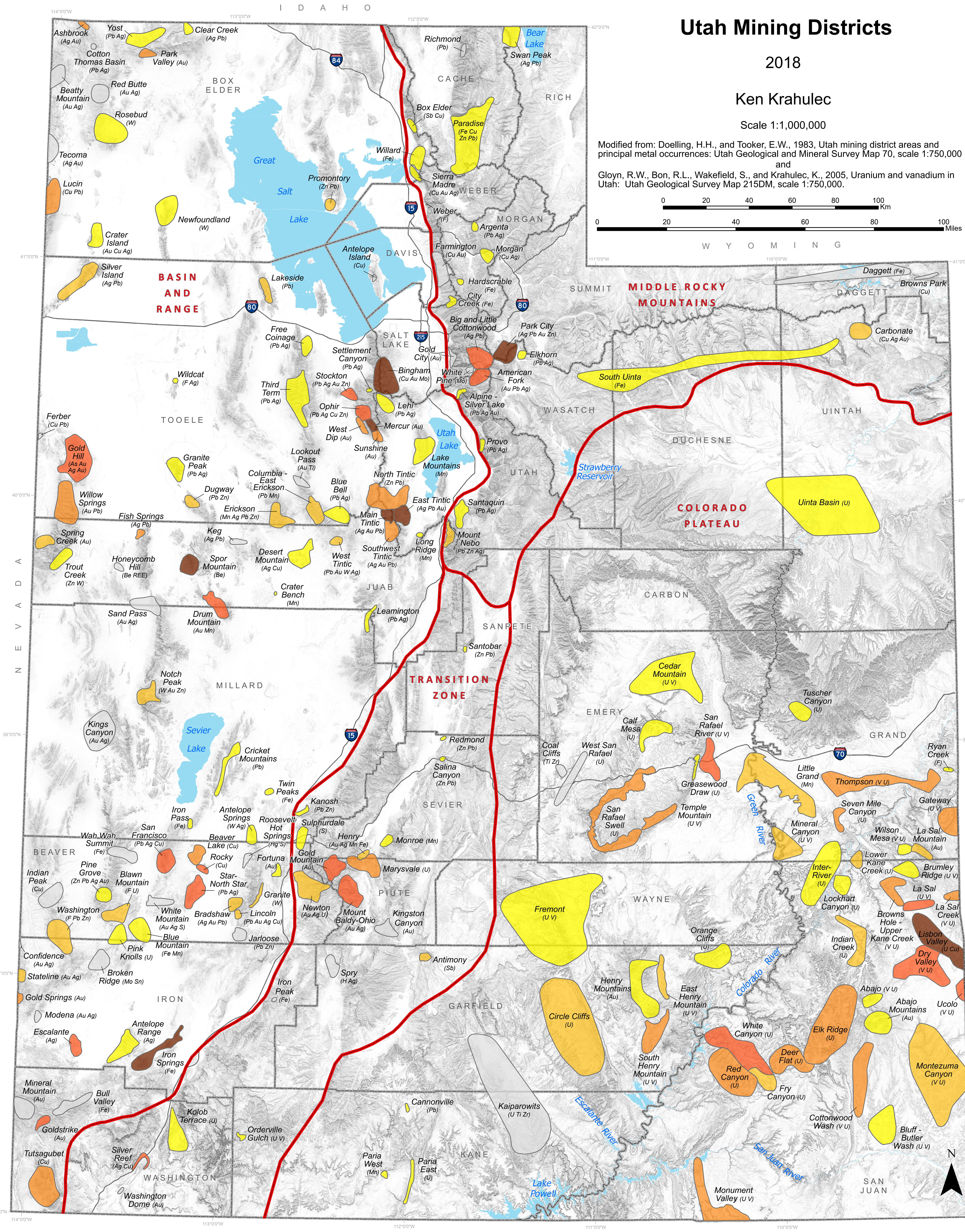
Utah Mining Districts

2018

Ken Krahulec

Scale 1:1,000,000

Modified from: Doelling, H.H., and Tooker, E.W., 1983, Utah mining district areas and principal metal occurrences: Utah Geological and Mineral Survey Map 70, scale 1:750,000
and
Gloyn, R.W., Bon, R.L., Wakefield, S., and Krahulec, K., 2005, Uranium and vanadium in Utah: Utah Geological Survey Map 215DM, scale 1:750,000.



