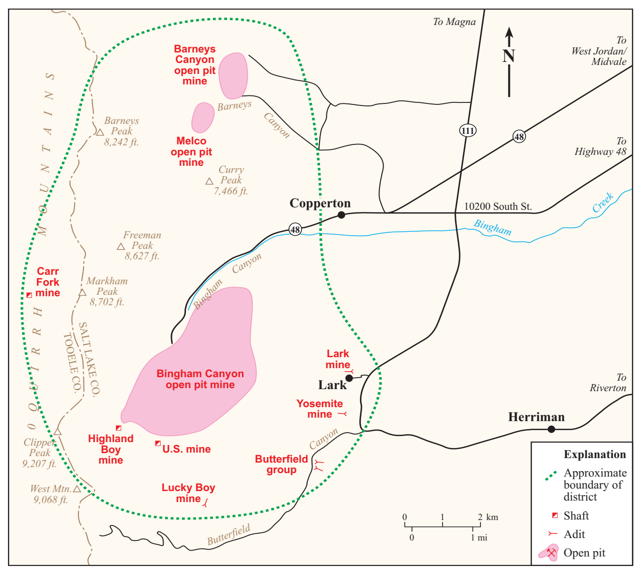
Current/Future Operations: In 2004, fluorspar is being mined on the Lost Sheep mine property. Brush Wellman continues to mine beryllium ore (which is shipped to a treatment facility in Millard County) and has 50 to 70 years of open-pit ore reserves remaining.

Bingham Mining District (West Mountain)

Kennecott's Bingham Canyon mine, Bingham mining district. The electric shovel has a 98-ton rock capacity scoop. The haulage truck holds 255 to 360 tons of rock.

Location: The Bingham mining district is situated in the central part of the Oquirrh Mountains about 20 miles southwest of Salt Lake City. The chief mine is Kennecott's Bingham Canyon open-pit copper mine. Other mines in the district include the Barneys Canyon and Melco gold mines, the U.S. and Lark lead-zinc mines, and the Carr Fork copper mine. Many other mines were operating during the early history of the district, but have since been absorbed by the Bingham pit.

The Bingham copper mine is an active mine, and mining operations can be viewed from a visitors' overlook. The overlook can be reached from exit #301 (7200 South) off of I-15. Travel southwest to 7800 South (New Bingham Highway). Turn right (west) and follow the New Bingham Highway (State Route 48) up to the mine. A visitor center and overlook (open April through October) provide information and a view of the mining operations.



Production: From 1864 to 1919, mining operations along Bingham Creek produced approximately 72,600 ounces of gold (Butler and others, 1920). From 1868 to 1972, the underground mines of the district produced approximately 2.42 million ounces of gold, 4.49 billion pounds of lead, 1.89 billion pounds of zinc, 143 million ounces of silver, and 832 million pounds of copper (James, 1973). From 1903 to 2003, the Bingham Canyon mine produced 23 million ounces of gold, 190 million ounces of silver, 890 million pounds of molybdenum, and 34 billion pounds of copper (Oberbeck, 2003). Secondary minerals and by-products include platinum group elements, uranium, selenium, tellurium, bismuth, and sulfuric acid. The cumulative mineral value of Bingham (over $1 billion annually) exceeds the total combined production value of the Comstock Lode (Virginia City, Nevada), California, and Klondike (northwest Canada) gold rushes. Over two-thirds of all mineral production in Utah has been from the Bingham Canyon mine. Recently, gold has been mined from the Barneys Canyon and Melco mines. Total mineral resources, including production and reserve estimates, indicate that Barneys Canyon is likely to produce 496,000 ounces of gold, and the Melco mine is expected to produce 1.21 million ounces of gold within their lifetimes (Phillips and Krahulec, in preparation).

History: In 1848, Erastus Bingham and his two sons were the first to discover mineralization in Bingham Canyon. Because the Church of Jesus Christ of Latter-Day Saints (L.D.S. church), of which they were members, discouraged mining, the location was forgotten until 1863, when Colonel P.E. Conner of the U.S. Army stationed at Fort Douglas in Salt Lake City and others rediscovered the silver-rich lead ore while picnicking in the area. On September 17, 1863, George Ogilvie (a logger who first reported the find), Colonel Conner, and 23 others staked the Jordan claim in Bingham Canyon (Eldredge and Wilkerson, 1990). This claim was the first in the district and the first recorded in Utah. In 1863, the West Mountain mining district was officially organized. In 1864, placer gold was discovered near the mouth of Bingham Canyon by a group of California miners. With this discovery, gold became the first mineral mined in the district. Placer mining recovered approximately 72,600 ounces of gold. The largest gold nugget (over 7 ounces) ever found in Utah (Boutwell, 1905) was in Bingham Canyon. By the early 1870s, placer mining was declining because the deposit was almost played out.

Beginning in 1870, mining began on the silver-rich oxidized lead ores at the Highland Boy, Jordan, Last Chance, Brooklin, and Yosemite mines (the Jordan, Last Chance, and Brooklin mines have since been consumed by the present-day Bingham Canyon open-pit mine). By the late 1880s, most of the shallow silver-rich ore bodies had been exhausted, and between 1890 and 1900 many of the mining properties were consolidated. Extensive underground mining of the silver, lead, gold, and copper ores began at mines that included the Lark, U.S., Butterfield Group, Highland Boy, and Carr Fork. Underground mining continued until 1971 when the Lark and U.S. mines closed.

In 1885, native copper found growing in organic-rich portions of upper Bingham Creek led to the discovery that the creek water contained copper in solution. A small operation began to produce metallic copper by running creek water over scrap iron, where the copper in solution would precipitate onto the iron (Engineering and Mining Journal, 1897). In 1897, Enos Wall noticed copper carbonate mineralization on both sides of Bingham Canyon and scattered copper mineralization in monzonite in several abandoned mining tunnels. He subsequently staked a number of claims, known as the Wall Group (subsequently acquired by the Utah Copper Company). About the same time, Samuel Newhouse, who developed and sold the Highland Boy mine, also was aware of scattered copper mineralization and acquired property southwest of the Wall Group for the Boston Consolidated Mining Company.

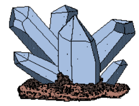
The Boston Consolidated and Utah Copper companies began to mine copper ore in the early 1900s. Both companies started steam-shovel stripping or open-pit mining in 1906. Utah Copper shipped the first ore in 1907, and Boston Consolidated shipped ore in 1908. Over the next several years, Utah Copper and Boston Consolidated properties were the leading producers of copper in the district. In 1910, Utah Copper merged with Boston Consolidated for 310,000 Utah Copper shares valued at nearly $19 million (Spencer and Pett, 1953). In 1936, Kennecott Utah Copper Corporation acquired the mine from the Utah Copper Company. During World War II, Kennecott supplied one-third of the total amount of copper used by the allied forces. In 1978, Kennecott Utah Copper was sold to Standard Oil Company, a subsidiary of British Petroleum. British Petroleum sold its interests to the Rio Tinto Zinc Corporation in 1987. In the 1980s, copper became uneconomical to mine due to high labor, haulage, smelting, and refining costs. Over the next several years, Kennecott spent $2 billion modernizing its operations and facilities. As a result, the mine is now one of the most efficient in the world. At present (2005), the Bingham Canyon mine is more than a half-mile deep and about 2.5 miles across from rim to rim.

The Barneys Canyon and Melco gold deposits, located north of the Bingham Canyon mine, were initially found in 1878, but the significance was unrecognized. Sampling was conducted in 1968-69 at an old mine dump in Barneys Canyon that returned values of 0.10 to 0.20 ounces of gold per ton. Drilling on the Barneys Canyon deposit began in 1985 and the deposit was discovered on the third hole. In 1986, drilling began on the Melco deposit and the ore body was discovered on the first hole. Mining began at Barneys Canyon and Melco deposits in 1989 and continued until late 2001.

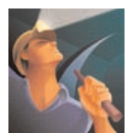
Geology: Approximately 300 million years ago (Permian-Pennsylvanian), a shallow sea covered the region in which a sequence of marine limestone and sandstone was deposited. During the Middle Jurassic to early Tertiary (170 to 40 million years ago), these sedimentary rocks were folded and faulted in a mountain-building episode called the Sevier orogeny. Approximately 39 to 37 million years ago, several magma bodies intruded into the overlying folded and faulted sedimentary strata forming the Bingham stock (Babcock and others, 1997). The oldest magma body formed a rock called monzonite, which was intruded by quartz monzonite porphyry, and younger magma bodies intruded both the monzonite and the quartz monzonite porphyry.

The magma bodies solidified into fractured rock and mineral-rich fluids were released. These solutions percolated through the fractures in the intrusive rock and adjacent sedimentary rocks. As these solutions slowly cooled, copper and other metals were deposited, forming an ore body known as a porphyry copper deposit. The copper mineralization occurs as small grains and veinlets of chalcopyrite and other copper-rich sulfides dispersed throughout a large area.

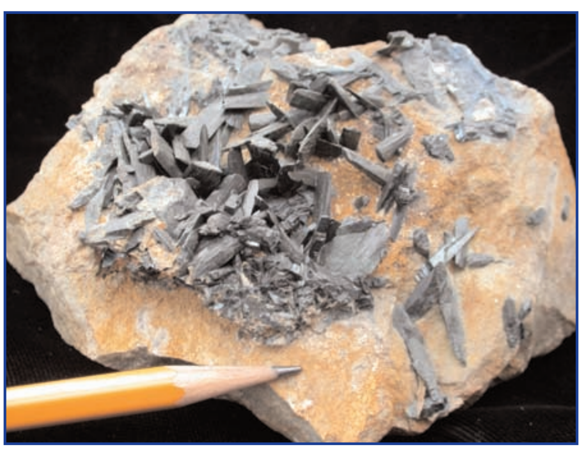
The copper deposit shows a crude zonal pattern having a core containing molybdenum and copper ores, an intermediate shell of rich copper ore, and an outer shell of pyrite that has low copper concentrations. Flanking the porphyry are skarn deposits, which formed when the cooling magma came in contact with limestone. These skarns are quite rich in copper and are 1,000 to 2,000 feet wide and 9,000 feet long along the northern and western edges of the Bingham Stock (Gloyn, 2000a). The most important host rocks for these skarns are Pennsylvanian (320 to 300 million years old) limestones of the Clipper Ridge Member of the Bingham Mine Formation (Gloyn, 2000a). Lead-zinc-silver vein and replacement deposits also formed around the porphyry and skarn deposits. The most important host rocks for these replacement deposits are Pennsylvanian (320 to 300 million years old) limestone of the Butterfield Peaks Formation and Lark, Commercial, and Jordan Limestones of the Bingham Mine Formation (Gloyn, 2000b). The Barneys Canyon and Melco gold deposits are sediment-hosted gold deposits where gold occurs as microscopic particles (similar to the Mercur mining district). These low-grade gold deposits occur in faulted and altered sandstone, quartzite, and dolomite of the Permian age (290 to 248 million years old) Freeman Peak Formation, Kirkman Limestone, Diamond Creek Sandstone, and Grandeur Member of the Park City Formation (Gloyn, 1998a & 1998b). Whether these deposits have a genetic relationship to the Bingham-Canyon copper porphyry deposit is still debated. Many believe that these sediment-hosted gold deposits formed during the last stages of mineralization approximately 38 to 33 million years ago.



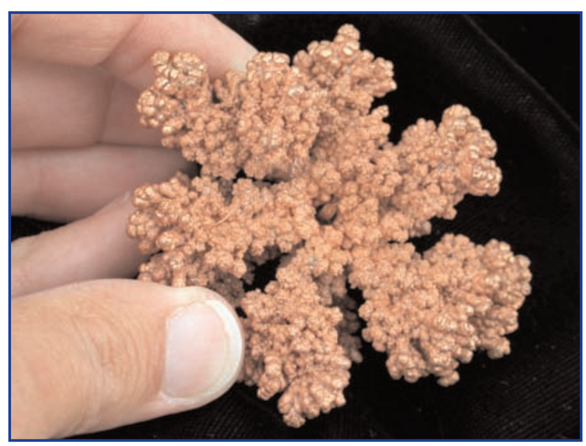
Mineralogy: The primary ore-bearing minerals at the Bingham district include gold, silver, copper, pyrite, marcasite, chalcopyrite, chalcocite, bornite, covellite, molybdenite, sphalerite, galena, enargite, tetrahedrite, realgar, orpiment, magnetite, arsenopyrite, stibnite, platinum, palladium, and the sulfosalts (bournonite, pyrargyrite, boulangerite, etc.). Secondary minerals include azurite, malachite, cuprite, tenorite, chrysocolla, anglesite, cerussite, smithsonite, hematite, melanterite, and chalcanthite. Associated minerals include quartz, calcite, gypsum, dolomite, siderite, barite, and rhodochrosite. At the Lucky Boy mine, a mineral called mallardite was first found and identified. The U.S. and Lark mines produced well-crystallized pyrite/quartz combinations, tetrahedrite, galena, and enargite. Other minerals found in the Bingham Canyon mine include wavellite, vivianite, turquoise, faustite, and apophyllite.



Current/Future Operations: The Bingham Canyon mine is currently (2005) mining ore from open-pit operations. In 2002, the mine produced 290,000 short tons of copper and 11,000 tons of molybdenum. Recently, Kennecott announced that open-pit mining operations would continue through 2017 (Nii and Bloomberg News, 2005). No formal decision has been made if the mine will be extended underground. Gold is still being produced from Barneys Canyon and the Bingham Canyon mine. Gold production from these properties in 2002 was nearly 500,000 troy ounces. The Barneys Canyon mine exhausted its ore reserve in late 2001, but will produce gold from stockpiles at a reduced rate.



Vivianite from the Bingham Canyon mine.

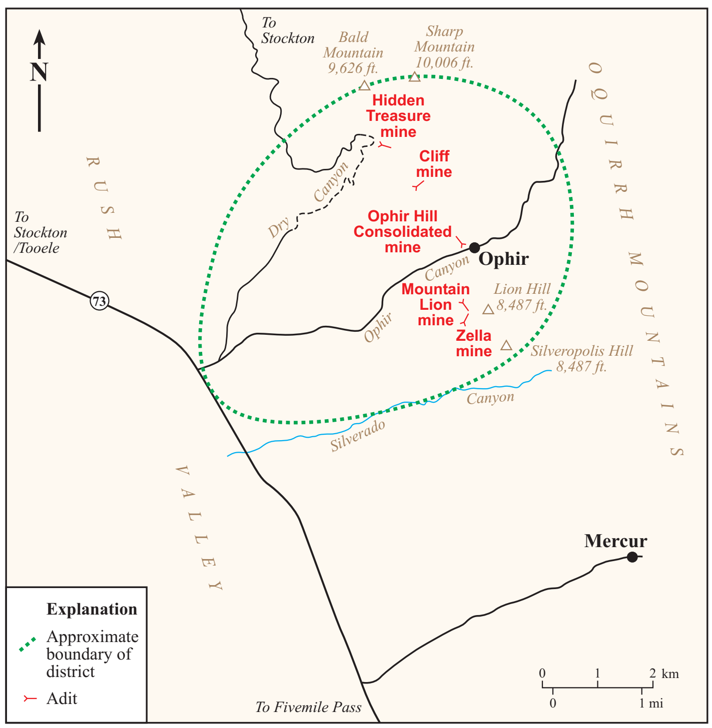


Native copper from the Bingham Canyon mine.

Ophir Mining District

The colorful mine dump of the Hidden Treasure mine, Ophir mining district.

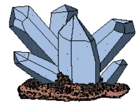
Location: The Ophir mining district in Tooele County is on the west side of the Oquirrh Mountains between Bald Mountain on the north and the Mercur (Camp Floyd) district on the south. It can be reached by traveling 14 miles south from Tooele on State Highway 36, and then turning left (east) onto State Route 73 for 5 miles to Ophir Canyon. The district includes all of the mines in Ophir Canyon, Lion Hill to the south, and Dry Canyon to the north.



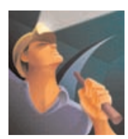
Production: Between 1870 and 1972, the Ophir district produced approximately 16,600 ounces of gold, 19.8 million ounces of silver, 46.6 million pounds of copper, over 356 million pounds of lead, and 88.2 million pounds of zinc (Tripp and others, 1990). The Ophir Hill Consolidated mine was the leading producer yielding 10.7 million ounces of silver, 1.65 million pounds of copper, and 10.1 million pounds of lead (Rubright, 1978).

History: Soldiers stationed at Fort Douglas in Salt Lake City discovered the district in 1865. These soldiers were attracted to the area by stories of Native Americans finding a metal to help make bullets. They found outcroppings of lead ore and located the St. Louis Lode, now known as the Hidden Treasure mine. Little work was done in the district until the early part of 1870, when the town of Ophir and the mining district were organized after silver-rich ore was located on Silveropolis Hill by W.T. Barbee (the same man who discovered the ore deposits at the Silver Reef mining district). Several days later, additional discoveries were made on nearby Lion Hill. Some of these mines included the Zella (which comprised the Zella, Mountain Tiger, Silver Chief, and Rockwell claims) and Mountain Lion mines. Approximately 2500 mineral occurrences were found, but only about 150 actually resulted in any mining activity. Many of the mines worked small ore deposits and were exhausted toward the end of 1880, with the exception of the Ophir Hill Consolidated, Hidden Treasure, and Cliff mines. The Ophir Hill Consolidated and Hidden Treasure mines were active until 1971 and had major periods of production during 1901-27 and 1936-71.

Geology: Sedimentary rocks in the district consist of a sequence of marine shale, limestone, dolomite, and minor sandstone ranging in age from Cambrian (540 million years old) to Mississippian (318 million years old). These sedimentary rocks were deposited on a wide, shallow shelf along the eastern edge of a sea. During the Middle Jurassic to early Tertiary (130 to 50 million years ago), these sedimentary rocks were folded and compressed forming the Ophir anticline during the Sevier orogeny. Later tectonic forces created a series of north-northeast-trending normal faults. During the middle Tertiary (30 million years ago), small tabular magma bodies intruded the overlying sedimentary rocks. As the magma cooled, igneous rocks formed, such as monzonite, quartz latite porphyry, and phonolite. These intrusions also led to the formation of the ore bodies found in the district. The ore bodies consist of (1) bedded replacement deposits, (2) irregular replacement deposits, and (3) fissure vein deposits. Many of the larger mines of the district (Cliff, Hidden Treasure, and Ophir Hill Consolidated) contained all three types of ore bodies. Bedded replacement deposits discovered in many of the district's mines contained rich values in silver, gold, lead, zinc, and copper. Limestone rock layers of Lower Cambrian to Upper Mississippian (540 to 318 million years old) age, particularly the Ophir Formation, Madison Limestone, and Great Blue Limestone below the Long Trail Shale Member, seem to be the most favorable for ore deposition. The bedded replacement deposits in the Ophir Hill Consolidated mine represented the most productive in the district. Some of the deposits in the mine reached lengths of over 2000 feet and thicknesses averaged 6 to 10 feet (Gilluily, 1932). Irregular replacement deposits are pipe-like masses that cut across the bedding of several limestone formations. At the Hidden Treasure mine, most of the ore was deposited in this form. Fissure veins were found in many areas throughout the district. These deposits are generally small, rarely exceeding a foot in width, 30 feet in height, and 300 to 400 feet in length (Gilluily, 1932). Although these fissure veins are small, they contained greater gold concentrations than the other deposits. The Cliff and Hidden Treasure mines are good examples for this type of ore deposition.



Mineralogy: The ore bodies at Ophir contain gold, lead, silver, zinc, and copper. The primary ore-bearing minerals consist of galena, tennantite, chalcopyrite, sphalerite, pyrrhotite, and pyrite. The majority of the ore is massive, but some good crystal specimens have been found. Secondary oxidized ore minerals include cerussite, anglesite, argentojarosite, plumbojarosite, jarosite, smithsonite, hemimorphite, aurichalcite, malachite, azurite, rosasite, and hydrozincite. Associated minerals in the district include calcite, quartz, barite, beaverite, melanterite, fluorite, and epidote. The Hidden Treasure mine has produced excellent specimens of smithsonite, hemimorphite, aurichalcite, barite, calcite, linarite, plattnerite, mimetite, malachite, and rosasite. The Ophir Hill Consolidated mine contains well-crystallized examples of quartz, pyrite, scheelite, smithsonite, azurite, chrysocolla, aurichalcite, and other associated minerals. Mines in the Lion Hill area intersected cave systems that contained delicate branching groups of calcite crystals and stalactites (Richardson and others, 1993).