District Total Production Value*

Geologic Province Boundary	No Production	< $1,000,000	$1,000,000 – $10,000,000	$10,000,000 – $100,000,000	$100,000,000 – $1,000,000,000	>$1,000,000,000

*Mining districts are color coded by their estimated total historical production value. District production values are calculated by multiplying the total quantities of metals produced by their estimated recent average price. Prices used: Cu \$2.50/lb, Pb \$1/lb, Zn \$1/lb, Au \$1100/oz, Ag \$15/oz, Be \$175/lb, As \$0.90/lb, Bi \$3.35/lb, Ga \$250/lb, Ge \$180/lb, Sb \$1.30/lb, Mn \$0.75/lb, MoS_2 \$10/lb, U_3O_8 \$30/lb, V_2O_5 \$6/lb, WO_3 \$7/lb, Hg \$400/76 lb flask, iron ore \$65/long ton, S \$30/short ton, and fluorite \$250/short ton.

UTAH MINING DISTRICTS

by Ken Krahulec

OPEN-FILE REPORT 695
UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES
2018

Blank pages are intentional for printing purposes

UTAH MINING DISTRICTS

By Ken Krahulec

***Cover photo**: Bingham Canyon open-pit porphyry Cu-Au-Mo mine, Salt Lake County, Utah. The view is to the northeast from West Mountain and the Wasatch Range is on the skyline.*

OPEN-FILE REPORT 695
UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES
2018

STATE OF UTAH
Gary R. Herbert, Governor

DEPARTMENT OF NATURAL RESOURCES
Michael Styler, Executive Director

UTAH GEOLOGICAL SURVEY
Richard G. Allis, Director

PUBLICATIONS
contact

1594 W. North Temple
Salt Lake City, UT 84116
telephone: 801-537-3320
toll-free: 1-888-UTAH MAP
website: utahmapstore.com
email: geostore@utah.gov

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

INTRODUCTION

The metal mining industry has been an integral part of Utah since the 1860s, long before becoming a state in 1896. The arrival of the railroad in 1869 and its rapid expansion across western Utah facilitated the transportation of needed mining materials and supplies to the mines and the haulage of ore from them. The railroad resulted in the rapid growth of the mining industry and the Salt Lake City area became the main ore concentrating and smelting center for the eastern Great Basin from the 1890s to the 1970s (Whitley, 2006).

Early in Utah's mining history, individual mining districts were organized by the miners and prospectors from the local camp. They elected a recorder, determined regulations for claims, named the district, and defined district boundaries. The U.S. General Mining Act of 1872 formalized a uniform set of claim regulations and the federal government eventually took over the recorder functions. After 1872, the organization of individual mining districts and the definition of their boundaries became somewhat superfluous due to the uniform federal regulations. However, by 1920, 115 mining districts were recognized in Utah along with numerous unorganized camps outside of these district boundaries (Butler and others, 1920). By 1983, Doelling and Tooker (1983) showed 159 districts in Utah. More recently the Utah U-V mining districts were defined by Gloyn and others (2005).

This report discusses 185 Utah mining districts but does not include several poorly documented mineralized areas in the state that have little or no production and several scattered placer gold prospects having limited production along the Colorado and Green Rivers. In an effort to make the district boundaries align better with the underpinning geological framework, a few of the previously defined districts were combined in this report (for example, Big Cottonwood and Little Cottonwood were combined into the Big and Little Cottonwood district), and some districts were subdivided (for example, the Tintic district was subdivided into the Main Tintic, East Tintic, Southwest Tintic, and North Tintic subdistricts). However, the vast majority of the previously recognized district boundaries have only undergone minor changes from Doelling and Tooker (1983) and Gloyn and others (2005).

Utah is situated at the intersection of three important geological provinces, the Middle Rocky Mountains in the northeast, the Colorado Plateau in the southeast, and the Basin and Range Province in the west. In addition, a transition zone lies along the boundary between the Basin and Range Province and the Colorado Plateau. These provinces have significantly different geologic histories resulting in the formation of different ore deposit types and the production of unique metal assemblages. For example, the Basin and Range Province has mainly produced Cu, Pb, Zn, Au, and Ag from intrusive-centered mining districts, but the Colorado Plateau is primarily recognized for sandstone-hosted U, V, and Cu deposits.