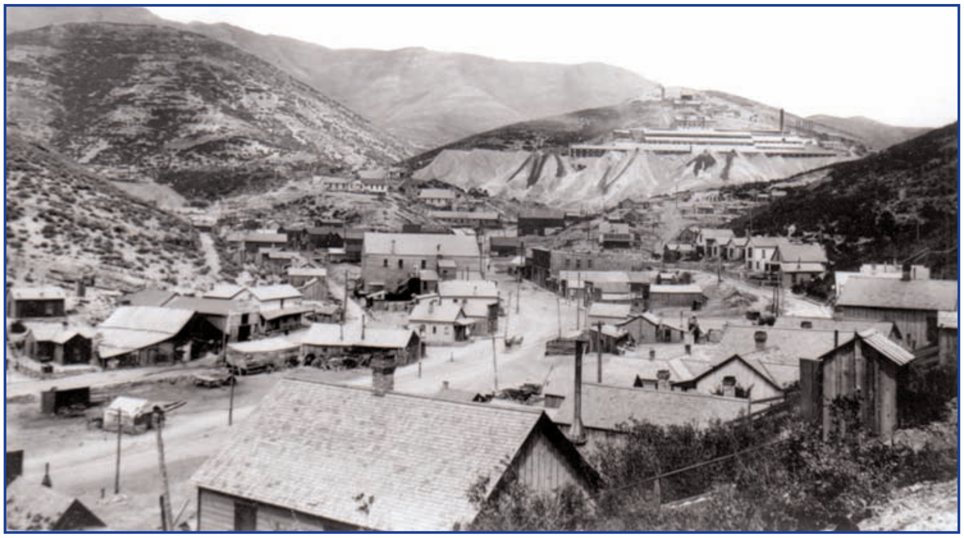


Current/Future Operations: All mining in the district has been suspended due to low metal prices or depleted ore bodies. Ore is still present in the deeper levels of the Ophir Hill mine, but will not likely be developed in the immediate future. Safety concerns have prompted reclamation of most of the district's mines. Recently, many of the patented claims were sold and the new landowner plans to develop the property into residential real estate.

Smithsonite from the Hidden Treasure mine.

Aurichalcite from the Hidden Treasure mine.

Mercur Mining District (Camp Floyd)

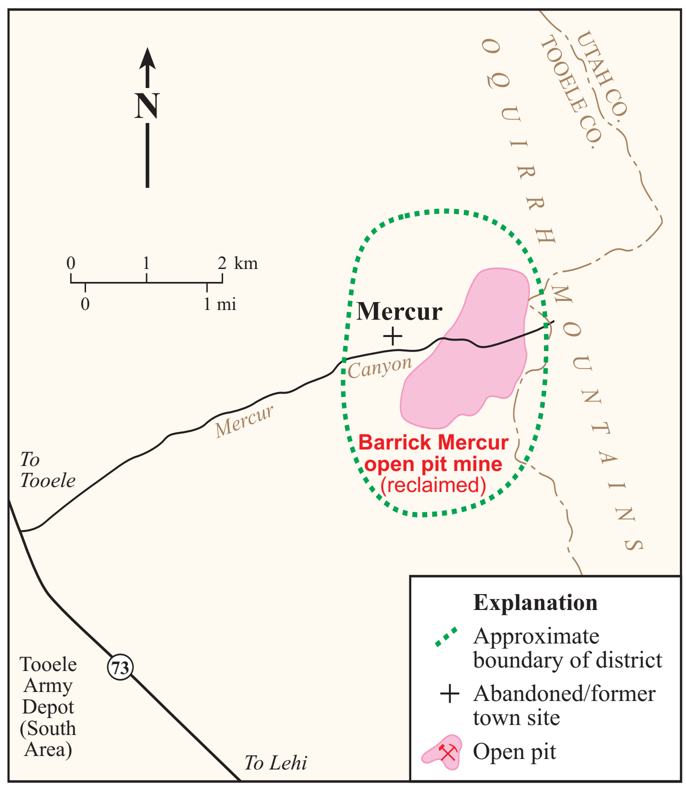


The town of Mercur, with Golden Gate Mill in background, circa early 1900s. Photo courtesy of the Utah State Historical Society.

Location: The Mercur mining district is in the southern part of the Oquirrh Mountains in Tooele County about 32 miles southwest of Salt Lake City. The principal routes to the district are along State Route 73 west from Lehi or on State Routes 36 and 73 south from Tooele. Mercur Canyon is inaccessible due to private landownership issues.

Production: In Mercur's 127-year history, over 41 million tons of ore were mined and processed containing 2.61 million ounces of gold, 1.18 million ounces of silver, and 3,470 flasks (equivalent to about 132 tons) of mercury (Mako, 1999).

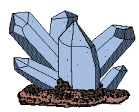
History: The initial discovery of the Mercur mining district was the "Silver Ledge" in 1869. The Camp Floyd district was organized and the town of Lewiston (known later as Mercur) was established the following year. For a period of about 11 years the oxidized silver ore was mined, but by 1881, the rich silver ore was exhausted and the district was temporarily abandoned. The district was later reorganized in 1894 after the discovery of gold ore.



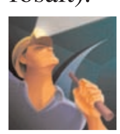
During the silver mining period in 1879, a Bavarian immigrant/prospector named Arie Pinedo found a vein of cinnabar (Blanthorn, 1998), which is a sulfide of mercury. He named his claim Mercur after the German word for mercury. This name stuck and eventually the mining district and former town site of Lewiston adopted the name of Mercur. In 1883, gold was found in an area called the Gold Ledge using assay methods. The miners were confused by the results because the gold was not visible to the naked eye and could not be recovered by panning or other gravitational methods. In 1890, the newly developed cyanide gold recovery method enabled the recovery of microscopic gold. In 1898, the Golden Gate mill in Mercur, the largest mill in North America at the time, was constructed to process 1,000 tons of ore per day. In 1902, the town of Mercur was destroyed by a fire and soon afterward became a ghost town. The area rejuvenated in 1933 when gold prices increased from $20.67 to $35 per ounce (Mako, 1999). Gold mining ceased in the district during World War II after the passage of the Federal Mine Closing Act, which banned all gold mining in the United States during the war. At this time, siliceous ores were mined instead, and used as a flux agent by smelters. Gold production resumed in the district in 1983 and estimated ore reserves were 15 million tons at 0.09 ounces gold per ton of ore. As mining progressed, additional reserves were discovered, but by 1997 all gold deposits were exhausted and efforts to find additional economic reserves were unsuccessful. The mine closed after the last of the stockpiled ore was processed for its gold content and heap leaching was completed.

Geology: Approximately 360 to 300 million years ago (Upper Mississippian-Lower Pennsylvanian), a shallow sea covered the region, depositing a sequence of marine limestone and calcareous sandstone. During the Middle Jurassic to early Tertiary (170 to 50 million years ago), these sedimentary rocks were folded and faulted during the Sevier orogeny. Hydrothermal events thought to be younger than 31.6 million years intruded the overlying sedimentary rock creating a rather unusual ore deposit. The Mercur mining district is considered to be the first discovery of a Carlin-type mineral deposit. A Carlin-type deposit is a sediment-hosted, disseminated gold deposit in which gold occurs as microscopic particles. The sediment-hosted mineralization at Mercur is restricted to the favorable horizons within the Mercur Member (lower member) of the Mississippian Great Blue Formation deposited approximately 330 million years ago (Mako, 1999). The more favorable beds for gold mineralization are porous and silty calcareous sedimentary rock. The mineralization at Mercur is thought to be from hydrothermal (hot) fluids either released from a deep magma source or mobilized from sedimentary rocks by the heat of a magma body. The mixing of the hydrothermal fluid with water leaching from the surface created an acidic, silica-saturated fluid. This acidic fluid reacted with and altered sedimentary rocks making them more favorable for gold deposition. Later, less acidic fluids carrying gold migrated through the altered sandstone and siltstone of the Mercur Member, where they deposited gold, pyrite, and other minerals. The gold is associated with pyrite, marcasite, orpiment, realgar, thallium minerals, and organic matter disseminated through the host rock (Mako, 1999).

Processed gold from the Barrick Mercur mine.
U.S. nickel for scale.



Mineralogy: The primary ore minerals include gold, silver, realgar, orpiment, cinnabar, stibnite, and possibly arsenopyrite (Gloyn, 1999). Gold occurs as very small grains not visible to the naked eye. Orpiment and realgar typically occur in a massive form; however, crystals can sometimes be found in calcite veins. Secondary oxidized ore minerals include chlorargyrite, cerussite, stibiconite, malachite, and azurite. Associated minerals are pyrite, marcasite, fluorite, barite, quartz, calcite, and gypsum. Two new minerals were first found and identified at Mercur: gillulyite (a thallium, arsenic, antimony sulfosalt), and a single specimen of fangite (a thallium, arsenic sulfosalt).



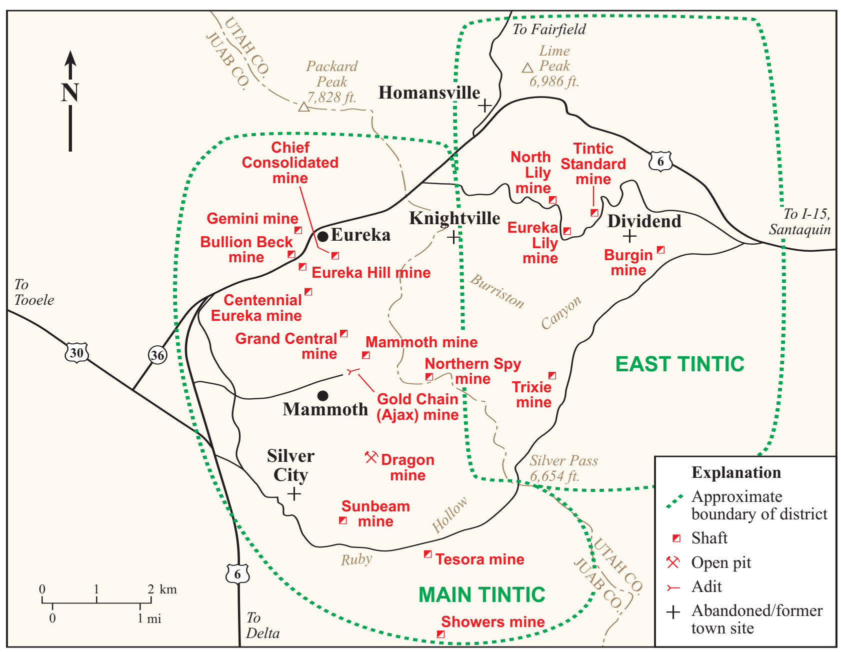
Current/Future Operations: Future production is unlikely. The site has been abandoned and reclaimed.

Tintic Mining District

The Bullion-Beck mine and the Gemini mine in the background, Tintic mining district circa 2002.

Location: The Tintic mining district is situated around the town of Eureka in northeastern Juab and southwestern Utah Counties. Eureka is located on U.S. Highway 6, west of Santaquin. Many mines are visible in the area. The most famous mines of the district, the Bullion Beck, Gemini, Eureka Hill, and Centennial Eureka, are on the southwestern outskirts of town. These mines are known as the "Big Four" and their head frames can still be seen today.

Production: The district is well known throughout the world for its substantial production values of lead, silver, gold, copper, and zinc. This production came mainly from an estimated 120 large and small mines. From 1869 to 1987, the district produced 19.1 million tons of ore containing 2.77 million ounces of gold, 272 million ounces of silver, 22.8 billion pounds of lead, 450 million pounds of zinc, and 254 million pounds of copper (Morris, 1990). With these totals, the Tintic mining district is the second-leading non-ferrous metal producer in the state behind the Bingham mining district. All recent production has been from the North Lily mine dump and the Trixie and Burgin mines, in the eastern part of the district.



The district is divided into two areas: (1) the Main Tintic in Juab and Utah Counties, which includes the area around the towns of Eureka, Mammoth, and former town site of Silver City; and (2) the East Tintic, also in Juab and Utah Counties, which includes the area around the former town sites of Dividend and Homansville.

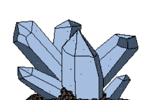
History: The Tintic mining district was discovered in 1869 by George Rust while returning from a prospecting adventure in the nearby Sheeprock Mountains. Within a few months, many claims had been staked in the vicinity of his initial discovery. The following year, the first ores from these properties were mined and freighted to reduction facilities in Reno, Nevada and Baltimore, Maryland. The extension of the Utah Southern Railroad reached the area in 1878 and production increased dramatically. Mills and small smelter furnaces were constructed on or near the mine sites to process ore to reduce transportation costs.

Several rich silver discoveries in the 1880s increased the importance of the Main Tintic district, making it one of the primary producers of silver in the country at the time. In 1882, John Beck found a concealed ore body in the Eureka Gulch area by sinking the Bullion Beck shaft and postulated that the ore body would continue to the south. This ore zone became known as the Gemini ore zone. In 1896, Jesse Knight found perhaps one of the richest ore shoots in the district when he drove an adit 450 feet into limestone and encountered an extensive linear ore body rich in silver, which developed into the Godiva ore zone. In 1905, Knight also discovered the massive Iron Blossom ore zone, a horizontal pipe-like deposit, which was mined continuously for up to 5200 feet in length (Morris, 1968). In 1909, Walter Fitch, Sr. and J.R. Finley discovered what was to be the Chief Consolidated mine after sinking a shaft 1400 feet and encountering rich ore. It was soon realized that the rich ore zone extended northward beneath the town site of Eureka. Consequently, all of the mineral rights for each building lot in the town had to be acquired before mining could continue. It was well worth the investment, because the mine became the most productive in the Main Tintic district, grossing over $50 million in its lifetime. Most of the mineral production came from ore rich in silver, lead, and zinc. With the closure of the Chief Consolidated mine in 1957, production ceased in the Main Tintic district.

Ore was first discovered in the East Tintic district in 1899 near the Eureka Lily shaft, but production was limited. Mining was difficult due to the hundreds of feet of volcanic rocks that cover the region. Only through extensive drilling and drifting were the ore deposits uncovered. In 1916, rich ore bodies were discovered at the Tintic Standard mine. Soon after the discovery, the Tintic Standard mine became one of the most productive silver mines in the world. In 1924, production was estimated at 4.20 million ounces of silver (Shepard and others, 1968). The Tintic Standard mine closed in 1949 and the district remained dormant for almost a decade. In 1958, rich lead-zinc ore was discovered by the Bear Creek Mining Co., an exploration company of Kennecott Copper Corporation, and the Burgin mine was established in 1963 to mine this new discovery. The Trixie ore body was also discovered around this time and the Trixie mine began production in 1969.

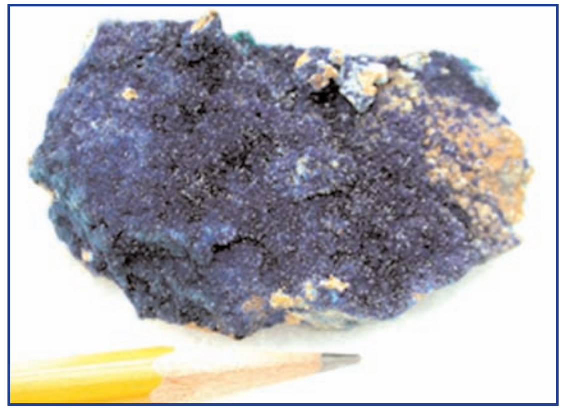
Geology: Sedimentary rocks in the district consist of a sequence of marine sandstone, limestone, and shale ranging in age from Precambrian (900 million years old) to Mississippian (325 million years old). These sedimentary rocks were deposited along the eastern edge of a large ocean. Starting in the Middle Jurassic (170 million years ago) and extending into the Tertiary (40 million years ago), the sedimentary rocks were slowly uplifted, faulted, and folded in the Sevier orogeny. During the middle Tertiary (approximately 35 million years ago), numerous volcanic eruptions deposited a series of volcanic ashes and tuffs. These volcanic eruptions were terminated by the intrusion of the Silver City stock (a granite rich in augite, biotite, and hornblende) 31.5 million years ago (Morris and Mogensen, 1978). The rich ore of the district formed when mineral-rich fluids released from the cooling stock migrated up fractures in the intrusive rock and adjacent sedimentary rocks. The ore was deposited in faults and fractures as replacement veins, replacement ore bodies, and fissure veins. The most important host rocks for ore deposition are Cambrian to Mississippian (570 to 330 million years old) sandstone, limestone, shale, dolomite, and quartzite of the Tintic Quartzite, Ophir Formation, Ajax Dolomite, Bluebell Dolomite, and Deseret Formation (Morris and Mogensen, 1978).

Replacement deposits are by far the most important ore bodies discovered in the district, and have produced over 90 percent of the ore (Morris, 1968). The five great ore zones in the Main Tintic district - the Gemini, Mammoth, Plutus, Godiva, and Iron Blossom - are all replacement deposits. Fissure vein deposits, averaging 2 feet in thickness and some over 4000 feet long, were the first discovered and the easiest to mine due to their close proximity to the surface. Fissure vein deposits were mined in the Sunbeam, Tesora, and Showers mines in the southern part of the district. Ore bodies in the East Tintic district formed in a similar manner to those in the Main Tintic district. Mineral-rich fluids from intrusions formed the rich ore, but in the East Tintic district later volcanic eruptions covered much of the ore-bearing rock with approximately 400 feet of rock. The ore was deposited in faults and fractures as replacement bodies in limestone beds of the Middle Cambrian Ophir Formation (513 million years old), veins in quartzite of the Lower Cambrian Tintic Quartzite (570 million years old), and as minor disseminated deposits in conglomerate and limestone of the middle Tertiary Apex Conglomerate (35 million years old) (Morris and Lovering, 1979).



Mineralogy: The primary ore-bearing minerals found at Tintic are enargite, tetrahedrite, galena, sphalerite, pyrite, marcasite, gold, silver, and copper. Visible native gold was found at the Centennial Eureka, Mammoth, Grand Central, and Gold Chain (Ajax) mines. The largest amount of gold ore was recovered at the Apex shoot of the Mammoth mine. Visible silver wires were found at the Chief Consolidated mine. Secondary oxidized ore minerals include smithsonite, hemimorphite, aurichalcite, malachite, azurite, cuprite, cerussite, anglesite, and hematite. Associated minerals include quartz, calcite, aragonite, dolomite, barite, and gypsum. Early mining and recent mineral collecting in the Tintic district uncovered rare mineral specimens of olivenite, clinoclase, mixite, tyrolite, conichalcite, linarite, scorodite, adamite, mimetite, carminite, cornwallite, jarosite, plumbojarosite, and connellite. The Centennial Eureka, Bullion Beck, Grand Central, Mammoth, and Northern Spy mines produced many of these minerals. The district is also the type locality (where the mineral was first identified and described) for the minerals argentojarosite, arsenobismite, billingsleyite, crandallite, and tinticite. Recently, the Centennial Eureka mine dumps were reworked for gold, during which micro-size specimens of previously unknown copper tellurates were found, including frankhawthorneite, utahite, juabite, jensonite, leisingite, and mcalpineite (Marty and others, 1993).