The purpose of this report is to offer a map (plate 1) and a brief summary of each of Utah's mining districts that includes: 1) geologic setting, 2) production significance, 3) metals produced, 4) recognized ore deposit types, and 5) a discussion on the most important mines. Each district summary also provides a few key references where interested readers can learn additional details and useful information about the district's geology and ore deposits. For ready access, the district's references are attached to each district summary.

In the text of this report and on the mining districts map (plate 1), the commodities listed for each district are reported in decreasing order of economic importance and must constitute over 10% of the total metal value. For example, the Bingham district's list of commodities is Cu, Au, and Mo with Cu as the most valuable, Au second, and Mo third. However, Bingham has also produced Ag, Pb, Zn, and a few other minor commodities, but these are not listed because they do not individually constitute over 10% of the total value of metal.

For easy reference, tables of the elemental symbols (appendix A), listing of U.S. Geological Survey (USGS) ore deposit models (appendix B), and mineral formulas (appendix C) referenced in this report are attached as appendices. Common abbreviations used within the text include: miles (mi), feet (ft), pounds (lbs), troy ounces (oz), square (sq), and million years (Ma).

PRODUCTION AND RESOURCES

Utah is the third largest metal producing state in the U.S., behind Arizona and Nevada, in terms of total historical production valued at recent estimated metal prices[1]. In the major base and precious metals, Utah ranks second in the production of Cu and

[1]District production values are calculated by multiplying the total quantities of metals produced by their estimated recent average price. Prices used: Cu \$2.50/lb, Pb \$1/lb, Zn \$1/lb, Au \$1100/oz, Ag \$15/oz, Be \$175/lb, As \$0.90/lb, Bi \$3.35/lb, Ga \$250/lb, Ge \$180/lb, Sb \$1.30/lb, Mn \$0.75/lb, MoS_2 \$10/lb, U_3O_8 \$30/lb, V_2O_5 \$6/lb, WO_3 \$7/lb, Hg \$400/76 lb flask, iron ore \$65/long ton, S \$30/short ton, and fluorite \$250/short ton.

Ag; third in Pb; fifth in Au; and ninth in Zn production (Long and others, 1998). Utah is also the largest Be and Mg producing state, second largest V, third largest Mo and U, and fourth largest Fe producer. Utah's total historical metal production valued at recent estimated metal prices is approximately $217 billion. Utah's most valuable metals by this calculation, in decreasing order of importance, are Cu, Au, Mo, Ag, Pb, Fe, Zn, U, Be, V, Mn, and W. The Bingham district alone accounts for approximately 80% of Utah's total historical production value.

Utah's mining districts range in importance from the giant Bingham district down to insignificant districts that have limited or no production. The Bingham district (1) is recognized for being the most productive mining district in the United States, the first porphyry Cu mine in the world, and having over a century and a half of continuous Cu, Au, Mo, Ag, Pb, or Zn production. The Park City district (2) ranks second in terms of total historical metal production in Utah followed by the Main Tintic district (3); both of these districts are very important historical Ag, Au, Pb, Zn, and Cu producers. These top three districts have much in common, all are intrusive-centered districts that have a similar suite of metals produced. Next in Utah production importance are some unique districts: Iron Springs Fe (4), East Tintic Ag-Pb-Au-Zn-Cu (5), Mercur Au (6), Spor Mountain Be (7), and Lisbon Valley U and Cu (8). All these mining districts have over a billion dollars of metal production, at current metal prices. Finally, rounding out the top 10 most productive mining districts in Utah are two more intrusive-centered Pb-Ag-Cu-Zn-Au districts, San Francisco (9) and Ophir (10).

The Bingham Cu-Au-Mo, Spor Mountain Be, Lisbon Valley Cu, and Rocky Cu mining districts all have mines that are currently in production. The Iron Springs district and several of the U districts in the Colorado Plateau, including the La Sal, Red Canyon, and South Henry Mountain districts, have recently operated mines (in the last decade) that are presently on standby due to low commodity prices.

Mining districts having significant ore reserves or subeconomic resources include the Bingham (Cu-Au-Mo-Ag), Southwest Tintic (Cu-Mo), Pine Grove (Mo), Stockton (Cu-Au), Iron Springs (Fe), Goldstrike (Au-Ag), Tecoma (Au-Ag), Gold Spring (Au-Ag), Fish Springs (Zn-Cu-In), East Tintic (Pb-Ag-Zn), Rocky (Cu), Lisbon Valley (Cu and U), La Sal (U-V) and South Henry Mountain (U-V) districts. Numerous districts, particularly in the Basin and Range Province, have ongoing metal exploration and/or development projects showing promise for new or renewed mineral production. Most notable among these districts are Bingham (Cu-Mo-Au-Ag), Goldstrike (Au-Ag), Gold Springs (Au-Ag), Rocky (Cu-Au), San Francisco (Cu-Au), Fish Springs (Zn-Cu-In), Southwest Tintic (Cu-Mo), and Gold Hill (Au-Ag) in the Basin and Range Province and Lisbon Valley (Cu and U) on the Colorado Plateau.

ACKNOWLEDGMENTS

This report was made possible by partial funding from the Utah State Office of the U.S. Bureau of Land Management (BLM). The support and encouragement of Terry Snyder of the BLM is gratefully acknowledged. The text of this document greatly benefited from thorough editorial reviews by Mike Hylland, Stephanie Carney, Andrew Rupke, Terry Snyder, and Michael Vanden Berg. The author also acknowledges important GIS and drafting contributions from Gordon Douglass and Martha Jensen.

REFERENCES

Butler, B.S., Loughlin, G.F., Heikes, V.C., and others, 1920, The ore deposits of Utah: U.S. Geological Survey Professional Paper 111, 672 p.

Doelling, H.H., and Tooker, E.W., 1983, Utah mining district areas and principal metal occurrences: Utah Geological and Mineral Survey Map 70, scale 1:750,000.

Gloyn, R.W., Bon, R.L., Wakefield, S., and Krahulec, K., 2005, Uranium and vanadium in Utah: Utah Geological Survey Map 215 DM, scale 1:750,000.

Long, K.R., DeYoung, J.H., Jr., and Ludington, S.D., 1998, Database of significant deposits of gold, silver, copper, lead, and zinc in the United States—Part A—database description and analysis: U.S. Geological Survey Open-File Report 98-226A, 58 p.

Whitley, C., 2006, From the ground up—The history of mining in Utah: Logan, Utah, Utah State University Press, 506 p.

ABAJO DISTRICT

The Abajo district is a part of the Monticello U mining area in central San Juan County. The district lies about 11 mi west-northwest of Monticello and is a small V-U producer; the initial mineral discoveries were made in the 1940s and 1950s. Total district metal production at modern metal prices is estimated at $216,000. The largest producer is the Indian Creek and Harts Draw underground V-U mines (Doelling, 1969, 1974).

The Abajo district is geologically situated north of the Abajo Mountains in the Paradox Basin of the Colorado Plateau. The district is on the north flank of the Abajo Mountain Oligocene (about 27 Ma) calc-alkaline laccolithic complex. The principal host in the district is the Upper Jurassic Salt Wash Member of the Morrison Formation. The orebodies generally occur in Salt Wash channel sandstones that cut into underlying claystones. The best orebodies are typically in the larger channels measuring about 25 ft thick and 300 ft wide (Witkind, 1964).

There are two common types of sandstone U orebodies (USGS Model 30c): (1) stratabound, tabular, ribbon-shaped deposits 30 ft wide by 3 ft thick by 600 ft long and (2) smaller, oval-shaped deposits 10 ft wide by 3 ft thick by 25 ft long. The stratabound, tabular, ribbon-shaped deposits account for most of the production. The ribbon-shaped deposits often contain accumulations of carbon trash and claystone pebbles, but similar zones are found without mineralization. These deposits often have sharp grade boundaries between ore and waste. The V-U ores average about 1.0% V_2O_5 and 0.06% U_3O_8 (Witkind, 1964; Doelling, 1969, 1974).

The Abajo district also has small Middle Jurassic Entrada Sandstone hosted Cu orebodies (Tuffy mine) of uncertain origin (Witkind, 1964).

Doelling, H.H., 1969, Mineral resources, San Juan County, Utah and adjacent areas, Part II—Uranium and other metals in sedimentary host rocks: Utah Geological and Mineral Survey Special Study 24, 64 p.

Doelling, H.H., 1974, Uranium-vanadium occurrences of Utah: Utah Geological and Mineral Survey Open-File Report 18, unpaginated.

Witkind, I.J., 1964, Geology of the Abajo Mountains area, San Juan County, Utah: U.S. Geological Survey Professional Paper 453, 110 p.