Current/Future Operations: In the East Tintic district, exploration is ongoing in the hopes of locating other concealed mineral deposits. Some of this exploration has yielded positive results by intersecting the extensions of known ore bodies. In 2000, exploration at the Trixie mine revealed a high-grade ore body estimated to contain 53,000 oz gold and 350,000 oz of silver (Bon and Gloyn, 2000). Several sections in recent drill holes showed assays as high as 17.1 oz of gold/per ton of ore. Between January and March of 2002, the Trixie mine produced 150 tons of ore per day from this newly discovered ore body. In late March, the mine experienced a cave-in, terminating operations. In the Main Tintic area, some of the old mine dumps have recently been reprocessed for gold. At the Dragon mine, about 2.5 miles south of Eureka, the Atlas mining company completed drilling in the summer of 2003 to verify reserve data. Estimated reserves indicate more than 300,000 tons of halloysite on the mine property. Many of the mines in the district still contain ore below the water table, but it is not economical to mine due to high costs of pumping water and mine maintenance. With cheaper foreign sources of gold and silver, large production from this mining district seems unlikely in the near future. Recently, safety concerns associated with children's elevated lead levels in their blood have prompted the Environmental Protection Agency (EPA) to clean up residential properties and reclaim the Gemini and Bullion Beck mines.



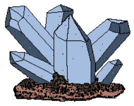
Azurite from the Mammoth mine, Main Tintic district. Pencil for scale.

Mountain Lake Mining District
(Big Cottonwood, Little Cottonwood, & American Fork)

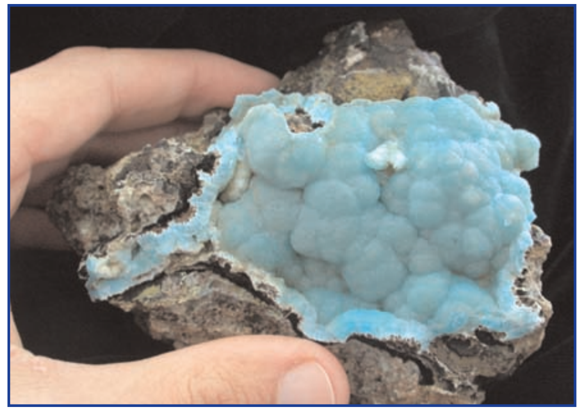
Ore bin at the Cardiff mine, Mill D South Fork, Big Cottonwood district.

Background: The Mountain Lake mining district encompasses an area from Warm Springs (north end of Salt Lake City) to the head of Utah Lake in Utah County. Soldiers stationed at Fort Douglas in Salt Lake City formally created the district in 1868. Many of these soldiers already had mining experience from Colorado, Nevada, and California. In 1870, the district was divided into several separate districts including Big Cottonwood, Little Cottonwood, and American Fork. The location, access, production, history, and current status for each of these districts are discussed separately. The geology and mineralogy of the three districts are similar and discussed below.

Geology: From the Precambrian (900 million years ago) to Mississippian (325 million years ago), marine sedimentary rocks (sandstone, limestone, and shale) were deposited on a shallow shelf along the eastern edge of a large ocean. In the Middle Jurassic to Tertiary (170 to 40 million years ago), these rocks were folded and faulted during the Sevier orogeny. Approximately 40 to 25 million years ago, magma bodies intruded these fractured marine rocks forming the quartz monzonite of the Little Cottonwood stock and granodiorite of the Clayton Peak and Alta stocks. Three types of ore bodies were formed by hydrothermal (hot) fluids from these intrusive rocks: (1) replacement of carbonate rock (limestone), (2) metallic fissure veins, and (3) skarn deposits. Replacement deposits are the most common type of deposit and exist throughout the Mountain Lake district. Limestone rock layers of Middle Cambrian to Mississippian (515 to 325 million years old), particularly the Maxfield Limestone, Gardison Limestone, Deseret Limestone, and Fitchville Formation, seem to have been the most favorable for ore deposition (James, 1979). In some replacement deposits, such as those in the Emma mine, renewed faulting has cut some of the ore bodies and displaced parts as much as several hundred feet. Fissure deposits occur in quartz veins within the Tintic Quartzite and generally persist many hundreds of feet, notably at the Howell mine (James, 1979). Skarn deposits are generally small and tend to be the most common near the contact of the stocks with carbonate rocks. At the Big Cottonwood mine, the skarn deposits are located at the contact of the carbonate rocks (Gardison, Deseret, and Humbug Formations) with the Alta and Clayton Peak stocks (James, 1979). All of these ore bodies are found either adjacent to the intrusives, within the intrusives, or along and at the intersection of faults.



Mineralogy: The major ore bodies in the Big Cottonwood, Little Cottonwood, and American Fork districts are vein and replacement deposits containing variable amounts of lead, zinc, manganese, silver, and copper with associated gold. Some deposits contain tungsten- and molybdenite-bearing minerals. The primary ore-bearing minerals include galena, sphalerite, argentite, tetrahedrite, bismuthinite, enargite, molybdenite, scheelite, bornite, pyrite, and gold. Secondary ore minerals include smithsonite, cerussite, malachite, azurite, aurichalcite, wulfenite, pyromorphite, hemimorphite, plumbojarosite, pyrolusite, and stolzite. Wulfenite and hemimorphite occur as small well-developed crystals in the oxidized ores of the Michigan-Utah, Alta Consolidated, and Flagstaff mines (Wilson, 1995). Associated minerals found in the districts are calcite, rhodochrosite, quartz, magnetite, epidote, barite, siderite, beaverite, gypsum, and ludwigite. Ludwigite, a relatively rare iron borate, is

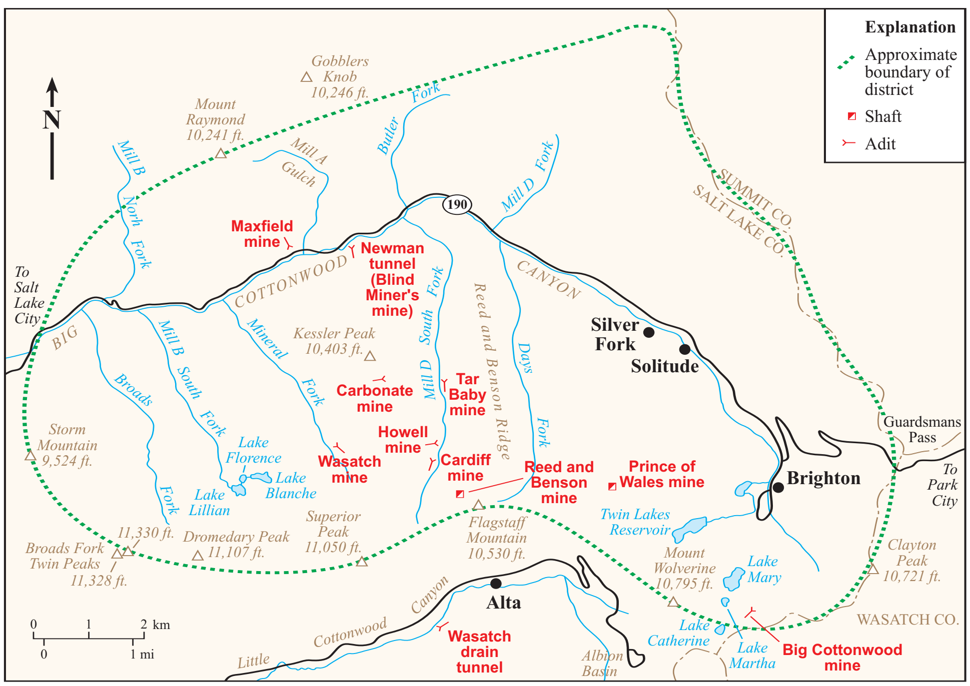


Hemimorphite from the Wasatch mine, Big Cottonwood district.

abundant at the Big Cottonwood mine along with magnetite, bornite, chalcopyrite, malachite, and other associated minerals (Wilson, 1995). Tungstenite (75 percent tungsten and 25 percent sulfur) was first found and identified from the Emma mine (Calkins and Butler, 1943). Tungstenite is a rare mineral found with pyrite, galena, sphalerite, tetrahedrite, and quartz.

Big Cottonwood Mining District

Newman tunnel (Blind Miner's mine), Big Cottonwood district.



Location: The Big Cottonwood district is approximately 18 miles southeast of downtown Salt Lake City on both sides of Big Cottonwood Canyon. Main access to the district is up Big Cottonwood Canyon on State Highway 190.

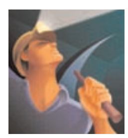
Production: It is impossible to give accurate metal production data for the Big Cottonwood district, because ores from the district have been mined through tunnels on both sides of the ridge between Big Cottonwood and Little Cottonwood Canyons. Also, historical records have grouped the Little Cottonwood and Big Cottonwood districts' production values together. From 1867 to 1976, the two districts produced approximately 30,600 ounces of gold, 17.5 million ounces of silver, 18.1 million pounds of copper, 252 million pounds of lead, and 4.7 million pounds of zinc (James, 1979). Of the two districts, Big Cottonwood has produced approximately 60 percent of the total combined metal production.

History: In 1870, the Big Cottonwood drainage basin was designated as the Big Cottonwood mining district, separate from the Little Cottonwood district to the south. The Reed and Benson mine, located in Mill D South (Cardiff) Fork, was one of the major producers during the early years of the district. The mine was located on high, sheer vertical limestone cliffs where miners had to be roped in to make a trail. A tramway 1582 feet long was constructed to transport the ore from the mine tunnel to the wagon road below (James, 1979). By 1872, over 650 claims were staked in the district. The early boom period lasted between 1871 and 1885, as production increased in rich oxidized and enriched ore. Major producers during this period included the Cardiff, Carbonate, Howell, Prince of Wales, Big Cottonwood, Tar Baby, and Maxfield mines, in addition to the Reed and Benson mine. By 1885, the shallow, rich ore bodies had been exhausted, and many of the miners had moved on to other boom areas. The start of the twentieth century brought a renewed interest in many of the mines due to rising silver prices and new mining/processing technology. Larger mining companies were organized to develop the deep prospects of the region. The largest ore body of the district was discovered in 1914 at the Cardiff mine. The ore body was 10 feet thick and continued horizontally for more than 300 feet. By the late 1920s, metal prices had dropped and only a few of the mines remained in op-eration.

In 1929, J.L. (Roy) Newman was almost completely blinded by a blast from a mining accident while working one of his mines. Known ever since as the "Blind Miner," he continued to work his mine, the Newman tunnel, for 45 years, driving over 1500 feet of straight tunnel (James, 1979). Roy managed this task by using a tiny area of sight remaining in the corner of his left eye to sight down the tunnel with a lighted lamp and a rock pick (Newman, undated).

In the early 1940s, mining production was briefly heightened by high metal demands of World War II. During the summer of 1955, the Wasatch Drain Tunnel was constructed on the other side of the ridge in Little Cottonwood Canyon to drain water and remove ore from the Cardiff mine. The tunnel was used until 1967. Between 1955 and 1967, approximately 23,000 tons of ore were removed from the Cardiff mine that contained over 230 ounces of gold, 344,000 ounces of silver, 850,000 pounds of copper, 6 million pounds of lead, and 5.7 million pounds of zinc (James, 1979).

The "Blind Miner," Roy Newman. Photo courtesy of the Utah State Historical Society.



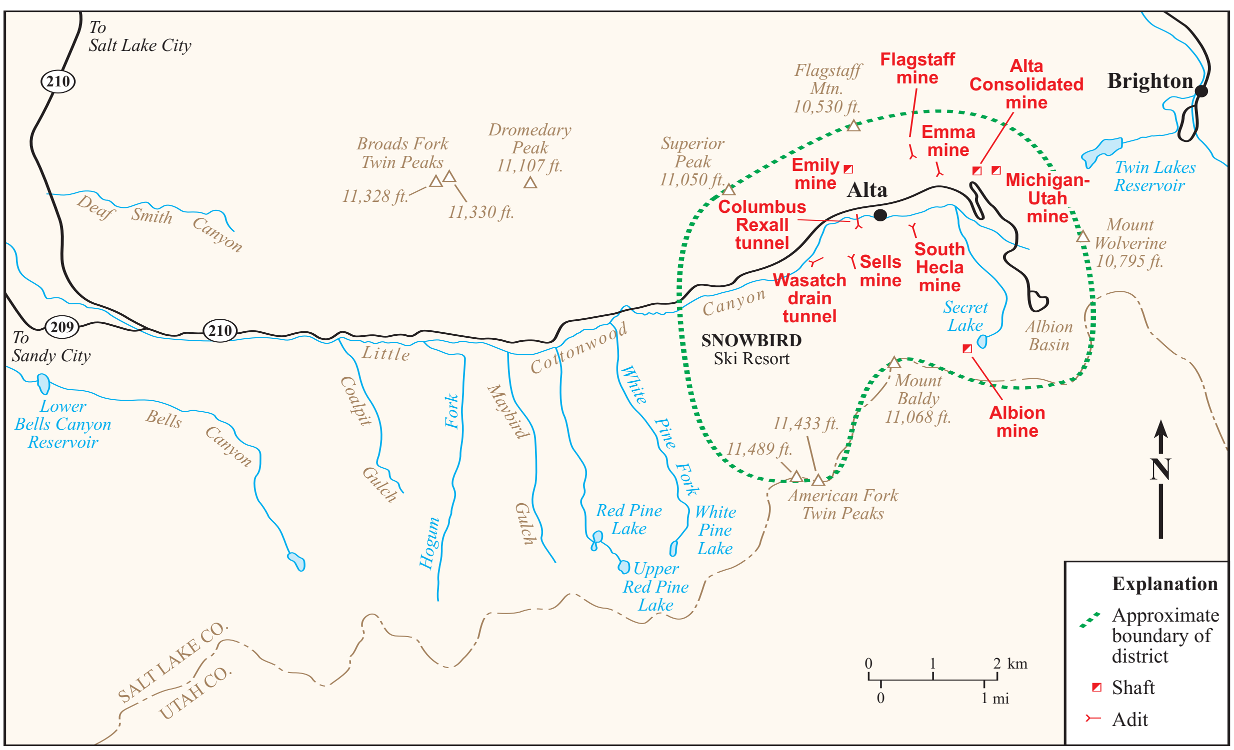
Current/Future Operations: The district is currently inactive and likely to remain so. Metal prices (gold, silver, and lead) have been too low to warrant further mineral exploration. Minable ore in known deposits was exhausted by the mid-1960s and other discoveries were small and uneconomic.

Little Cottonwood Mining District

Location: The Little Cottonwood district is located near the headwaters of Little Cottonwood Creek, approximately 27 miles southeast of downtown Salt Lake City. The only access to the district is up Little Cottonwood Canyon on State Highway 210. Travel approximately 8 miles up the canyon to the town of Alta, which is the center point for the district.

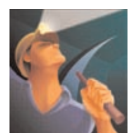
South Hecla mine, Little Cottonwood district circa early 1900s.
Photo courtesy of the Utah State Historical Society.

Production: It is impossible to give accurate metal production data for the Little Cottonwood district, because ores from the district have been mined through tunnels on both sides of the ridge between Little Cottonwood and Big Cottonwood Canyons (James, 1979). Also, historical records have grouped the Little Cottonwood and Big Cottonwood districts' production values together. From 1867 to 1976, the two districts produced approximately 30,600 ounces of gold, 17.5 million ounces of silver, 18.1 million pounds of copper, 252 million pounds of lead, and 4.7 million pounds of zinc (James, 1979). Of the two districts, the Little Cottonwood district produced approximately 40 percent of the total combined metal production.



History: In 1865, the first mining claims were filed north of today's town of Alta by Silas Brain. Most of the claims were long and narrow: 100 feet wide and 2000 to 3000 feet long. In 1868, J.B. Woodman and Robert Chusholm discovered silver mineralization and created the Emma mine. Production began in 1870, and in the early mining stages the ore was incredibly rich, assaying 100 to 216 ounces of silver per ton (Calkins and Butler, 1943). Much of the ore was so rich that it could be shipped to New York via railroad and then by ship to Liverpool, England to be processed for a profit. J.E. Lyon, T.W. Park, and H.H. Baxter bought shares of the Emma mine in 1871 for $375,000. Probably realizing the ore body was about to be played out, production was dramatically increased to trick potential buyers. The sensational profits obtained from the increase in production enabled the promoters to sell the mine in 1872 to a British company for a million English pounds. After the sale, the ore body was discovered to suddenly end against a post-mineral fault. This created an international incident, because of the participation by the American foreign minister to London, Robert Schenck (one of T.W. Park's company board of directors). Extensive court proceedings and a U.S. Congressional investigation by the U.S. House of Representatives Committee on Foreign Affairs brought out many of the details, but failed to establish the extent of Schenck's role. Schenck later resigned his post as the American foreign minister to London and returned to the United States. The Emma mine continued to produce low-grade ore until 1879. For the next 30 years, the mine remained idle and the lower workings filled with water. The continuation of the ore body on the other side of the fault was not located until 1916 by Joseph J. Beeson, a geologist from Stanford University and the University of Utah. Shortly after the discovery, the Emma mine was dewatered and in 1917 the first new shipment of ore left the mine. The mine continued to operate until 1919.

Other mines that produced ore in the early history of the district include the Flagstaff, Albion, and Emily. Of these, the Flagstaff mine was the most productive, yielding approximately 100,000 tons of high-grade silver ore from 1869 to 1880 (Butler and others, 1920). Between 1901 and 1940, the largest producers of the district were the Michigan-Utah, South Hecla, Emma, Columbus-Rexall, and Sells (Calkins and Butler, 1943).



Current/Future Operations: All mining in the district has been suspended due to low metal prices, high cost of mining, or depletion of mineable ore bodies.

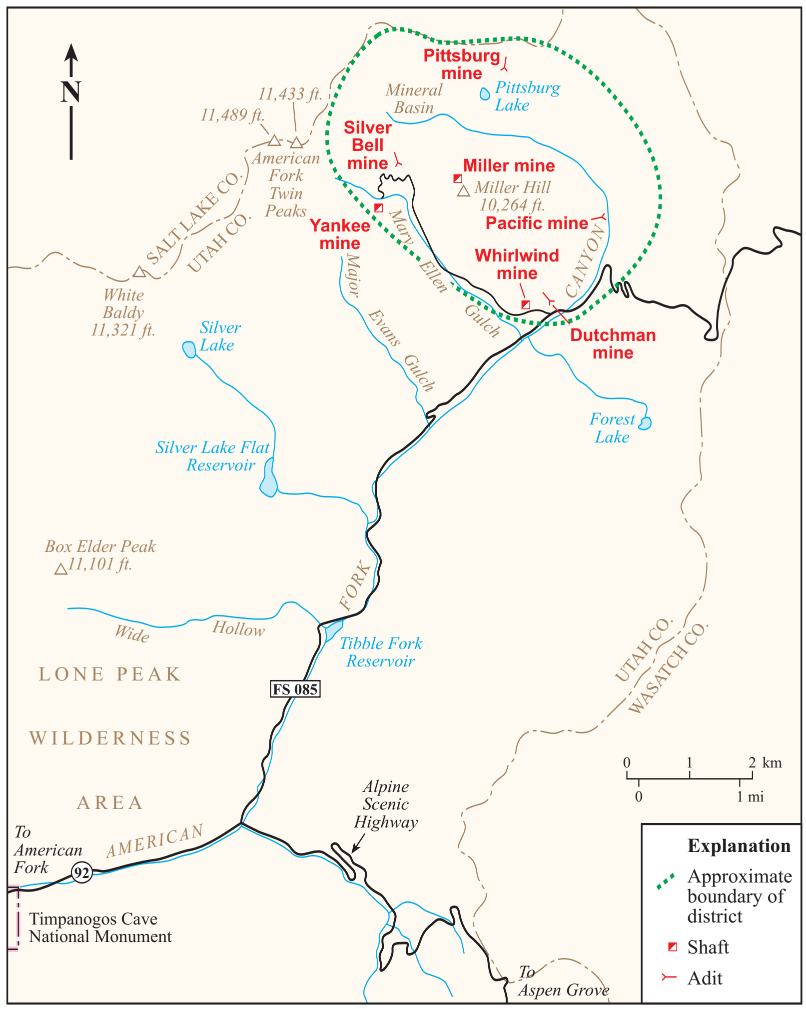
American Fork Mining District

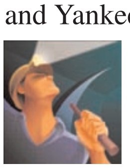
Pacific mine, American Fork district circa 1916. Photo courtesy of Melvin Anderson.