ABAJO MOUNTAINS DISTRICT

The Abajo Mountains mining district lies in central San Juan County about 9 mi west-southwest of Monticello. The district was first prospected in 1892–93 during the "Bluff Excitement" and it became a small Au producer. The Abajo Mountains were intermittently productive from about 1893 to 1935. Total district metal production at modern metal prices is estimated at $275,000. The Dream underground Au mine is the largest producer.

The Abajo Mountains district is geologically situated in the Paradox Basin of the Colorado Plateau. The district covers the Abajo Mountain Oligocene (about 27 Ma) calc-alkaline laccolithic complex. Lode Au ±Cu deposits are primarily limited to the area in and around the East Mountain and West Mountain quartz diorite porphyry stocks and their associated shatter zones. The East Mountain stock is cut by closely spaced, sub-vertical fractures ranging from one-eighth to one inch apart. Many of the fractures are filled with silica, bipyramidal quartz, or cockscomb quartz veins. The quartz diorite porphyry adjoining the fractures is yellow-orange, altered (sericite and kaolinite?), and pyritized. The sedimentary rocks in the shatter zone are only slightly metamorphosed despite close proximity to the stock but are intensely fractured (Witkind, 1964; Mutschler and others, 1997).

Two types of lode ore deposits are reported: Au in quartz or calcite veins and Cu at the intrusive contact. The Au veins are more common, but none of these operations seem to have been economically successful. The typical primary sulfide minerals are pyrite and chalcopyrite, but no Au grades are reported. The Dream mine is reported to have produced about 150 ounces of Au (Gregory, 1938). The Copper Queen mine is at the contact between a laccolith and Cretaceous sandstone. Disseminated pyrite and chalcopyrite impregnate the sandstone at the Copper Queen.

The southern Abajo Mountains have also been prospected for placer gold, particularly from Johnson Creek, Recapture Creek, and South Creek (Dickson Gulch). The gold occurs as flour (very fine flakes) gold which is difficult to concentrate and recover. Johnson (1973) reports about 100 ounces of placer gold was recovered.

Gregory, H.E., 1938, The San Juan Country, a geographic and geologic reconnaissance of southeastern Utah: U.S. Geological Survey Professional Paper 188, 123 p.

Johnson, M.G., 1973, Placer gold deposits of Utah: U.S. Geological Survey Bulletin 1357, 26 p.

Mutschler, F.E., Larson, E.E., and Ross, M.L., 1997, Potential for alkaline igneous rock-related gold deposits in the Colorado Plateau laccolithic centers, in *Laccolith complexes of southeastern Utah—time of emplacement and tectonic setting—workshop proceedings: U.S. Geological Survey Bulletin 2158, p. 233–252.*

Witkind, I.J., 1964, Geology of the Abajo Mountain area, San Juan County, Utah: U.S. Geological Survey Professional Paper 453, 101 p.

ALPINE-SILVER LAKE DISTRICT

The Alpine-Silver Lake mining district lies in north-central Utah County, 7 mi northeast of American Fork. Mineralization in the district was discovered in the 1870s and it became a minor Pb-Ag producer with the Alpine Galena underground mine as the sole productive property (Butler and others, 1920). Total district metal production at modern metal prices is estimated at $83,000. The district is entirely within the Lone Peak Wilderness Area.

The Alpine-Silver Lake district is in the Wasatch Range of the Middle Rocky Mountain province. The district is underlain by a structurally complex jumble of Neoproterozoic, Cambrian, and Mississippian sedimentary strata on the south flank of the Eocene-Oligocene, calc-alkaline, 50-mi-long, east-west-trending Bingham-Wasatch batholith, exemplified here by the Oligocene, 50-sq-mi Little Cottonwood batholith.

Mineralization in the Alpine-Silver Lake district is principally small, uneconomic Pb-Zn-Ag veins and replacement bodies, mostly in Mississippian carbonate rocks, particularly the Gardison Limestone. The primary ore/sulfide minerals are argentiferous galena, sphalerite, pyrite, and barite. Geochemical sampling in the district shows anomalous As, Au, Mo, Sb, Sn, and W in ore grade material from the dumps (Bromfield and Patten, 1981).

Butler, B.S., Loughlin, G.F., Heikes, V.C., and others, 1920, The ore deposits of Utah: U.S. Geological Survey Professional Paper 111, 672 p.