Location: The American Fork district is located near the headwaters of American Fork Creek, approximately 20 miles northeast of Lehi, Utah County.

Production: From 1870 to 1976, the American Fork district produced approximately 2.45 million pounds of copper, 36.4 million pounds of lead, 5.54 million pounds of zinc, 45,000 ounces of gold, and 2.39 million ounces of silver (Perry and Mc-Carthy, 1977).

History: In 1869, ore was found at a locality referred to as Miller Hill in American Fork Canyon. The district was officially organized in 1870. Little work was done on the located prospects until the autumn of 1870 when a large ore body was discovered at the Miller mine. This ore body was mined until 1876. Average assays of ore were 40 to 54 percent lead, 30 to 47 ounces of silver per ton, and $2 to $10 in gold per ton (Calkins and Butler, 1943). Other properties that produced ore prior to 1880 include the Dutchman, Pittsburg, Silver Bell, Yankee, and Whirlwind mines. The district was active until 1963; major periods of production occurred during 1870-80, 1905-09, 1917-18, 1923-29, 1931-41, and 1946-49 (Perry and Mc-Carthy, 1977). Major mines that produced ore during these periods include the Miller, Pacific, Pittsburg, Dutchman, Whirlwind, and Yankee.





Current/Future Operations: All of the mines are currently inactive. In 2000, Unico, Inc. re-opened the Silver Bell mine and began restoring the underground workings. In 2003, exploration work continued on the property. Safety concerns prompted the cleanup of the Pacific mine tailings by the U.S. Forest Service in the spring of 2003.

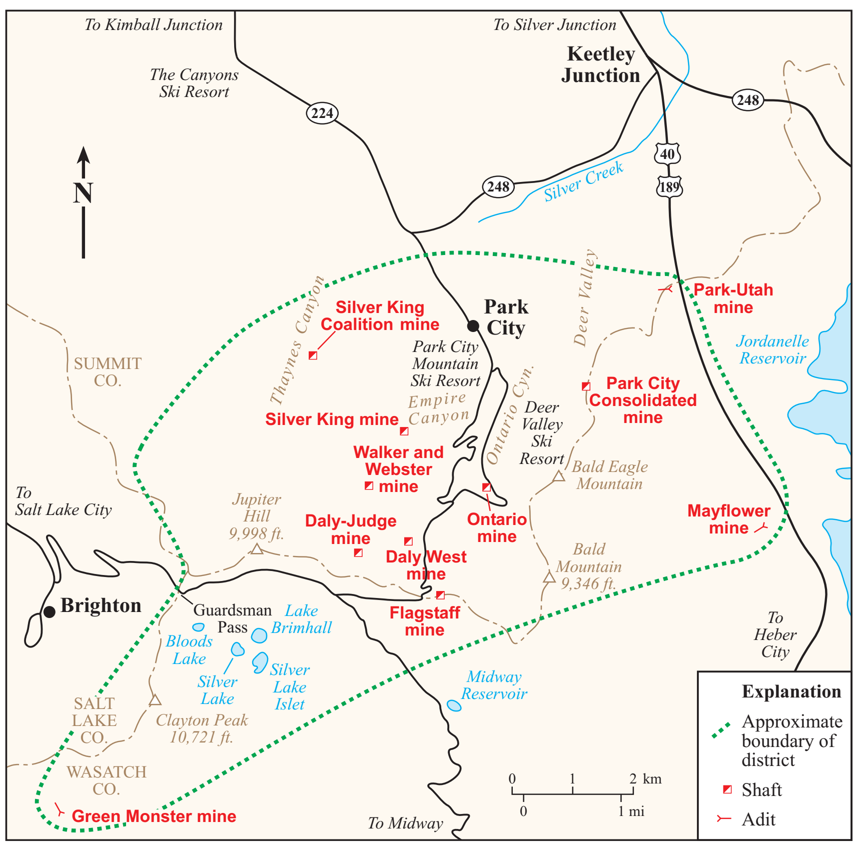
Park City Mining District

The Ontario mine, Park City mining district circa 1885.
Photo courtesy of the Utah State Historical Society.

Location: The Park City mining district is near Park City in southwestern Summit and northwestern Wasatch Counties. The mines are south of Park City.

Production: From 1875 to 1982, the Park City mines produced 16.7 million tons of ore recovering 1.45 million ounces of gold, 253 million ounces of silver, 2.7 billion pounds of lead, 1.5 billion pounds of zinc, and 129 million pounds of copper (John, in preparation). With these totals, the Park City mining district is the third-leading non-ferrous metal producer in the state (John, in preparation).

History: The Park City district comprises three former districts (Uinta, Snake Creek, and Blue Ledge), and who made the first mineral discovery in the district is unknown. The first claims recorded were the Young America in 1868 and the Green Monster in 1869 (Boutwell, 1912). A short time later Rufus Walker located the Walker and Webster

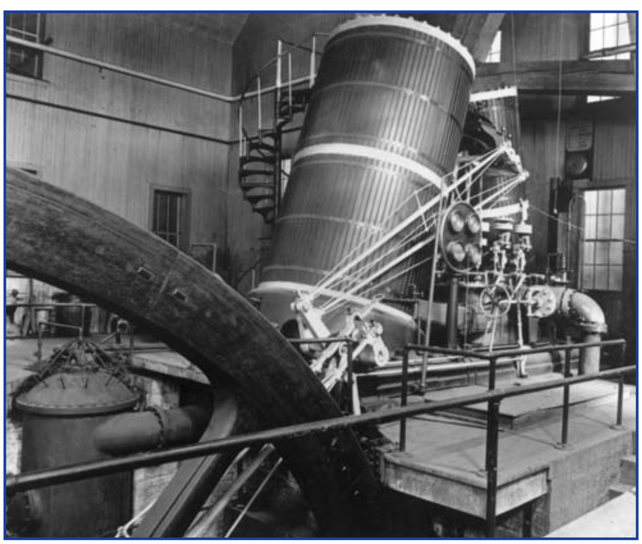


claim and exploration began in earnest. With an increasing number of discoveries, the Uinta district was organized in 1869. The Snake Creek and Blue Ledge districts were established in the spring of 1870. The first recorded production of lead-silver ore in the Park City district was from the Flagstaff mine in 1871. The discovery of the Ontario vein in 1872 by Rector Steen, John Kain, and Gus McDowell catapulted the district into prominence (John, in preparation). The vein was exposed on the surface as a knob, protruding two inches out of the ground. The first ore mined from this property averaged $200 dollars of silver per ton. These prospectors subsequently sold the mineral rights to George Hearst and partners in 1872 for the amount of $27,000 (Hampshire and other, 1998).

In 1881, a Cornish pump was installed in the Ontario mine to pump out ground water (John, in preparation). The pump had a wheel that was 30 feet in diameter, weighed 70 tons, and pumped 2560 gallons of water per minute. As the mine became deeper, the Cornish pump became inefficient at handling the excessive amount of water.

In 1888, excavation work began on the 3-mile-long Ontario drain tunnel to eliminate water from the lower workings of the mine. The tunnel took six years to complete at a cost of $400,000. The tunnel linked up with the 1500-foot level of the mine and was capable of draining up to 13,000 gallons of water per minute (John, in preparation). In its lifetime, the Ontario produced ore worth over $50 million, making this property one of the best land purchases of all time. The Ontario was mined from the surface to a depth of 2000 feet, and was highly productive in the upper 1500 feet. The ore averaged 21 ounces of silver per ton and approximately 3 percent lead (Garmoe and Erickson, 1968). Other major mines in the district include the Daly West, Daly-Judge, Park-Utah, Mayflower, Park City Consolidated, and Silver King.

During World War II, metal production from the mines decreased dramatically. Many of the skilled workers were sent to the war and government restrictions prevented the search for new mineral deposits.



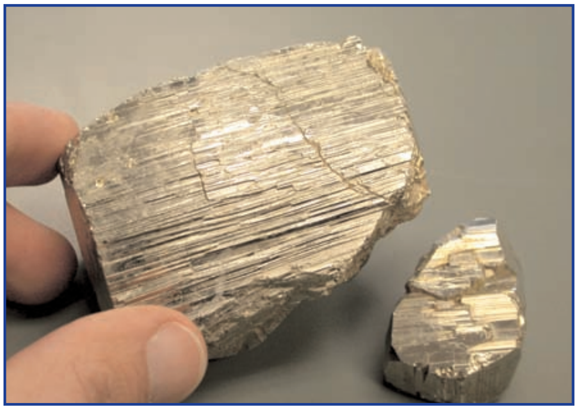
Cornish pump at the Ontario mine. Photo courtesy of the Utah State Historical Society.

In 1958, the United Park City Mines, the last surviving mining company in Park City, looked closely at their property for other ways to generate money. Because the silver market was on the downside, the company turned to skiing with assistance from the federal government. With a federal loan of $1.2 million and land ownership of the surface rights to approximately 10,000 acres of mountainside, the mining company created Park City's first ski resort. In 1963, Treasure Mountain, now known as the Park City Mountain Resort, opened to the public.

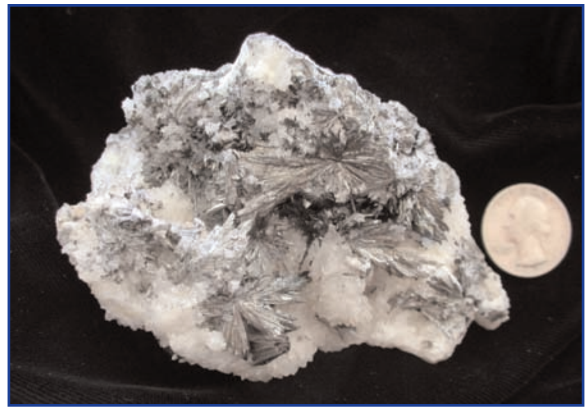
Mining continued at the Mayflower mine, where the ore contained higher gold and copper values per ton than any of the other mines in the district. In 1966, the Mayflower mine ranked sixth in gold production in the United States, and in 1967 the mine produced 72,000 ounces of gold (Quinlan and Simos, 1968). The Mayflower mine closed in 1972.

After a period of inactivity, mining resumed at the Ontario mine in the spring of 1975. For three years, the Ontario mine produced ore until its closure in 1978 (John, in preparation). The Noranda Mining Company leased the mine from 1979 to 1982. In 1995, the Ontario mine was opened for the first time to tourists. Called the Park City Mine Adventure, tourists could descend 1500 feet underground to view the Cornish pump, minerals, and old mine workings. Unfortunately, this latest venture lasted only several years.

Geology: Sedimentary rocks in the Park City district range in age from Precambrian (1400 million years old) to Jurassic (160 million years old). During the Middle Jurassic to Tertiary (170 to 40 million years ago), these rocks were folded and faulted during the Sevier orogeny. During the Tertiary (35 to 34 million years ago), six magma bodies intruded the overlying sedimentary rocks. Hydrothermal (hot) fluids associated with the cooling magma migrated upward through pre-existing faults and fractures creating the important ore deposits of the Park City mining district. Limestone rock layers of Pennsylvanian to Late Permian (300 to 240 million years old) age, particularly the Humbug and Park City Formations and the Weber Quartzite, seem to have been the most favorable for ore deposition (John, 1997). The Park City mining district contains two major types of ore deposits: (1) fissure or lodes that contain the highest-grade silver mineralization, and (2) limestone replacements that contain less silver, but higher grades of lead and zinc. The vein or lode deposits were the first discovered, contained the richest ore, and were the easiest to mine due to their close proximity to the surface. The best examples of these ore deposits can be found at the Mayflower and Park-Utah mines. The Pennsylvanian Weber Quartzite is the main host rock for fissure deposits (John, 1997). After exhaustion of the rich lode ores, replacement deposits became the major source of production. About 75 percent of the ore recovered in the district was from replacement

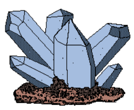


Pyrite from the Silver King Coalition mine.



Stibnite from the Silver King Coalition mine. U.S. quarter for scale.

deposits in Park City Formation (Garmoe and Erickson, 1968). Major replacement bodies in the district include those exposed in the Silver King, Ontario, and the Daly West mines (John, 1997).



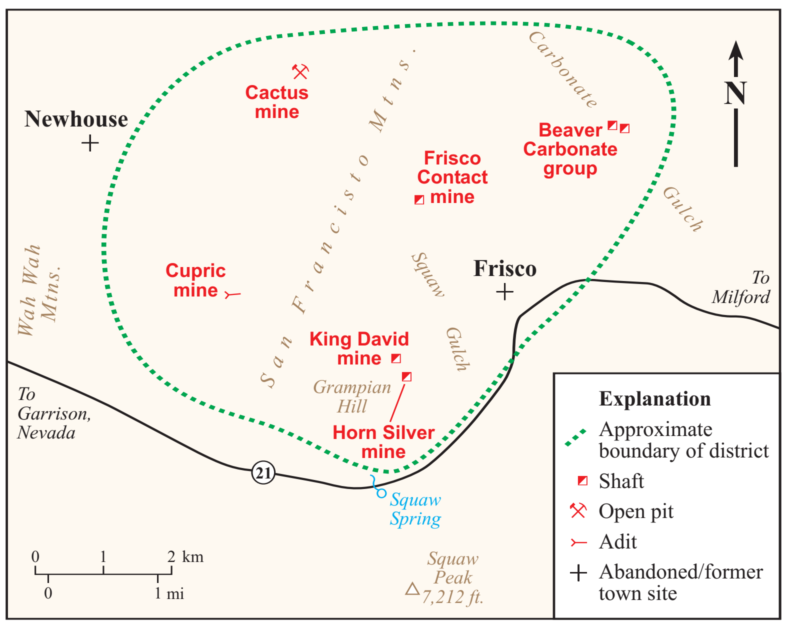
Mineralogy: The primary ore-bearing minerals in the district are galena, pyrite, sphalerite, gold, stibnite, tetrahedrite, jamesonite, and boulangerite. Secondary ore minerals include cerussite, anglesite, bindhamite, chlorargyrite, argentite, malachite, and azurite. Associated minerals are calcite, siderite, quartz, fluorite, barite, and gypsum. The mining district is well known for its fantastic pyrite crystals. Pyrite cubes up to 1 inch were found in some of the mines of the district. One specimen in the Utah Museum of Natural History mineral collection is a large cluster of crystals, the largest crystal measuring over 3 inches across.

Current/Future Operations: The last ore was produced from the district in 1978 from the Ontario mine. All of the mines are presently closed or inactive due to low silver prices and the high cost of rehabilitation and mining. To generate revenue, several of the mines sold the water leaking into the mines to ski resorts for their snowmaking machines. Some mines were maintained, such as the Ontario, but in July 2003 the United Park City Mining Company sold all interests to Capital Partners LLC. Capital Partners LLC is a development corporation and is unlikely to use the property for mining. Real estate and skiing are now the main revenue sources for the area.

San Francisco Mining District

The King David mine, southwest of the former town site of Frisco, San Francisco mining district.

Location: The San Francisco mining district is in the southern one-third of the San Francisco mountain range approximately 15 miles west of the town of Milford in Beaver County. The district can be reached by traveling west from Milford on State Highway 21 to the ghost town of Frisco.



Production: From 1870 to 1976, the San Francisco district produced 2.36 million tons of ore that yielded 44,900 ounces of gold, 19.6 million ounces of silver, 44.1 million pounds of copper, 405 million pounds of lead, 46.8 million pounds of zinc, and 892 pounds of tungsten (Wray, in preparation).

History: In 1870, the Cactus ore body was the first metallic mineral deposit discovered here, and the district was formally organized in 1871. Four years later, the Horn Silver ore body (the largest lead-silver ore body ever found in Utah) was discovered by James Ryan and Samuel Hawkes (Butler, 1913). These two prospectors sunk a shaft 30 feet and encountered chlorargyrite or horn silver (a rich silver ore), hence the name, Horn Silver mine. Fearing that the ore deposit would be small, they decided to sell the claim five months later, in 1876, to A.G. Campbell, Matthew Cullen, Dennis Ryan, and A. Byram for $25,000. These new owners proceeded to develop the ore body, erect a smelter, and process and sell the ore. During the three-year period from 1876 to 1879, the total value of mine production was $2.54 million, which included almost 50 percent paid out as dividends. In 1879, they sold the greater part of their interest to the newly incorporated company, Horn Silver Mining, for $5 million. The town of Frisco was established and by 1880 had about 800 inhabitants. Drinking water was brought to the town via the railroad from Black Rock, Utah about 30 miles to the east, or hauled by wagon for 10 miles from springs in the Wah Wah Mountains to the west.

From 1880 to February 12, 1885, the mine was a constant producer until the upper 800 feet of the original shaft caved in. The desire for high production possibly caused disregard for good mining practice;

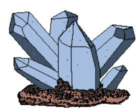
miners reported the mine creaking and shifting prior to the cave-in. Luckily, the mine collapsed during a shift change and no one was hurt. The cave-in was so violent that windows shattered 15 miles away in the town of Milford. This was the beginning of the end for the Horn Silver mine, town, and district. Mining ceased while the underground workings were improved and a new 1600-foot-deep shaft (Horn No. 1) was constructed east of the old shaft. Mining resumed in 1886 and continued until 1952 with a brief period of inactivity from 1932 to 1937. From 1875 to 1952, the Horn Silver mine produced 834,000 tons of ore yielding 196,000 tons of lead, 17.9 million ounces of silver, 25,700 ounces of gold, 9,650 pounds of copper, and 23,300 pounds of zinc (Wray, in preparation).

Other mines that produced ore in the district include the Beaver Carbonate group, Cactus, King David, Cupric, and the Frisco Contact. Of these, the Beaver Carbonate group (including the Carbonate, Rattler, and Quadmetals mines) was the largest silver producer. From 1879 to 1942, this group produced an estimated 92,900 tons of ore generating 12 million pounds of lead and 1.18 million ounces of silver (Wray, in preparation). The Cactus mine was the most productive for gold and copper. From 1870 to 1957, the Cactus mine produced 1.40 million tons of ore yielding 13,500 ounces of gold, 34.5 million pounds of copper, and 301,000 ounces of silver (Wray, in preparation).

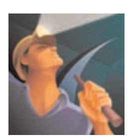
Geology: Sedimentary rocks in the district consist of limestone, dolomite, and shale ranging in age from Late Cambrian (515 million years old) to Late Ordovician (458 million years old). These rocks formed from sediments that were deposited on a wide, shallow shelf along the eastern edge of a large ocean. From the Middle Jurassic to early Tertiary (170 to 40 million years ago), these rocks were uplifted, folded, and faulted during the Sevier orogeny. Approximately 35 million years ago, volcanic lava flows covered the immediate area followed by magma intrusions 31 to 28 million years ago (Best and others, 1989). Hydrothermal (hot) fluids from the cooling magma bodies migrated upward through pre-existing faults and fractures creating the ore deposits of the district: (1) replacement deposits, (2) skarns, and (3) breccia pipes. Replacement deposits are the most important type of ore body found in the district. The Horn Silver ore body is an example of a replacement deposit that formed along the Horn Silver fault. The maximum dimensions of the ore body were approximately 700 feet along strike, 100 feet in width, and 1000 feet in length (Whelan, 1973). The ore host rock consists of Cambrian limestone and shale of the Orr Formation (approximately 515 million years old).

Chalcanthite from the King David mine.

Skarns are small deposits found along the contact of the intruded rock (quartz monzonite) with carbonate rocks in the district. At the Cupric mine, copper ore was mined from a skarn deposit. Mineral deposits within the granodiorite in the district are referred to as breccia pipes or breccia zones. A breccia pipe is a pipe-like body composed of angular or rounded rock fragments of the country rock held together by natural mineral cement. At the Cactus mine, breccia pipes may have formed from faulting or hydrothermal alteration (where soluble material has been partly or completely removed by a hot water solution causing the overlying rock to collapse).



Mineralogy: The ore bodies at the San Francisco district contain gold, lead, silver, zinc, and copper. Primary ore-bearing minerals include chlorargyrite, galena, sphalerite, wurtzite, chalcopyrite, stibnite, argentite, bornite, pyrite, and hematite. The zinc sulfides of sphalerite and wurtzite are common in the ores of the Horn Silver mine. These zinc minerals will luminate a yellow color when exposed to ultraviolet light (called fluorescence). These minerals will also spark when scratched with a metallic object. This rare and unusual property is known as triboluminescence. Secondary oxidized ore minerals are cuprite, azurite, malachite, cerussite, smithsonite, scorodite, and wulfenite. Associated minerals include barite, gypsum, chalcanthite, beaverite, jarosite, wollastonite, and calcite. Chalcanthite and gypsum coat the walls of the King David mine. Beaverite, a hydrous sulfate of copper, lead, and iron, was first found and identified from the Horn Silver mine (Butler and Schaller, 1911).



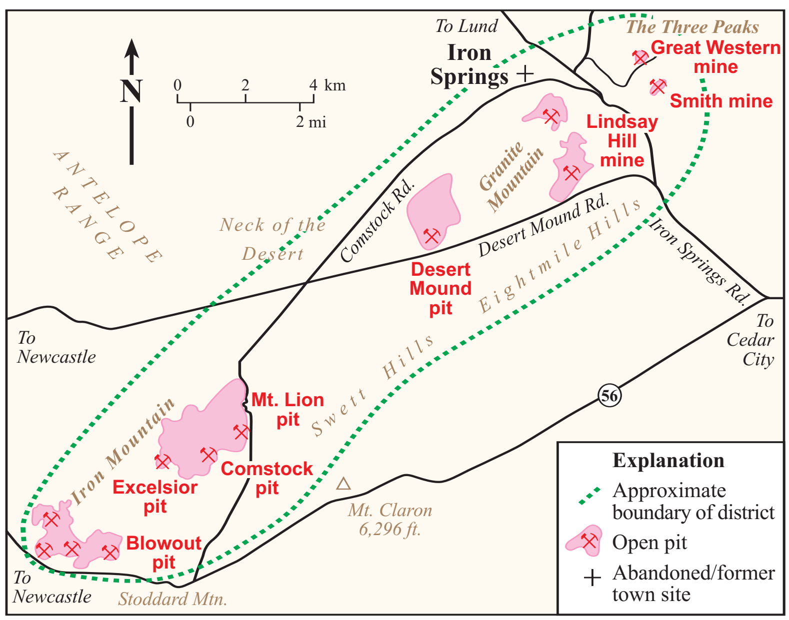
Current/Future Operations: Exploration work is presently being conducted by Franconia Minerals Corporation on the Horn Silver/King David mine properties. All other mines are currently inactive.

Iron Springs Mining District

The Desert Mound pit, Iron Springs mining district.

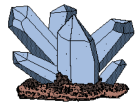
Location: The Iron Springs mining district is about 20 miles west of Cedar City, along State Highway 56 in Iron County. The district comprises three areas: The Three Peaks, Granite Mountain, and Iron Mountain.

Production: From 1923 to 1968, the district produced an estimated 87 million tons of iron ore (Bullock, 1970). Most of this production was achieved through open-pit mining methods using steam shovels and diesel-powered equipment. A resource of as much as 500 million tons of ore is proven to still be available, most of it in the Iron Mountain area (Bullock, 1970).

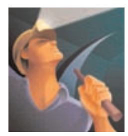


History: Parley P. Pratt discovered the iron deposits in 1849, while exploring southern Utah for the L.D.S. Church. His discovery led the L.D.S. Church to call for 120 men, 30 women, and 18 children to volunteer their services to produce iron from the ore (Larson, 1963). In 1852, this area became the first site west of the Mississippi River where iron was produced from native ores (Larson, 1963). After thousands of work hours, only 25 tons of iron were produced. After this venture ended in failure, several other unsuccessful attempts were made to process the iron ore. During the 1920s, new advancements in mining technology and iron production resulted in profitable mining operations. From 1923 to 1965, 72.1 million tons of ore were mined (Mackin, 1968). In 1981, mining operations at the Comstock and Mountain Lion properties were suspended due to increased operating costs and foreign competition. A resurgence in the steel industry occurred in 1989 with the reopening of the Comstock mine. Mining was suspended in 1995 due to cheaper foreign sources of iron.

Geology: Approximately 170 million years ago (Middle Jurassic), a long, narrow, shallow sea originating from the north covered the region, into which a sequence of marine limestone was deposited. By the Late Jurassic (150 million years ago), the sea had receded. From the Late Jurassic to late Tertiary (150 to 40 million years ago), sandstone, conglomerate, shale, and limestone were deposited. Mineralization began about 20 million years ago with the intrusion of several magma bodies into the overlying sedimentary rock (Hintze, 1988). As the magma cooled, it formed quartz monzonite. Hot fluids released from the cooling quartz monzonite migrated upward through fractures in the quartz monzonite and overlying sedimentary rock. When these fluids cooled, the important iron ore deposits of the district were formed. Three different types of ore deposits were created: massive replacement deposits, breccia fillings, and fissure veins. The replacement deposits contain most of the iron ore found in the district. Massive replacement iron ore bodies are found in the Middle Jurassic (approximately 170 million years old) Homestake Limestone Member of the Carmel Formation (Stokes, 1986). The Lindsay Hill mine is a good example of a massive replacement deposit. Breccia fillings are composed of angular broken-up rock fragments held together by natural mineral cement. In the Iron Springs district, breccias are formed by faulting and later replaced by iron ore, such as at the Blowout mine. Common in the quartz monzonite, fissure vein deposits were probably some of the first iron ore deposits located in the district. Many of these deposits were too thin to be mined economically, and only a small proportion were mined, such as the Excelsior and Great Western fissures where the veins were quite thick (approximately 12 feet).



Mineralogy: Magnetite and hematite are the primary ore-bearing minerals. Massive magnetite can be found in all of the mines of the district. Magnetite crystals or crystal aggregates can be found in fissure veins in some of the mines. Crystals can reach 2 to 3 inches across. In some mines, such as the Blowout and Excelsior, magnetite occurs in a fibrous form. Other minerals that can occur with the magnetite include calcite, fluorapatite, quartz (variety amethyst or crystal), chalcedony, pyrite, marcasite, siderite, barite, and epidote. These associated minerals generally occur in open spaces within a vein and usually form good crystals.



Current/Future Operations: Although large reserves (approximately 500 million tons of ore) still exist at the Iron Mountain mine (Bullock, 1970), the district is currently inactive. Geneva Steel (in Utah County) was the main purchaser of ore from the district. Early in 2003, Geneva Steel declared bankruptcy and their assets sold to the highest bidder. In February 2004, Geneva Steel sold its equipment to Qingdao Iron & Steel, a Chinese company that plans to dismantle, ship, and install the equipment in the Chinese province of Shandong (Anderson, 2004). In February 2005, Palladon Ventures Ltd. secured a contract to buy an idle iron mine near Cedar City from Geneva Steel for $10 million (Oberbeck, 2005). Palladon Ventures Ltd. also plans to build a steel mill adjacent to the mine that could cost as much as $1 billion. Currently (2005), the Lindsay Hill mine is used as a landfill for Cedar City.

Fluorapatite on weathered magnetite from the Iron Mountain area.

Magnetite from The Three Peaks area.

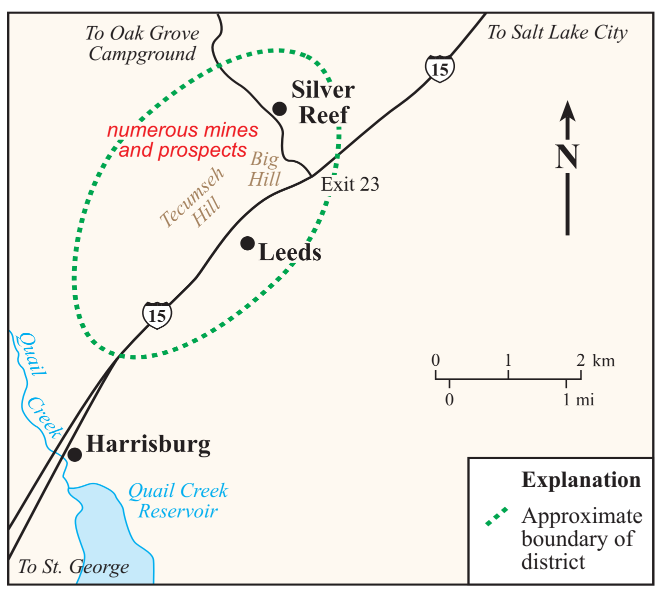
Silver Reef Mining District (Harrisburg)
(Originally known as the Union Mining District)

Silver Reef mining district circa late 1880s. Photo courtesy of the Utah State Historical Society.

Location: The Silver Reef mining district is in southwestern Utah, just north of the town of Leeds in Washington County. Principal access is approximately 15 miles north of St. George from the Leeds exit (#23) of Interstate 15. A museum containing a treasure trove of historical information on Silver Reef is located in the old Wells Fargo Bank building in Leeds at the Silver Reef town site.

Production: The mining district is unique; it is the only major mining district in the United States that produced silver ore from sandstone. From 1875 to 1972, the Silver Reef district produced 7.52 million ounces of silver, 665 ounces of gold, and 10.7 million pounds of copper (Stowe, 1975). The 665 ounces of gold reported by Stowe is likely in error because district boundaries were not specific and gold production from other districts was added to the total. The district also produced 8400 pounds of uranium oxide from 1950 to 1957 (Dasch, 1967). Average grade of the silver ore hoisted was 20 to 50 ounces per ton (Proctor and Brimhall, 1986).

History: John Kemple is credited for the discovery of silver ore at Silver Reef in 1866. His assayed ore samples were found to be rich in silver. Many did not believe the assay numbers because silver ore had never before been found in sandstone. Kemple did not trust his own assay results and set off for other mining camps in the West. He returned to Silver Reef for additional prospecting and in 1871 helped organize the Union mining district with L.D.S. church leaders and family heads from Harrisburg. All claims were later abandoned due to L.D.S. church concerns about the lawless aspect associated with mining and worries that farmers would leave their farms and orchards to become miners. Kemple again returned to Silver Reef and reorganized the district as the Harrisburg mining district in 1874. However, development

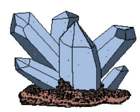


of the district is credited to William Tecumseh Barbee after his 1875 silver ore discovery on Tecumseh Hill along a wagon road between Quail Creek and Leeds. A wheel from a wagon hauling wood to Leeds dislodged a piece of ore-bearing sandstone. The ore from this outcrop averaged 300 to 400 ounces of silver per ton. Barbee then promoted the district through glowing newspaper articles in Salt Lake City and Pioche, Nevada. Within the next two years, the new town of Silver Reef had reached a population of 1500. The town had all of the modern amenities, such as a post office, churches, schools, a bank, and a hospital. Most of the silver was produced during a five-year period between 1878 and 1882. Production began to decline in 1880, and by 1888 all of the major company-operated mines had closed. The rich, near-surface ores were mined out, ore grade decreased with depth, mining became more expensive, and ground water occupied the lower mine workings; all of these factors led to the closure of the district (Biek and Rohrer, in preparation). Decline can also be attributed to the low price of silver on the international market. In 1877, silver was $1.20 per ounce and when mining ended in 1888, it was just $0.94 (Biek and Rohrer, in preparation). By 1903, Silver Reef was deserted.

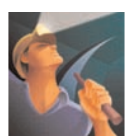
The Silver Reef district received renewed interest in the 1950s for its uranium potential. In 1950, Western Gold and Uranium Corporation shipped at least 2500 pounds of uranium oxide (Biek and Rohrer, in preparation). In 1979, 5M Corporation acquired the claims from the Western Gold and Uranium Corporation to process old mine tailings. This venture was short lived due to a decrease in silver prices. All that remains of the former town is a few old foundations and the Wells Fargo Building that is now a museum that documents the history of the mining district.

Geology: Sedimentary rocks in the Silver Reef mining district range in age from Late Triassic (215 million years old) to Early Tertiary (40 million years old). The ore bodies are restricted to the Springdale Sandstone Member of the Early Jurassic-age Moen-ave Formation deposited approximately 200 million years ago (Proctor and Brimhall, 1986). The Springdale Sandstone represents sediments found primarily in braided stream and minor floodplain environments. The ore bodies were tabular shaped, averaging 200 to 300 feet long and 100 to 150 feet wide (Biek and Rohrer, in preparation). Two ideas have been suggested for silver deposition in the sandstone: (1) a sedimentary origin where metals accumulated at the time of deposition or later through the interaction of ground water, and (2) an igneous origin where the metals derived from intrusions associated with the formation of the Pine Valley Mountains to the west. Current models support the sedimentary origin theory.

Malachite that has replaced fossilized plant material. U.S. quarter for scale.



Mineralogy: The primary silver-bearing mineral that constituted more than 90 percent of the ore is chlorargyrite. Other silver minerals include embolite, native silver, and argentite. Secondary copper minerals are azurite and malachite, which are present as coatings and replacements of fossilized plant material. Secondary uranium and vanadium minerals include carnotite, autunite, tobernite, roscoelite, volborthite, and montroseite. Associated minerals found with the ore are quartz, calcite, and hematite.



Current/Future Operations: Nearly all of the high-grade ore was mined out by the late 1800s. Mineral potential still exists, but the remaining deposits would likely be small or deeply buried. Recently, a Canadian company re-evaluated the district for its copper and silver potential and concluded that exploration results were not positive enough to warrant further exploration or mining. Even if new deposits are found, it is unlikely that major mining would resume in the district. Much of the area is now residential and any attempt to revive mining would have serious environmental and social concerns. Safety concerns coupled with the population explosion in Washington County have prompted reclamation on most of the district's mines.

Principal Uranium Districts

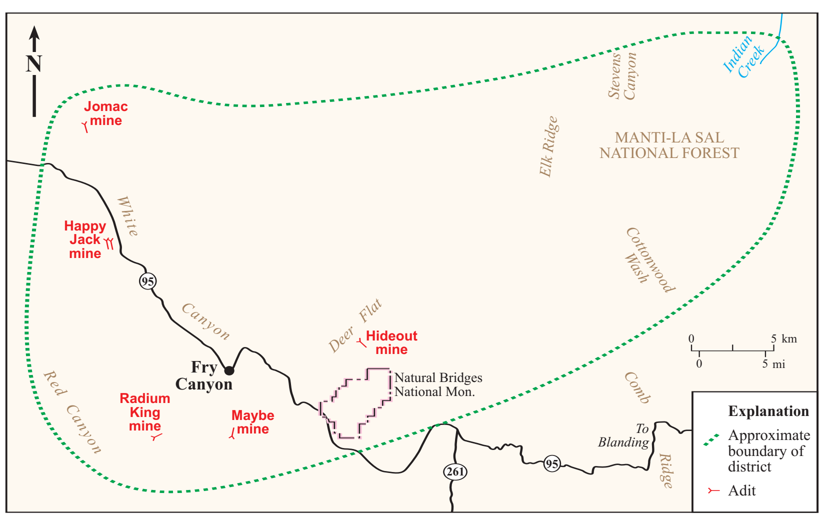
Ores containing uranium were first discovered in Utah around 1900. These deposits were first mined for their radium content. Radium was used primarily for medical purposes in the treatment of cancer. From 1910 to 1923, Utah produced between 12 and 15 grams of radium (one gram of radium is present in every 200 to 300 tons of uranium ore) (Chenoweth, 1990a). That amount may not seem like much, but during this period pure radium was worth between $70,000 and $180,000 per gram on the world market! By 1922, mines had closed due to foreign competition. In 1936, mines were reopened for their vanadium potential. Vanadium was used as a steel hardener in the manufacture of machinery before and during World War II. In 1948, the deposits were finally mined for their uranium content, when the U.S. Atomic Energy Commission created a guaranteed price schedule for uranium ore. This price guarantee led to the great uranium boom on the Colorado Plateau. From 1948 to 1989, the uranium deposits in Utah produced approximately 118 million pounds of uranium oxide (Chenoweth, 1990a), which was used in the development of nuclear weapons and atomic energy. The largest and most productive uranium districts in Utah are White Canyon and Lisbon Valley, and are discussed herein.

White Canyon Mining District

Aerial view of a uranium mine in the White Canyon mining district circa 1950s. Photo courtesy of the Utah State Historical Society.

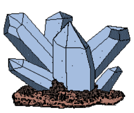
Location: The White Canyon mining district is in San Juan County, 20 to 50 miles west of Blanding, and can be accessed by Utah State Highway 95. The district is approximately 65 miles long and 10 miles wide (Chenoweth, 1993). It encompasses the following geographic areas: Red Canyon, Fry Canyon, White Canyon, Deer Flat, and Elk Ridge.

Production: The White Canyon district ranks second in overall uranium production in the state. From 1949 to 1982, 2.26 million tons of ore containing 11.1 million pounds of uranium oxide were produced from 125 mines (Chenoweth, 1993).

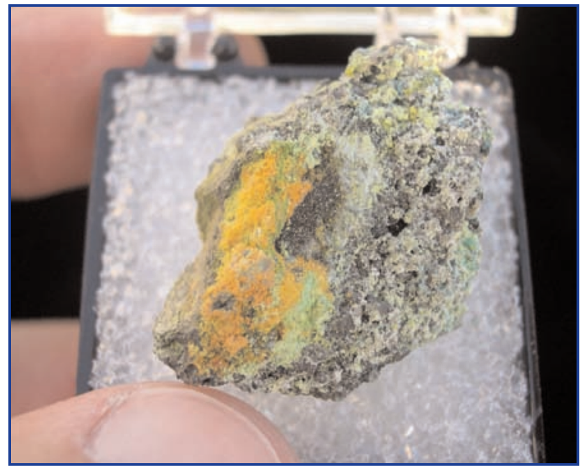


History: In the summer of 1893, John Wetherill (one of the discoverers of Mesa Verde National Park's Anasazi ruins) found yellow minerals around a fossilized tree stump in White Canyon. Bert Butler of the U.S. Geological Survey identified the minerals as sulfates of uranium (Chenoweth, 1993). However, the main commodity of interest at the time was copper, not uranium. The district was organized and began producing copper ore in 1906-07. When these ores were processed, it was discovered that they contained large amounts of vanadium and uranium. In the 1940s, the demand for vanadium caused a prospecting boom in the area. In the late 1940s, hundreds of uranium mining claims were staked including the Happy Jack mine. The Happy Jack mine quickly became the leading producer in the area and by the time of its closure in 1987 had produced more than 500,000 tons of ore. Nearly 30 percent of the total uranium produced from the district came from the Happy Jack mine. Other large producers of ore (>100,000 tons) included the Hideout, Maybe, and Radium King mines.

Geology: The ore bodies are in Triassic-age (230 to 208 million years old) river-channel deposits of the Shinarump Member of the Chinle Formation. After deposition, uranium-bearing ground water migrated through and along these channels. When this ground water encountered a reducing agent, such as carbonaceous plant material, uranium and other elements such as copper and vanadium were deposited. The ore bodies generally average 3.5 feet in thickness and are tabular with dimensions of 50 to 1,000 feet long by 10 to 500 feet wide.



Mineralogy: Ore consists of uraninite with associated copper sulfide minerals (chalcopyrite, bornite, chalcocite, and covellite) and the vanadium mineral montroseite. Secondary oxidized minerals include andersonite, uranophane, uranopilite, coffinite, meta-autunite, zippeite, azurite, and malachite. The copper-uranium minerals cuprosklodowskite, johannite, and metatorbernite have also been identified (Chenoweth, 1993). Associated minerals include quartz, hematite, gypsum, jarosite, and minor barite. Most of these minerals are found at the Happy Jack mine along with sphalerite and galena. The Jomac mine is where blatonite, a uranium carbonate, was first discovered and identified as a new mineral in 1997 (Haynes, 2000).



Johannite (green) and zippeite (orange-yellow) from the Happy Jack mine.

Current/Future Operations: Unmined uranium ore bodies still exist on several properties. Several mills that can process the ore are present in the area, including White Mesa to the east near Blanding, and Shootaring Canyon to the west in Garfield County, but they have been idle due to the weak market for uranium. No mining and milling of uranium ore is expected until the price of uranium or its by-product vanadium significantly increases.