Bromfield, C.S., and Patten, L.L., 1981, Mineral resources of the Lone Peak Wilderness Study Area, Utah and Salt Lake Counties, Utah: U.S. Geological Survey Bulletin 1491, 117 p.

AMERICAN FORK DISTRICT

The American Fork mining district is located about 19 mi north of Provo in northeastern Utah County, in the headwaters of the American Fork River. The district was organized on July 21, 1870, and became a large Au-Ag-Pb-Zn producer with small, but continuous, production from the 1880s into the mid-1950s. The district's production finally sputtered to a halt in 1963. Total district production is estimated at 175,000 tons. Total district metal production at modern metal prices is estimated at $133 million. The main producers were the Miller Group, Dutchman, Yankee, and Pacific underground mines (Perry and McCarthy, 1977).

The American Fork district is geologically situated on the Bingham-Park City mineral belt in the Wasatch Range of the Middle Rocky Mountain province. American Fork is immediately south of the Big and Little Cottonwood district across a topographic divide and county line, but, for geological purposes, it is a continuation of that district. The American Fork district has complex geology with Neoproterozoic to Mississippian sedimentary strata cut by early low-angle faults, later high-angle faults, and intruded by the early Oligocene Little Cottonwood quartz monzonite stock (about 33 Ma) and associated dikes (Calkins and Butler, 1943).

The primary ore deposits in the American Fork district are polymetallic vein and replacement deposits (USGS Model 19a), with the replacement deposits being far more important than the veins. These deposits are typically associated with roughly east-west-trending, high-angle normal faults and the principal hosts are the Cambrian Ophir Formation and Maxfield Limestone and the Mississippian Gardison Limestone. The principal sulfide/ore minerals are galena, sphalerite, pyrite, bornite, covellite, argentite, freibergite, bournonite, jamesonite, and molybdenite. Gangue minerals include quartz, calcite, dolomite, rhodochrosite, and barite (Perry and McCarthy, 1977). The orebodies typically range from a few hundred to about 10,000 tons and have average grades of over 500 ppm Ag, 9 ppm Au, 11% Pb, 2% Zn, and 1% Cu. Mineralization is associated with strongly anomalous As, Cd, Hg, Sb, Se, and Te.

Calkins, F.C., and Butler, B.S., 1943, Geology and ore deposits of the Cottonwood-American Fork area, Utah: U.S. Geological Survey Professional Paper 201, 152 p.

Perry, L.I., and McCarthy, B.M., 1977, Lead and zinc in Utah, 1976: Utah Geological and Mineral Survey Open-File Report 22, 525 p.

ANTELOPE ISLAND

Antelope Island lies in Great Salt Lake, Davis County, approximately 16 mi northwest of Salt Lake City. The district has no credited production, but the area was prospected for Cu in the early twentieth century. All of Antelope Island is now a state park.

Antelope Island is a portion of a northerly trending mountain range in the Basin and Range Province of north-central Utah. Most of the mineral occurrences consist of small, Cu-bearing quartz veins hosted by Paleoproterozoic gneiss and slate. The veins are generally a few feet wide and may be traced for up to several hundred feet, trending northeasterly with variable dips. Some of the workings explore weathered rock that consists of hematitic gossans with silica boxwork structures. The only recognized primary sulfides in the deposits are chalcopyrite and pyrite (Doelling and others, 1988). Limited assays of high-grade dump rock samples show from 1 to 4% Cu and very low Ag, Au, Pb, and Zn.

Doelling, H.H., Willis, G.L., Jensen, M.E., Hecker, Suzanne, Case, W.F., and Hand, J.S., 1988, Geology of Antelope Island, Davis County, Utah: Utah Geological and Mineral Survey Open-File Report 144, scale 1:24,000, 100 p.

ANTELOPE RANGE DISTRICT

The Antelope Range (Silver Belt) mining district lies in south-central Iron County about 23 mi west of Cedar City. The district was an insignificant Ag producer. The mines in the Bullion Canyon area were probably the largest producers.