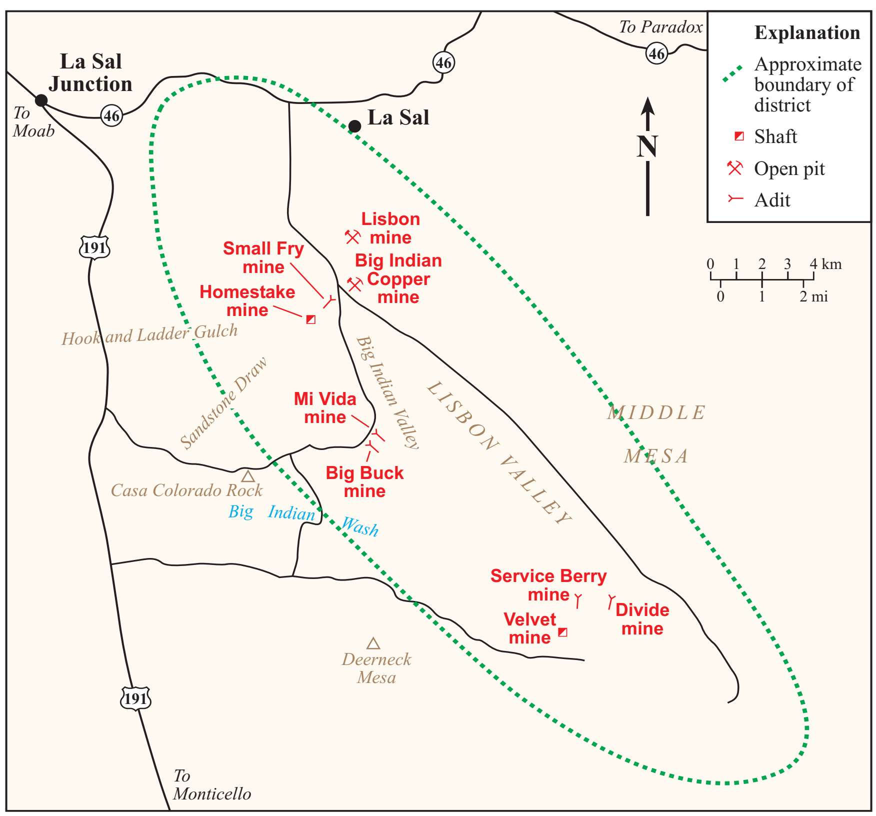
Lisbon Valley Mining District
(Originally known as the Big Indian Mining District)

Ore bins and hauling area for the Mi Vida mine, Lisbon Valley mining district.

Location: The Lisbon Valley mining district is 10 miles south of La Sal in San Juan County. Paved roads lead to the district from Utah State Highway 46 and U.S. Highway 191. Much of the district is on private land so landowner permission is necessary for access.

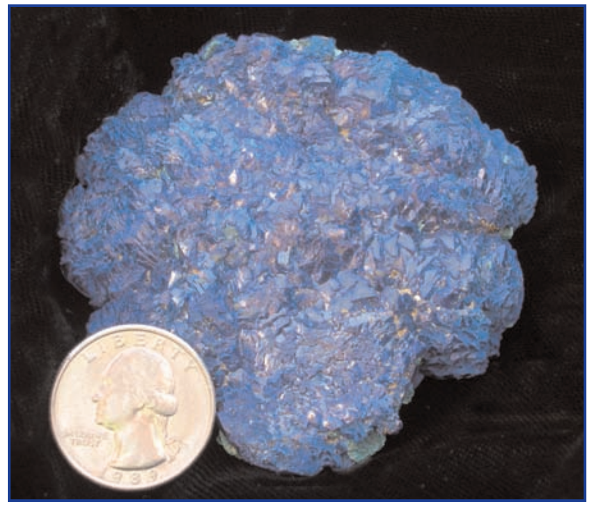
Production: The Lisbon Valley mining district produced more uranium ore than any other district in Utah. Overall production has been estimated at about 12.8 million tons of ore containing 39,000 tons of uranium oxide, also known as "yellow cake," mined from the spring of 1948 to October of 1988 (Chenoweth, 1990b).

History: The district was originally established as the Big Indian mining district in 1892 following the discovery of oxidized copper ore (Butler and others, 1920). Around 1903, copper ore was mined in Big Indian

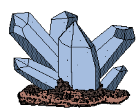


Valley. The district became inactive due to low copper prices, but was re-established as the Lisbon Valley district in 1913 when the first outcropping of uranium-vanadium ore was encountered in the area. The first recorded vanadium production came from the Divide and Service Berry mines in 1917. Copper ore was later mined by open-pit methods at the Big Indian Copper mine during World War II. In 1948, Dan Shays of Monticello, Utah found uranium-bearing exposures and located the Big Buck claims. All of these mines produced small-scale shipments of ore until Charlie Steen's discovery on July 6, 1952, when he located unoxidized uranium ore after drilling 70 feet into sandstone. This discovery was made without the aid of a Geiger counter, which detects the radioactivity of uranium. All discoveries prior to and after this discovery relied heavily on the aid of the Geiger counter. Charlie Steen's mine, called Mi Vida, produced a total of 6,150 tons of uranium until its closure in 1962. This mine became the largest producer of uranium in the district, yielding about 16 percent of the total production. Other mines in the district include the Homestake, Small Fry, Velvet, and Libson mines. Low uranium prices and a weak market in the early 1980s forced many of the mines to cease operations. In late 1988, mining operations in the district ceased with the closure of Rio Alsom's Lisbon mill, located south of La Sal.

Geology: Copper ore bodies are restricted to the Late Cretaceous (92 million years old) Dakota Sandstone as fault and fracture fillings, cavity fillings, and replacements of fossilized plant material (Hampson, 1993). Uranium ore bodies are mostly in Triassic-age (230 to 208 million years old) river-channel deposits of the Moss Back Member of the Chinle Formation. After deposition, these ancient river-channel deposits functioned as pathways for ground-water migration because of their high porosity. Dissolved uranium ions in the ground water were precipitated out of solution by a reducing agent. Carbonaceous material, such as plant fragments, is a particularly effective reducing agent. As a result, areas that originally contained abundant plant material formed large deposits of uranium ore. The uranium ore deposits form a mineralized belt 16 miles long and 1 mile wide on the southwestern flank of the Lisbon Valley anticline (Chenoweth, 1990b). Ore bodies average 6 feet thick and are tabular-like masses. Ore deposits are also found in Permian-age (290 to 245 million years old) rocks of the Cutler Group, close to overlying ore deposits of the Moss Back Member and near the Permian-Triassic age boundary.



Azurite from the Big Indian Copper mine.
U.S. quarter for scale.



Mineralogy: The principal uranium ore mineral is uraninite found in pore fillings or concentrated areas where it has replaced carbonaceous material. Vanadium minerals such as montroseite and doloresite are also present. Secondary oxidized minerals include metatyuyamunite, pascoite, and corvusite (Chenoweth, 1990b). At the Big Indian Copper mine, the most abundant minerals are azurite, malachite, cuprite, copper, and chalcocite.

Current/Future Operations: Little potential remains for new deposits to be found in the Moss Back Member, but considerable promise exists for new discoveries in the Cutler Group. Several mines in the Cutler Group, such as the Velvet mine, still contain considerable reserves of uranium ore. Until the demand for uranium increases and a mill is built, future mining remains unlikely.

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GLOSSARY

adit - a horizontal tunnel used to extract ore from an ore body.

anticline – a fold with the middle curved upward.

ash flow tuff – tuff deposited by an ash flow from a volcanic eruption.

assay – to test an ore sample for mineral composition.

breccia – rock composed of angular, broken-up rock fragments held together by natural mineral cement.

claim – a section of public land where an individual is granted mining rights.

fault – a break or fracture in the Earth's crust, along which one side has moved relative to the other.

fluorescence – the emission of light when a mineral is exposed to ultraviolet light.

fold – a curve or bend in the rock layers.

formation – a mappable body of rock distinguished by its physical characteristics and age (or stratigraphic position).

granite – an intrusive igneous rock, commonly pink or gray in color. Composed of quartz, feldspar, hornblende, and mica.

granodiorite – an intrusive igneous rock, similar to granite. Composed of quartz, plagioclase, and potassium feldspar, hornblende, and mica.

host rock – a body of rock containing mineral deposits or other rocks.

hydrothermal – generally referring to hot water that has circulated through hot rock or has originated from a cooling magma body.

igneous rocks – rocks that formed (solidified) by the cooling of molten material (magma or lava), including rocks that have solidified within the Earth (intrusive) and those that erupted onto the surface (extrusive).

intrusion – igneous process of injecting magma into pre-existing rock strata.

magma – molten liquid rock material created within the Earth that can form igneous rocks through intrusive or extrusive means.

member – a rock unit that is a specific part of a formation.

metamorphic rocks – rocks that form when existing rocks are buried in the Earth and encounter high temperatures and (or) pressures (such as quartzite, formed from sandstone).

mine – an excavation in the Earth for the sole purpose of extracting mineral resources.

mineral – a naturally occurring inorganic element or compound, generally solid and crystalline.

mining district - a group of mines that have been located and operated under specific regulations and guidelines created by the miners and mine operators.

monzonite – an intrusive igneous rock containing equal amounts of alkali feldspar and plagioclase, little or no quartz, and augite.

open pit mining – a form of mining, in which mineable ore is exposed by the removal of overburden or waste rock.

ore – metalliferous rock that is economical to mine.

ore body – a mass of ore of sufficient size and mineral content to be economically feasible to be mined.

ore reserves – the grade and total amount of ore that has been established by drilling or other means.

orogeny – a mountain-building event.

oxidized ore – ore material formed by the alteration of metallic minerals by weathering and the interaction of surface waters. Present at or near the surface, but can also be found at great depths.

phonolite – a fine-grained intrusive igneous rock composed of alkali feldspar.

placer mining – the extraction of heavy metals by using running water.

porphyry – an igneous rock that contains large crystals embedded in a fine-grained groundmass.

quartz latite porphyry – an intrusive igneous rock that contains quartz, plagioclase, and potassium feldspar.

quartz monzonite – an intrusive igneous rock, similar to granite but contains a different ratio of feldspar and quartz.

sedimentary rocks – rocks that form from sediment, such as sand, mud, or gravel, and then harden into rock.

shaft – a vertical excavation made primarily for mining ore bodies.

skarn - a type of mineral deposit where the mineral composition of the limestone or dolomite host rock is replaced by silicate minerals.

stock – an igneous intrusion that is less than 40 square miles in size.

reclamation – the act of cleaning up the land from previous mining activity.

replacement – a type of mineral deposit where the mineral composition of the original rock is replaced by an ore mineral.

rhyolite – an extrusive igneous rock that exhibits flow texture and consists of small crystals of quartz and alkali feldspar.

triboluminescence – the emission of light when a mineral is hit with another rock or other object.

vein – a type of mineral deposit created from the precipitation/crystallization of mineral-rich fluids in open fractures or fissures.

APPENDIX A
Descriptive List of Minerals

Adamite: $Zn_2(AsO_4)OH$
Occurs as individual crystals or rounded aggregates. Adamite is yellow, white, green, or violet in color and has a hardness of 3.5. Found at the Gold Hill mine, Gold Hill (Clifton) mining district and at the Centennial Eureka mine, Tintic mining district.

Andersonite: $Na_2Ca(UO_2)(CO_3)_3 \cdot 6H_2O$
Occurs as crystals up to 1 cm, clusters, or veins. Andersonite is bright yellow-green and has a hardness of 2.5. Under ultraviolet light, andersonite fluoresces a bright yellow-green. Found in various mines in the White Canyon mining district.

Anglesite: $PbSO_4$
Commonly found as crystals or gray masses that have replaced galena. Anglesite is colorless, white, or gray and has a hardness of 2.5-3. Found at the Eureka Hill mine, Tintic mining district.

Apophyllite: $KCa_4Si_8O_{20}(F,OH) \cdot 8H_2O$
Occurs as tabular or pyramidal crystals and in masses. Apophyllite is colorless, white, or greenish and has a hardness of 4.5-5. Found at the Bingham Canyon mine, Bingham (West Mountain) mining district.

Aragonite: $CaCO_3$
Occurs as elongated or needle-like crystals. Aragonite is colorless to white and has a hardness of 3.5-4. Found in many of the mining districts.

Argentite: Ag_2S
Found as cubic or octahedral crystals, coatings, or as masses. Argentite is black gray to steel gray and has a hardness of 2-2.5. Found in various mines in the Park City, Silver Reef, Big Cottonwood, Little Cottonwood, and San Francisco mining districts.

Argentojarosite: $Ag_2Fe_6(OH)_{12}(SO_4)_4$
Occurs as small, flattened hexagonal crystals, crusts, or masses. Argentojarosite is golden yellow to brown and has a hardness that has not been determined. First discovered at the Tintic Standard mine, Tintic mining district and later found in several mines in the Ophir mining district.

Arsenobismite: $Bi_2(AsO_4)(OH)_3$
Occurs as yellowish brown to yellowish green masses and has a undetermined hardness. First found and identified from the oxidized ore of the Mammoth mine, Tintic mining district.

Arsenopyrite: $AsFeS_2$
Commonly found as bladed radiating crystals that may have a garlic odor. It is silver gray and has a hardness of 5.5-6. Found at the U.S. and Gold Hill mines, Gold Hill (Clifton) mining district and in the Bingham (West Mountain) mining district.

Aurichalcite: $(Zn,Cu)_5(OH)_6(CO_3)_2$
A secondary zinc and copper mineral commonly found as small scales or tufts of needle-like crystals. Aurichalcite is pale greenish-blue or sky-blue and has a hardness of 1-2. Found at the Hidden Treasure and Ophir Hill Consolidated mines, Ophir mining district and the Carbonate mine in the Big Cottonwood mining district.

Austinite: $CaZn(AsO_4)(OH)$
Occurs as small crystals or fibrous clusters. Austinite is colorless, white, pale yellow, or bright green and has a hardness of 4-4.5. First found and identified at the Gold Hill mine, Gold Hill (Clifton) mining district.

Azurite: $Cu_3(CO_3)_2(OH)_2$
A secondary copper mineral found as well-developed crystals and as aggregates. It is blue and has a hardness of 3.5-4. Found in many of the mining districts.

Barite: $BaSO_4$
Occurs as curved blades or rose-like crystals. Barite is white, yellow, blue, brown or gray in color and has a hardness of 2.5-3.5. Found in many of the mining districts.

Beaverite: $Pb(Cu^{2+},Fe^{3+},Al)_6(SO_4)_4(OH)_{12}$
A secondary lead mineral found as crusts or masses. It is yellow and has a undetermined hardness. First found at the Horn Silver mine, San Francisco district. Also found in the Ophir and Little Cottonwood mining districts.

Bertrandite: $Be_4Al_2Si_6O_{18}$
Occurs as thin tabular crystals or as disseminated masses. It is colorless or pale yellow and has a hardness of 6-7. Found at the Brush Wellman property, Spor Mountain mining district in disseminated quantities in a volcanic tuff.

Beudantite: $PbFe_3(AsO_4)(SO)_4(OH)_6$
Occurs as small crystals and masses. It has a yellow to cinnamon-brown color and a hardness of 4. Found at the Gold Hill mine, Gold Hill (Clifton) mining district and the Centennial Eureka mine, Tintic mining district.

Billingsleyite: $Ag_7(As,Sb)S_6$
Occurs as small fine-grained masses. Billingsleyite has a lead-gray color and has a hardness of 2.5. First found and identified at the North Lily mine, Tintic mining district.

Bindhamite: $Pb_2Sb_2O_6(O,OH)$
Occurs as nodular masses or crusts. Bindhamite is yellow, brown, reddish brown, gray, or white and has a hardness of 4-4.5. Found in mines in the Park City mining district.

Biotite: $K(Mg,Fe)_3AlSi_3O_{10}(OH)_2$
Occurs as scales or rarely as crystals that are flexible. Biotite is yellowish to black and has a hardness of 2.5-3. Found in many of the mining districts.

Bismuth: Bi
Occurs as small grains or in foliated masses. Bismuth is silver white and has a hardness of 2-2.5. Found in the Gold Hill (Clifton), Bingham (West Mountain), Ophir, and Tintic mining districts.

Bismuthinite: Bi_2S_3
Occurs as masses or as fibrous acicular crystals. Bismuthinite is gray to white and has a hardness of 2. Found in the Gold Hill (Clifton), Tintic, and Little Cottonwood mining districts.

Bismutite: Bi_2O_3
Occurs as fibrous crystals or earthy masses. Bismutite is white, green, yellow, or gray and has a hardness of 4. Found in the Gold Hill (Clifton), Bingham (West Mountain), and Tintic mining districts.

Bixbyite: $(Mn,Fe)O_2$
Commonly found as well-developed cubic crystals. It is black and has a hardness of 6-6.5. Found at Topaz Mountain, east of the Spor Mountain mining district.

Blatonite: $UO_2CO_3{\bullet}H_2O$
Found as canary-yellow fibers and has a hardness of 2-3. First found and identified at the Jomac mine, White Canyon mining district.

Bornite: Cu_5FeS_4
Occurs in masses, crystals are rarely found. Bornite is reddish-bronze that tarnishes on exposure to iridescent purple and has a hardness of 3. Found in many of the mining districts.

Boulangerite: $Pb_5Sb_4S_{11}$
Occurs as long crystals or in fibrous masses. Boulangerite is lead gray to bluish gray in color and has a hardness of 2.5-3. Found in various mines of the Park City mining district.

Bournonite: $PbCuSb_3$
Occurs as wheel-shaped or cross-shaped crystals, but can also be massive. It is steel-gray and has a hardness of 2.5-3. Found in the Bingham (West Mountain) and Park City mining districts.

Calcite: $CaCO_3$
Generally found as nice crystals, but also can be massive. It is the main mineral found in most limestones. Calcite is generally white, but can also be colorless, brown, yellow, orange, red, black, gray to black, or blue and has a hardness of 3. Found in all of the mining districts.

Carminite: $PbFe_2(AsO_4)_2(OH)_2$
Occurs as microcrystals or clusters in scorodite-rich boulders. It is red and has a hardness of 2.5-3. Found at the Gold Hill mine, Gold Hill (Clifton) mining district and at the Centennial Eureka mine, Tintic mining district.

Carnotite: $K_2(UO_2)_2VO_4)_2 \bullet 3H_2O$
Found as powdery masses around petrified tree trunks in sandstones of the Colorado Plateau. Carnotite is bright yellow and has a hardness of 1-2. Found in the mines of the Silver Reef (Harrisburg) and White Canyon mining districts.

Cerussite: $PbCO_3$
A secondary lead mineral commonly found as crystals and masses coating galena. It is white or smoky gray and has a hardness of 3-3.5. Common mineral found in the Ophir, Tintic, Little Cottonwood, and Park City mining districts.

Cervantite: $Sb^{3+}Sb^{5+}O_4$
A yellow mineral often found as massive, fine-grained material and has a hardness of 4-5. Found in some of the mines in the Park City mining district.

Chalcanthite: $CuSO_4 \bullet 5H_2O$
Occurs as blue, fibrous hairs growing on the sides of mine tunnels. It is soluble in water and has a hardness of 2.5. Found at the Gold Hill (Clifton) and San Francisco mining districts.

Chalcedony: (see quartz)

Chalcocite: Cu_2S
Usually massive and crystals are very rare. It is has a lead gray color that tarnishes to a dull black and has a hardness of 2.5-3. Large quantities found at the Bingham Canyon mine, Bingham (West Mountain) mining district and lesser amounts in other mining districts.

Chalcophanite: $(Zn,Fe,Mn)Mn_3O_7 \bullet 3H_2O$
Occurs as small hexagonal plates and crystals. It is a shiny, black mineral and has a hardness of 2.5. Found at the Gold Hill mine, Gold Hill (Clifton) mining district.

Chalcopyrite: $CuFeS_2$
Usually massive and crystals are rare. It has a deep golden or yellow color, and has a hardness of 3.5-4. Primary copper ore found at the Bingham Canyon mine, Bingham (West Mountain) mining district. Lesser amounts found in other mining districts.

Chlorargyrite: $AgCl$
Usually found as masses, often as crusts or coatings. Chlorargyrite is colorless when freshly exposed, but tarnishes to violet-brown on exposure to light. It has a hardness of 2.5. Primary silver-bearing ore mineral mined at the Silver Reef (Harrisburg) mining district, also found in the Gold Hill (Clifton), Ophir, San Fransciso, and Tintic mining districts.

Chrysocolla: $CuSiO_3 \bullet 2H_2O$
A secondary copper mineral usually found as compact masses or crusts. It is a blue-green mineral that will stick to your tongue, and has a hardness of 2-4. Sometimes mistaken for turquoise because of its color. Found in many of the mining districts.

Cinnabar: HgS
Usually found as masses, crystals are rare. It has a bright scarlet-red color and has a hardness of 2-2.5. Cinnabar is the main ore of mercury. Found at the Mercur (Camp Floyd) mining district.

Clinoclase: $Cu_3(AsO_4(OH)_3$
Commonly found as clusters, bladed single crystals or as rounded aggregates. It is dark blue and has a hardness of 2.5-3. Found at the Gold Hill mine, Gold Hill (Clifton) district and various mines in the Tintic mining district.

Cobaltite: $CoAsS$
Found as cubic crystals that resemble pyrite or can be massive. Cobaltite is silver-white and has a hardness of 5.5. Found at the U.S. mine, Gold Hill (Clifton) mining district.

Coffinite: $U(SiO_4)_{1-x}(OH)_{4x}$
Found as aggregates and well-crystallized masses. Coffinite is black and has a hardness of 5-6.
Found in the White Canyon mining district.

Conichalcite: $CaCu^{2+}(AsO_4)(OH)$
Occurs as nice crystals or coatings on rock. Conichalcite is apple-green or emerald green in color and has a hardness of 4.5. Found at various mines in the Gold Hill (Clifton) and Tintic mining districts.

Connellite: $Cu_{19}Cl_4(SO_4)(OH)_{32}{\bullet}3H_2O$
Occurs as sprays of crystals or stout hexagonal prisms. Connellite is dark blue and has a hardness of 3. Found at the Gold Hill (Clifton) mining district and the Grand Central mine, Tintic mining district.

Copper: Cu
Occurs in branching forms, masses, or as crystals. Copper is copper-red on a fresh broken surface and quickly tarnishes to a brown color. It is a soft, malleable mineral and has a hardness of 2.5-3. Found at the Gold Hill mine in the Gold Hill (Clifton) mining district, Bingham Canyon mine in the Bingham (West Mountain) mining district, various mines in the Tintic mining district, and the Big Indian mine, Lisbon Valley mining district.

Cornwallite: $Cu_5(AsO_4)_2(OH)_4{\bullet}H_2O$
Found as crystalline aggregates and masses. Cornwallite is dark to emerald green and has a hardness of 4.5. Found at the Gold Hill mine, Gold Hill (Clifton) mining district and at the Centennial Eureka mine, Tintic mining district.

Corvusite: $(Na,Ca)(V^{5+},V^{4+},Fe^{2+})_8O_{20}{\bullet}4H_2O$
Occurs as massive material or as very small irregular flakes. Corvusite is brown, bluish black, or greenish black and has a hardness of 2.5-3. Found in the White Canyon and Lisbon Valley mining districts.

Covellite: CuS
Occurs as platy masses that split into thin flakes. It has a dark indigo blue color that is subject to tarnish, and has a hardness of 1.5-2. Found at the Barneys Canyon and Melco mines, Bingham (West Mountain) mining district and the Happy Jack mine, White Canyon mining district.

Crandallite: $CaAl_3(PO_4)_2(OH)_5{\bullet}H_2O$
Occurs as massive nodules or as tiny crystals. Crandallite is yellow to yellowish white in color and has a hardness of 5. First found and identified at the Brooklyn mine, Tintic mining district.

Cuprite: Cu_2O
Commonly occurs as massive aggregates or octahedral crystals. Cuprite is red of various shades or sometimes black and has a hardness of 3.5-4. Found in the Gold Hill (Clifton), Bingham (West Mountain), Tintic, San Francisco, and Lisbon Valley mining districts.

Cuprosklodowskite: $(H_3O)_2Cu^{2+}(UO_2)_2(SiO_4){\bullet}2H_2O$
Occurs as crystals up to 1 cm long or as coatings. Cuprosklodowskite is pale green to emerald green and has a hardness of 4. Found in various mines in the White Canyon mining district.

Diopside: $CaMgSi_2O_6$
Occurs as fibrous masses or as thin prismatic crystals. Diopside is pale green, blue, white, yellow, or black and has a hardness of 5-6. Present in many of the mining districts.

Dolomite: $CaMg(CO_3)_2$
Occurs as nice curved crystals and can also be massive. Dolomite can be brown, white, green, gray, black, or rose-red and has a hardness of 3.5-4. Present in many of the mining districts.

Doloresite: $H_8V_6^{4+}O_{16}$
Often found as massive material or as tiny crystals. Doloresite is dark brown or black and has a undetermined hardness. Found in various mines of the White Canyon and Lisbon Valley mining districts.

Embolite: $Ag(BrCl)$
Found as cubic crystals, massive aggregates, or as coatings. Embolite is gray or yellowish-gray and has a hardness of 2.5. Found in various mines of the Silver Reef (Harrisburg) mining district.

Enargite: Cu_3AsS_4
Commonly occurs as striated prismatic crystals or masses. It is black and has a hardness of 3. Found at the Bingham Canyon mine, Bingham (West Mountain) mining district and in various mines of the Tintic and Big Cottonwood mining districts.

Epidote: $Ca_2(Al,Fe)_3(SiO_4)_3(OH)$
Often found as short to long crystals or as massive material that is course or granular. Epidote is usually yellowish green to brownish green and has a hardness of 6-7. Found in the Ophir, Big Cottonwood, Little Cottonwood, and Iron Springs mining districts.

Erythrite: $Co_3(AsO_4)_2 \cdot 8H_2O$
Occurs as small, delicate tufts or prismatic crystals. Erythrite is pink and has a hardness of 1.5-2.5. Found at the U.S. mine, Gold Hill (Clifton) mining district.

Fangite: Tl_3AsS_4
Occurs as crystals with flat surfaces in vugs. Fangite exhibits a deep red to maroon color and has a hardness of 2-2.5. First found and identified at the Barrick Mercur gold mine, Mercur (Camp Floyd) mining district.

Faustite: $(Zn,Cu)Al_6(PO_4)_4(OH)_8 \cdot 4H_2O$
Occurs as massive or compact masses. It is apple green and has a hardness of 5.5. Found at the Bingham Canyon mine, Bingham (West Mountain) mining district.

Fluorapatite: $Ca_5(PO_4)_3F$
Commonly found as well-developed six-sided crystals or as small grains. Fluorapatite is yellow-green and has a hardness of 5. Found in the iron mines of the Iron Springs mining district.

Fluorite: CaF_2
Commonly found in cubes, but also found in masses. It is found in many colors, including purple, yellow, light green, pink, white, or colorless and has a hardness of 4. Primary ore found at the Spor Mountain mining district (in masses) and a common mineral occurring in most mining districts.

Frankhawthorneite: $Cu_2{}^{2+}Te^{6+}O_4)(OH)_2$
Occurs as isolated crystals or as elongated crystals in groups found in quartz-lined vugs. Frankhawthorneite is leaf green in color and has a hardness of 3-4. First found and identified at the Centennial Eureka mine, Tintic mining district.

Galena: PbS
Commonly occurs as cubic crystals and also in masses. It is a lead-gray mineral that has a hardness of 2.5. Found in many of the mining districts.

Garnet (almandine): $Fe_3Al_2(SiO_4)_3$
Occurs as nice dodecahedral or trapezohedral crystals, sometimes can also be massive. Almandine is deep red to brownish red and has a hardness of 7-7.5. Found in the rhyolite at Topaz Mountain, east of the Spor Mountain mining district.

Garnet (grossularite): $Ca_3Al_3(SiO_4)_3$
Occurs as nice dodecahedral or trapezohedral crystals, sometimes can also be massive. Grossularite is light green to green and has a hardness of 7-7.5. Found in the Gold Hill (Clifton) and San Francisco mining districts.

Gillulyite: $Tl_2(As,Sb)_8S_{13}$
Occurs as small slender crystals found in masses of barite and in barite or calcite veins. Gillulyite has a deep-red color and has a hardness of 2-2.5. First found and identified at the Barrick Mercur gold mine, Mercur (Camp Floyd) mining district.

Goethite: $FeO(OH)$
Occurs as prisms often striated, also as scales or masses. Goethite has a yellowish, reddish, or brown color and has a hardness of 5-5.5. Found in many of the mining districts.

Gold: Au
Usually occurs as irregular masses, branches, or as crystals. Gold has a bright golden-yellow color and has a hardness of 2.5-3. It is a soft, malleable metal that is commonly mistaken for pyrite and chalcopyrite. Gold was the primary precious metal recovered from the Barneys Canyon and Melco mines, Bingham (West Mountain) mining district and the Barrick Mercur mine in the Mercur (Camp Floyd) mining district. Found in limited quantities in many of the other districts.

Gypsum: $CaSO_4 \cdot 2H_2O$
Commonly found as large masses or elongated crystals. Gypsum is colorless, white, gray, yellowish or brownish and has a hardness of 2. Found at all of the mining districts.

Halloysite: $Al_2Si_2O_5(OH)_4$
Found as masses and tends to be greasy to the touch. Halloysite is generally white and has a hardness of 2-2.5. Found at the Dragon mine, Tintic mining district.

Hematite: Fe_2O_3
Commonly found as thin tabular crystals or in masses resembling a bunch of grapes. Hematite is steel-gray to iron black and has a hardness of 5-6. Found in many of the mining districts.

Hemimorphite: $Zn_4Si_2O_7(OH)_2 \cdot H_2O$
Commonly occurs as crystals or aggregates. Hemimorphite is white, green, blue or brown and has a hardness of 6.5. Found in many of the mining districts.

Hydrozincite: $Zn_5(CO_3)_2(OH)_6$
Found as crusts or massive aggregates. Hydrozincite is white or gray in color and has a hardness of 2-2.5. Sometimes fluoresces blue under ultraviolet light. Found in various mines of the Ophir mining district.

Jamesonite: $Pb_4FeSb_6S_{14}$
Commonly occurs as hair-like crystals or fibrous masses. Jamesonite is a dark gray mineral and has a hardness of 2.5. Found in the Park City mining district.

Jarosite: $KFe_3(SO_4)_2(OH)_6$
Found as small tabular crystals, rounded aggregates, or crusts. Jarosite is yellow to yellowish brown in color and has a hardness of 2.5-3.5. Present in many of the mining districts.

Jensonite: $Cu_3Te^{6+}O_6 \cdot 2H_2O$
Occurs as single crystals or groups of crystals with quartz. Jensonite is emerald green and has a hardness of 3-4. First found and identified at the Centennial Eureka mine, Tintic mining district.

Johannite: $Cu(UO_2)_2(SO_4)_2(OH)_2 \cdot 8H_2O$
Occurs as tabular crystals, aggregates, or coatings. Johannite is emerald-green to greenish yellow and has a hardness of 2-2.5. Found at the Happy Jack mine, White Canyon mining district.

Juabite: $Cu_5(Te^{6+}O_4)_2(As^{5+}O_4)_2 \cdot 3H_2O$
Occurs as isolated or groups of elongated crystals on quartz. Juabite is emerald green and has a hardness of 3-4. First found and identified at the Centennial Eureka mine, Tintic mining district.

Juanitaite: $(Cu,Ca,Fe)_{10}Bi(AsO_4)_4(OH)_{10} \cdot 2H_2O$
Occurs as square plates or as crystallized aggregates. Juanitaite is olive-green to grass green and has a hardness of 1. First found and identified at the Gold Hill mine, Gold Hill (Clifton) mining district.

Leisingite: $Cu(Mg,Cu,Fe,Zn)_2Te^{6+}O_6 \cdot 6H_2O$
Occurs as hexagonal thin plates or as masses on quartz. Leisingite is pale yellow to pale orange-yellow and has a hardness of 3-4. First found and identified at the Centennial Eureka mine, Tintic mining district.

Linarite: $PbCu(SO_4)(OH)_2$
Occurs as deep-blue elongated crystals and is often misidentified as azurite by its color. Linarite has a hardness of 2.5 and a high specific gravity. Found in the Hidden Treasure mine, Ophir mining district, and mines in the Tintic mining district.

Ludwigite: $Mg_2Fe^{3+}BO_5$
A rare mineral found in radiating, fibrous masses. Ludwigite is blackish-green to black in color and has a hardness of 5. Found at the Big Cottonwood mine, Big Cottonwood mining district.

Magnetite: Fe_3O_4
Commonly occurs in massive form or as large octahedral crystals. Magnetite is black, strongly magnetic, and has a hardness of 6. Magnetite is the primary iron ore that was mined in the Iron Springs mining district. Also found in other mining districts.

Malachite: $Cu_2(CO_3)(OH)_2$
A secondary copper mineral, commonly found as small radiating crystals or aggregates resembling a bunch of grapes. It is pale green and has a hardness of 3.5-4. Found in many of the mining districts.

Mallardite: $MnSO_4 \bullet 7H_2O$
Occurs as masses or crusts. Mallardite is light pink and has a hardness of 2. First found and identified at the Lucky Boy mine, Bingham Canyon (West Mountain) mining district.

Marcasite: FeS_2
Found as crystals having a cockscomb structure or radiating masses. It is whiter than pyrite on a fresh broken surface and has a hardness of 6-6.5. Found in the Bingham (West Mountain) and other mining districts.

Mcalpineite: $Cu_3TeO_6 \bullet H_2O$
Occurs as coatings or nodules lining quartz vugs. Mcalpineite is olive-green to dark green to black and has a hardness that has not been determined. Found at the Centennial Eureka mine, Main Tintic mining district.

Melanterite: $Fe^{2+}SO_4 \bullet 7H_2O$
Commonly occurs as green masses, sometimes as stalactites. It is soluble in water, has a bitter taste, and a hardness of 2. Found at the Gold Hill mine, Gold Hill (Clifton) mining district, Ophir Hill Consolidated mine, Ophir mining district, and in the Bingham (West Mountain) district.

Meta-autunite: $Ca(UO_2)_2(PO_4)_2 \bullet 2\text{-}6H_2O$
A dehydrated form of autunite. Meta-autunite is lemon yellow to greenish yellow and has a hardness of 2-2.5. Found in various mines in the White Canyon mining district.

Metatorbernite: $Cu^{2+}(UO_2)_2(PO_4)_2 \bullet 8H_2O$
Occurs as thin tablets or aggregates. Metatorbernite is pale green to dark green and has a hardness of 2.5. Found at various mines in the White Canyon mining district.

Metatyuyamunite: $Ca(UO_2)_2V_2^{5+}O_8 \bullet 3H_2O$
Occurs as small crystalline masses and as thin coatings. It is canary yellow to greenish yellow when freshly broken, but changes to dark green or yellow green on exposure. Metatyuyamunite has a hardness of 2. Found in various mines of the Lisbon Valley mining district.

Mimetite: $Pb_5(AsO_4)_3Cl$
Occurs as barrel-shaped crystals, also sometimes rounded or globular in nature. Mimetite is colorless, white, pale yellow, or orange and has a hardness of 3.5. Found in the Ophir and Tintic mining districts.

Mixite: $Cu_6Bi(AsO_4)_3(OH)_6 \bullet 3H_2O$
Mixite is found as small tufts or clusters. It is bluish-green to green in color and has a hardness of 3-4. Found at the Gold Hill mine, Gold Hill (Clifton) mining district and the Northern Spy mine, Tintic mining district.

Molybdenite: MoS_2
Commonly found as foliated masses or scales that have a greasy feel. It is bluish-gray and has a hardness of 1-1.5. Found at the Bingham Canyon mine in the Bingham (West Mountain) mining district, and several mines in the Little Cottonwood district.

Montroseite: $(V^{3+}, Fe^{3+}O)(OH)$
Occurs as very small black crystals and has an undetermined hardness. Found in various mines in the Silver Reef (Harrisburg), White Canyon, and Lisbon Valley mining districts.

Olivenite: $Cu_2^{2+}(AsO_4)(OH)$
Commonly found as well-developed prismatic crystals or is fibrous. It is olive-green, pistachio green, and blackish green and has a hardness of 3. Found in various mines in the Gold Hill (Clifton) and Tintic mining districts.

Orpiment: As_2S_3
Occurs in foliated masses that can be split into thin flakes. It has a lemon yellow color and a hardness of 1.5-2. Found at the Barneys Canyon and Melco mines, Bingham (West Mountain) mining district and the Mercur (Camp Floyd) mining district.

Palladium: Pd
Occurs as small grains, sometimes as crystals in the shape of octahedrons. Palladium is whitish steel-gray and has a hardness of 4.5-5. Found at the Bingham Canyon mine in the Bingham (West Mountain) mining district.

Pascoite: $Ca_3V_{10}^{5+}O_{28}\cdot 17H_2O$
Commonly occurs as yellowish orange to reddish orange granular crusts on sandstone. Pascoite is soluble in water and has a hardness of 2.5. Found in the White Canyon and Lisbon Valley mining districts.

Pharmacosiderite: $(Na,K,Ba)Fe_4(AsO_4)_3(OH)_4\cdot 7H_2O$
Occurs as micro-cubic or tetrahedral crystals. Pharmacosiderite is olive, emerald-green, honey yellow, dull orange mineral and has a hardness of 2.5. Found at the Gold Hill mine, Gold Hill (Clifton) mining district.

Philipsburgite: $(Cu,Zn)_6(AsO_4)_2(OH)_6\cdot H_2O$
Occurs as microrosettes or blades associated with olivenite and mixite. Philipsburgite is emerald-green and has a hardness of 3-4. Found at the Gold Hill mine, Gold Hill (Clifton) mining district and the Centennial Eureka mine, Tintic mining district.

Plagioclase: $NaAlSi_3O_8$ – $CaAl_2Si_2O_8$
Occurs as tabular crystals or as large masses. Plagioclase is gray, white, or colorless and has a hardness of 6.0-6.5. Found in many of the mining districts.

Platinum: Pt
Occurs as small grains, thin scales, or crystals (rare). Platinum is whitish steel-gray and has a hardness of 4-4.5. Found at the Bingham Canyon mine in the Bingham (West Mountain) mining district.

Plattnerite: PbO_2
Occurs as small crystals or is massive. Plattnerite is iron-black and has a hardness of 5-5.5. Found at the Hidden Treasure mine, Ophir mining district.

Plumbojarosite: $PbFe_6(OH)_{12}(SO)_4$
Occurs as small tabular crystals or irregular masses. Plumbojarosite is dark to cinnamon brown and has a hardness that is undetermined. Found in many of the mining districts.

Powellite: $Ca(Mo,W)O_4$
Occurs as massive material, sometimes as small pyramid-shaped crystals. Powellite is yellow, brown, gray, or greenish and has a hardness of 3.5-4. Fluoresces light blue under long-wave ultraviolet light. Found at the Yellow Hammer mine, Gold Hill (Clifton) mining district.

Pseudobrookite: $(Fe^{3+},Fe^{2+})_2(Ti,Fe^{3+})O_5$
Found as tiny elongated crystals that are striated vertically. Pseudobrookite has a black to dark brown and has a hardness of 6. Found at Topaz Mountain east of the Spor Mountain mining district.

Pyrargyrite: Ag_3SbS_3
Commonly found as nice crystals or massive material. Pyrargyrite is a black to grayish black mineral and has a hardness of 2.5. Found in minor amounts in the Bingham (West Mountain) mining district.

Pyrite: FeS_2
Often found as striated cubes, but can also be massive. Pyrite is a brass-yellow mineral that may tarnish to a black color and has a hardness of 6-6.5. Occurs in many of the mining districts. Pyrite cubes up to 1.5 cm with galena and sphalerite occur in many of the mines in the Park City mining district.

Pyrolusite: MnO_2
Commonly massive or concretionary forms, but can also occur as rare crystals. Pyrolusite is steel-gray to iron-gray and has a hardness of 6-6.5. Found in many of the mining districts.

Pyromorphite: $Pb_5(PO_4)_3Cl$
Often found as barrel-shaped crystals, can also be fibrous or granular. Pyromorphite is a lime green, yellow, brown, or grayish white mineral and has a hardness of 3.5-4. Found in the Big Cottonwood and American Fork mining districts.

Pyrrhotite: $Fe_{1-x}S$
Commonly found as massive aggregates, crystals are rare. Pyrrhotite is bronze yellow and has a hardness of 4. Found at the U.S. mine, Gold Hill (Clifton) mining district and Ophir Hill Consolidated mine, Ophir mining district.

Quartz: SiO_2
Occurs as well-formed hexagonal crystals, irregular masses, or in microcrystalline forms (chalcedony, jasper, flint, or agate). Quartz can be found in a variety of colors and has a hardness of 7. Present in all of the mining districts.

Realgar: AsS
Occurs as granular masses or more rarely as crystals. The distinct orange-red color will quickly alter to orpiment if exposed to light. Realgar also has a hardness of 1.5-2. Found at the Barneys Canyon and Melco mines, Bingham (West Mountain) mining district and the Mercur (Camp Floyd) mining district.

Red beryl: $Be_3Al_2(SiO_3)_6$
Occurs as small hexagonal prisms with flat terminations. Red beryl is pinkish to red in color and has a hardness of 7.5-8. Found at Topaz Mountain east of the Spor Mountain mining district.

Rhodochrosite: $MnCO_3$
Found as nice crystals or in globular masses. Rhodochrosite is pale pink to red and has a hardness of 3.5-4. Found in small quantities in many of the mining districts.

Rosasite: $(Cu,Zn)_2CO_3(OH)_2$
Occurs as small round balls having a fibrous structure. Rosasite is bluish green to green or blue and has a hardness of 4.5. Found at the Hidden Treasure mine, Ophir mining district and in several mines in the Tintic mining district.

Roscoelite: $K(V,Al,Mg)_3(Al,Si_3)O_{10}(OH)_2$
Commonly occurs as small scales. Roscoelite is greenish brown and has a hardness of 2.5. Found in various mines of the Silver Reef (Harrisburg) mining district.

Scheelite: $CaWO_4$
Occurs as sharp, well-developed crystals or irregular masses. Scheelite can be colorless, white, gray, yellow, or red and has a hardness of 4.5-5. Fluoresces yellow under long-wave ultraviolet light. Found in the Ophir and Little Cottonwood mining districts.

Scorodite: $FeAsO_4 \cdot 2H_2O$
Occurs as sharp, well-developed crystals or in large masses. It has a blue to bluish-green color and has a hardness of 3.5-4. Found at the Gold Hill (Clifton), Tintic, and San Francisco mining districts.

Siderite: $FeCO_3$
Commonly occurs as curved, rhombohedral crystals. It is reddish-brown, brown, or tan and has a hardness of 4. Common mineral found in the iron mines of the Iron Springs mining district and other mining districts.

Silver (native): Ag
Found as branching aggregates, masses, scales, or as crystals. It is bright silver-white on fresh broken surfaces and tarnishes to brown or black. Silver is a soft, malleable mineral and has a hardness of 2.5-3. Found at the Chief No. 1 mine, Tintic mining district. Many of the mining districts contained mines that recovered ore rich in silver.

Smithsonite: $ZnCO_3$
Commonly found as masses or aggregates that resemble a bunch of grapes. It is white, gray-white, pale brown,

green to blue-green, yellow or pink and has a hardness of 4-4.5. Found in many of the mining districts.

Sodium pharmacosiderite: $NaFe_4(AsO_4)_3(OH)_4 \bullet 7H_2O$
Generally occurs as very small cubic crystals, also can be granular. It is dull orange and has a hardness of 2.5. Found at the Gold Hill mine, Gold Hill (Clifton) mining district.

Sphalerite: ZnS
Commonly found as groups of rounded crystals and in masses. It is amber yellow to reddish brown to black, red, green, and colorless and has a hardness of 3.5-4. Found at the Horn Silver and King David mines, San Francisco mining district. Found in other mining districts in lesser amounts.

Stibiconite: $Sb_3O_6(OH)$
Occurs as massive material or crusts. Stibiconite is chalky white to pale yellow, but can be orange, brown, gray, or black. It has a hardness of 3-7. Found at the Park City and Mercur (Camp Floyd) mining districts.

Stibnite: Sb_2S_3
Occurs as massive material or slender crystals that are striated and twisted. Stibnite is light gray to dark gray in color and has a hardness of 2. Found at the Silver King mine in the Park City mining district, U.S. mine in the Gold Hill (Clifton) mining district, various mines in the Mercur (Camp Floyd) mining district, and Horn Silver mine in the San Francisco mining district.

Stolzite: $PbWO_4$
Occurs as pyramidal crystals. Stolzite is a green, brown, or gray mineral and has a hardness of 3. Found in the Big Cottonwood, Little Cottonwood, and American Fork mining districts.

Tennantite: $(Cu,Ag,Fe,Zn)_{12}As_4S_3$
Commonly found in masses or as tetrahedral crystals. Tennantite is steel-gray to iron black and has a hardness of 3-4.5. Found as massive material in quartz at the Gold Hill mine, Gold Hill (Clifton) mining district. Also found at the Ophir Hill Consolidated mine, Ophir mining district.

Tenorite: CuO
Commonly found as black scales with a metallic luster. Tenorite has a hardness of 3-4 and is usually associated with chrysocolla, malachite, and cuprite. Present in many of the mining districts.

Tetrahedrite: $(Cu,Fe,Ag,Zn)_{12}Sb_4S_{13}$
Commonly occurs as masses, but crystals up to 1 to 3 cm in length have been found. It is generally dark gray to iron-black and has a hardness of 3-4.5. Found at the Tintic Standard mine, Tintic mining district and the Daly-Judge mine, Park City mining district. Found in other mining districts in lesser amounts.

Tinticite: $Fe_4(PO_4)_3(OH)_3 \bullet 5H_2O$
Occurs as a dense earthy mass that is white with a yellow-green tint. Tinticite has a hardness of approximately 2.5. First found and identified in a limestone cavern near the Tintic Standard mine, Tintic mining district.

Tooeleite: $Fe_8(AsO_4)_6(OH)_6 \bullet 5H_2O$
Occurs as coatings or crystal aggregates. Tooeleite is brown orange to cadmium orange and has a hardness of 3. First found and described from the dumps of the U.S. mine, Gold Hill (Clifton) mining district.

Topaz: $Al_2(SiO_4)(F,OH)_2$
Occurs as nice single crystals or clusters. Topaz can be white, light blue, light green, yellow, pink, red, or yellow brown, and has a hardness of 8. Found at Topaz Mountain east of the Spor Mountain mining district.

Torbernite: $Cu(UO_2)_2(PO_4)_2 \bullet 8\text{-}12H_2O$
Commonly found as scaly flakes or aggregates emerald-green in color. Torbernite is radioactive and has a hardness of 2-2.5. Found in the Silver Reef (Harrisburg) and White Canyon mining districts.

Tourmaline (schorl): $NaFe_3^{2+}Al_6(BO_3)_3Si_6O_{18}(OH)_4$
Occurs as radiating groups of crystals. Schorl is black or brownish black and has a hardness of 7. Found throughout the Gold Hill (Clifton) mining district and at the Cactus mine, San Francisco mining district.

Tungstenite: WS_2
Massive with a scaly or feathery appearance. It is lead gray in color and had a hardness of 2.5. Tungstenite was

first found and identified at the Emma mine, Little Cottonwood mining district.

Turquoise: $Cu^{2+}Al_6(PO_4)_4(OH)_8 \cdot 4H_2O$
A secondary phosphate mineral commonly found as masses or veins. It is sky-blue, light green, or blue-green in color and has a hardness of 5-6. Found at the Bingham Canyon mine, Bingham (West Mountain) mining district.

Tyrolite: $CaCu_5^{2+}(AsO_4)_2(CO_3)(OH)_4 \cdot 6H_2O$
Occurs as flattened scales, crusts, or rarely as crystals. Tyrolite is greenish blue to sky blue in color and has a hardness of 2. Found in various mines of the Gold Hill (Clifton) and Tintic mining districts.

Uraninite: UO_2
Commonly occurs as massive material that has a high specific gravity. It is black, radioactive, and has a hardness of 5-6. Found in the White Canyon and Lisbon Valley mining districts.

Uranophane: $Ca(UO_2)_2(SiO_3(OH))_2 \cdot 5H_2O$
Commonly occurs as hair-like crystals up to 8 mm long, crusts, or massive material. Uranophane is pale yellow, yellowish green, or yellowish orange in color and has a hardness of 2.5. Found at the Yellow Chief mine, Spor Mountain mining district and in various mines in the White Canyon district.

Uranopilite: $(UO_2)_6(SO_4)(OH)_{10} \cdot 12H_2O$
Occurs as crusts, aggregates, or crystals. Uranopilite is bright lemon yellow to straw yellow in color and has a hardness that has not yet been determined. Found in various mines of the White Canyon mining district.

Utahite: $Cu_5Zn_3(Te^{6+}O_4)_4(OH)_8 \cdot 7H_2O$
Occurs as isolated or groups of crystals with quartz. Utahite is pale blue in individual crystals or blue-green in aggregates and has a hardness of 4-5. First found and identified at the Centennial Eureka mine, Tintic mining district.

Vivianite: $Fe_3(PO_4)_2 \cdot 8H_2O$
Occurs as small bladed crystals, crusts, or is fibrous. It is colorless when freshly exposed and becomes dark blue on exposure to light. Vivianite has a hardness of 1.5-2. Found at the Bingham Canyon mine, Bingham (West Mountain) mining district.

Volborthite: $Cu_3(VO_4)_2 \cdot 3H_2O$
Found as scaly crusts or in masses. Volborthite is olive green, yellowish green, or yellow and has a hardness of 3.5. Found at various mines of the Silver Reef (Harrisburg) mining district.

Wavellite: $Al_3(OH)_3(PO_4)_2 \cdot 5H_2O$
Wavellite is commonly found as rounded aggregates. It is white, green, brown or black and has a hardness of 3.5-4. Found at the Bingham Canyon mine, Bingham (West Mountain) mining district.

Weeksite: $K_2(UO_2)_2(SiO_5)_3 \cdot 4H_2O$
A yellow mineral found in fibrous clusters in opal veins and replacements in conglomerate and has a hardness of less than 1. Found at the Yellow Chief mine, Spor Mountain mining district.

Wollastonite: $CaSiO_3$
Commonly found as tabular crystals that tend to be fibrous when cleaved. It is white, gray, brown or yellow and has a hardness 4.5-5. Found at various mines in the Gold Hill and San Francisco mining districts.

Wulfenite: $PbMoO_4$
Occurs as square, thin tabular crystals and also as massive material. Its color is highly variable from yellow to orange, brown, or green, and has a hardness of 3. Found in various mines of the Little Cottonwood mining district and at the Horn Silver mine, San Francisco mining district.

Wurtzite: (Zn,Fe)S
Occurs as crystals, crusts, or is massive. Wurtzite is brownish black to orange-brown in color and has a hardness of 3.5-4. Fluoresces orange under long-wave ultraviolet light. Found in the Horn Silver and King David mines, San Francisco mining district.

Zippeite: $K_4(UO_2)_6(SO_4)_3(OH)_{10} \cdot 4H_2O$
Occurs as crusts and in small aggregates. Zippeite is orange-yellow in color and has a hardness of 2. Fluoresces lemon-yellow to green under ultraviolet light. Found in the Happy Jack mine, White Canyon mining district.

APPENDIX B

Generalized Geologic Time Scale showing Significant Geologic Events

Era	Millions of years ago	Period	Significant Geologic Events
Cenozoic	1.8	Quaternary	• Lake Bonneville • Erosion exposing mineral deposits
	65	Tertiary	• Basin and Range faulting • Volcanic activity • Precious metals emplaced from numerous igneous intrusions throughout the state • End of Sevier orogeny
Mesozoic	144	Cretaceous	• Terrestrial sedimentation • Eastern half of Utah covered by inland sea
	206	Jurassic	• Start of Sevier orogeny • Precious metals emplaced from igneous intrusions
	248	Triassic	• River deposits host the important uranium deposits in southern Utah • Shallow seas retreat
Paleozoic	290	Permian	• Warm shallow seas covered western half of Utah and deposited numerous layers of marine sediment • Many of these marine rocks become host units for Utah's mineral deposits (especially limestone rock units of Permian, Pennsylvanian, Mississippian, Pennsylvanian, Mississippian, and Cambrian age)
	323	Pennsylvanian	
	354	Mississippian	
	417	Devonian	
	443	Silurian	
	490	Ordovician	
	543	Cambrian	
	Precambrian		• Igneous events • Metamorphism

APPENDIX C

Mineral Resources of the Selected Mining Districts

COMMODITY	USES	MINING DISTRICT AND OCCURRENCE	ORE MINERAL	ASSOCIATED METALS
ANTIMONY	Alloys, ceramics,plastics, batteries, tracer bullets, and glass	Mercur (Camp Floyd) - replacement/disseminated Little Cottonwood - replacement Big Cottonwood - replacement Park City - replacement	Stibnite, tetrahedrite, stibiconite, pyrargyrite, and jamesonite.	Copper, gold, lead, silver, and zinc.
ARSENIC	Pesticides, herbicides, and wood preservatives.	Gold Hill (Clifton) - skarn/replacement Bingham (West Mountain) - by-product Tintic - replacement	Arsenopyrite, enargite, orpiment, realgar, and scorodite.	Copper, silver, gold, lead, and zinc.
BERYLLIUM	Electrical components, satellite navigation systems, and fluorescent lights.	Gold Hill (Clifton) - vein Spor Mountain - replacement	Bertrandite	Fluorspar and manganese.
BISMUTH	Ceramics, chemicals, paints medicine, cosmetics, peptobismol, and fire extinguishing systems.	Gold Hill (Clifton) - replacement Bingham (West Mountain) - by-product Little Cottonwood - replacement Tintic - replacement	Bismuth, bismutite, and bismuthinite.	Copper, gold, lead, silver, and zinc.
COBALT	Steel alloys, paint pigment, magnets, and gas turbine engines.	Gold Hill (Clifton) - replacement	Cobaltite and erythrite.	Silver and arsenic.
COPPER	Alloys, coinage, construction, electrical products, plumbing, automobiles, wood preservatives, the base metal in brass and bronze.	Gold Hill (Clifton) - replacement/skarn Bingham (West Mountain) - disseminated/replacement/skarn Ophir - replacement/vein Tintic - replacement/vein Big Cottonwood - replacement/skarn Little Cottonwood - replacement/vein American Fork - vein Park City - replacement/vein San Francisco - replacement/skarn/breccia Silver Reef (Harrisburg) - replacement White Canyon - replacement Lisbon Valley - replacement	Copper, enargite, tetrahedrite, chalcopyrite, bornite, malachite, azurite, covellite, chalcocite, cuprite, and tennantite.	Bismuth, gold, iron, lead, molybdenum, silver, and zinc.
FLUORSPAR	Toothpaste, paint pigments, hydrofluoric acid, and making steel.	Spor Mountain - replacement	Fluorite	Uranium
GOLD	Coinage, dentistry, jewelry, electronics, telecommunications, airbags, spacecraft equipment, lasers optics, car engines, and ornamental uses.	Gold Hill (Clifton) - replacement/vein Bingham (West Mountain) - placer/disseminated/skarn Ophir - replacement/vein Mercur (Camp Floyd) - disseminated Tintic - replacement/vein Big Cottonwood - replacement	Gold and tellurides.	Bismuth, copper, lead, molybdenum, silver, and zinc.

Appendix C (continued)

COMMODITY	USES	MINING DISTRICT AND OCCURRENCE	ORE MINERAL	ASSOCIATED METALS
GOLD (continued)		Little Cottonwood - replacement American Fork - replacement Park City - replacement/vein San Francisco - replacement/breccia		
IRON	Transportation, construction, machinery, cans and containers, and appliances.	Tintic - replacement/vein Iron Springs - replacement/vein	Magnetite, hematite goethite, and pyrrhotite.	Copper, lead, and zinc.
LEAD	Batteries, construction, electrical products, glass, shotgun pellets, paint, television screens, and chemical compounds.	Gold Hill (Clifton) - replacement/vein Bingham (West Mountain) - replacement/vein Ophir - replacement Tintic - replacement/vein Big Cottonwood - replacement Little Cottonwood - replacement American Fork - replacement Park City - replacement/vein San Francisco - replacement	Galena, cerussite, anglesite, and plumbojarosite.	Bismuth, copper, gold, molybdenum, silver, and zinc.
MANGANESE	Batteries, machinery, steel alloys, and transportation.	Bingham (West Mountain) - by-product Ophir - replacement Tintic - replacement Big Cottonwood - vein Little Cottonwood - vein Park City - replacement San Francisco - replacement	Rhodochrosite and pyrolusite.	Lead
MERCURY	Dental, thermometers, pharmaceutical, batteries, pesticides, and photography.	Bingham (West Mountain) - by-product Mercur (Camp Floyd) - vein	Mercury and cinnabar.	Lead
MOLYBDENUM	Missiles, aircraft, chemicals, and automobiles.	Bingham (West Mountain) - disseminated Little Cottonwood - replacement/vein San Francisco - replacement	Molybdenite and wulfenite.	Copper, gold, lead, silver, and zinc.
SILVER	Coinage, alloys, dentistry, jewelry, sterling ware, mirrors, photography, electrical products, and electroplating.	Bingham (West Mountain) - replacement/disseminated Little Cottonwood - replacement Big Cottonwood - replacement American Fork - replacement Tintic - replacement/vein Silver Reef (Harrisburg) - replacement Ophir - replacement Gold Hill (Clifton) - replacement/vein	Silver, chlorargyrite, galena, argentojarosite, pyrargyrite argentite, and tetrahedrite.	Copper, gold, lead, and zinc.

Appendix C (continued)

COMMODITY	USES	MINING DISTRICT AND OCCURRENCE	ORE MINERAL	ASSOCIATED METALS
SILVER (continued)		Mercur (Camp Floyd) - replacement Park City - replacement/vein San Francisco - replacement/breccia/skarn		
TUNGSTEN	Lighting, television tubes, stained glass, paints, wires, rods, and aerospace industry.	Gold Hill (Clifton) - skarn Big Cottonwood - skarn Little Cottonwood - replacement American Fork - skarn	Powellite, scheelite, stolzite, and tungstenite.	Lead and molybdenum.
URANIUM	Nuclear power, nuclear weapons, age dating of geologic material, and medical applications.	Bingham (West Mountain) - by-product Silver Reef (Harrisburg) - replacement White Canyon - replacement Lisbon Valley (Big Indian) - replacement	Uraninite, carnotite, and andersonite.	Vanadium and copper.
VANADIUM	Steel alloys, strengthen steel, and ceramics.	Silver Reef (Harrisburg) - replacement Lisbon Valley (Big Indian) - replacement	Calciovolborthite, pascoite, and vanadinite.	Uranium and copper.
ZINC	Alloys, brass, architecture (roofs or facades), electrical, machinery, cameras, coinage, water purification, cosmetics, and pharmaceuticals.	Gold Hill (Clifton) - replacement/vein/skarn Bingham (West Mountain) - replacement/vein Ophir - replacement/vein Tintic - replacement/vein Little Cottonwood - replacement Big Cottonwood - replacement American Fork - replacement Park City - replacement/vein San Francisco - replacement/skarn	Sphalerite, wurtzite, tetrahedrite, smithsonite, hemimorphite, and aurichalcite.	Copper, gold, lead, and silver.