The district lies on the west flank of the Antelope Range in the Basin and Range Province of southwestern Utah. The Antelope Range is primarily a northeast-dipping, faulted, homoclinal sequence of Miocene volcanic rocks. The district contains generally northwest-striking veins hosting epithermal Ag-Au sulfosalt mineralization (USGS Model 25b). The veins vary in dimensions but are typically 2 to 4 ft wide and have a maximum width of 46 ft. They can be followed along strike for 100 to 4600 ft. The veins are generally vuggy quartz-calcite with abundant barite and some base metals. Recognized hypogene sulfide minerals include galena, chalcopyrite, sphalerite, pyrite, and the sulfosalts tennantite, pearceite, stromeyerite, and proustite. Maximum grades from vein samples have a low Au:Ag ratio with 7.5 ppm Au and 300 ppm Ag, and the ores are also anomalous in Cu, Pb, Zn, As, Sb, Hg, Ba, Mo, and W (Shubat and McIntosh, 1988). There is a roughly 1.25 sq mi zone of weak, but pervasive, argillic alteration and hematitic staining of the Miocene Racer Canyon Tuff about 2 mi northwest of Silver Peak, southwest of the bulk of the mineralization. Shubat and McIntosh (1988) interpreted mineralization as the product of episodic boiling of hydrothermal fluids at about 200°C related to rhyolitic and dacitic volcanism (about 8.5 Ma).

Shubat, M.A., and McIntosh, W.S., 1988, Geology and mineral potential of the Antelope Range mining district, Iron County, Utah: Utah Geological and Mineral Survey Bulletin 125, 26 p.

ANTELOPE SPRINGS DISTRICT

The Antelope Springs (McGarry) mining district is located on the Millard and Beaver County line about 15 mi northeast of Milford. The district has been an insignificant Ag producer. The district had several small, generally unsuccessful drilling campaigns in the 1960s, 1980s, and 1990s. The Pay Streak Ag-Pb-Au mine is believed to be one of the few productive properties.

The district lies on the northern end of the Mineral Mountains of the Basin and Range Province. To the south, the Mineral Mountains expose a large, mostly gray, alkalic, high-silica, composite Oligocene-Miocene (25 to 17 Ma) granite, monzonite, and syenite batholith (80 sq mi), the largest exposed batholith in Utah. The batholith was strongly rotated to the east (40°–85°) in the middle to late Miocene, so that the east side of the mountain is closer to the paleo-top of the batholith (Coleman and others, 2001).

The strata in the Antelope Springs district are structurally complex Lower Cambrian quartzites thrust over Middle (?) Cambrian carbonates. Scattered mineralization has been prospected in the carbonates adjacent to the northern margin (side) of the Mineral Mountain batholith (Liese, 1957). The mineral occurrences are generally small Ag-Pb-Zn ±Cu vein and replacement deposits (USGS Model 22c). The primary sulfide/ore minerals are pyrite, argentiferous galena, chalcopyrite, and presumably sphalerite with abundant barite. These ores may also be geochemically anomalous in As, Hg, Mn, Sb, and Te.

The prospects farther south, near the batholith, have more Cu ±W and less Pb-Zn-Ba. Adjacent to the batholith the Cambrian carbonates are metamorphosed to marble and hornfels. On the extreme west flank of the range, the carbonates are metamorphosed locally to a large body of massive, foliated, fibrous tremolite (16 million tons; Crawford and Buranek, 1942) (USGS Model 18e).

Coleman, D.S., Walker, J.D., Bartley, J.M., and Hodges, K.V., 2001, Thermochronologic evidence for footwall deformation during extensional core complex development, Mineral Mountains, Utah, in Erskine, M.C., Faulds, J.E., Bartley, J.M., and Rowley, P.D., editors, The geologic transition, High Plateaus to Great Basin—a symposium and field guide—the Mackin volume: Utah Geological Association Publication 30, p. 155–168.

Crawford, A.L., and Buranek, A.M., 1942, Tremolite deposits of the Mineral Range, Millard County, Utah: Utah Department of Publicity and Industrial Development Circular 2, 7 p.

Liese, H.C., 1957, Geology of the northern Mineral Range, Millard and Beaver Counties, Utah: Salt Lake City, University of Utah, unpublished M.S. thesis, 88 p.

ANTIMONY DISTRICT

The Antimony (Coyote Canyon) mining district lies about 30 mi southeast of Marysvale in north-central Garfield County. The district was discovered in 1879 and became a modest producer of hand-cobbed, high-grade Sb ores from 1880 to about 1908 and intermittently into the 1960s (Doelling, 1975). Total district metal production at modern metal prices is estimated at $1,120,000. The district is the largest Sb producer in Utah and minor, intermittent production occurred during high demand and high Sb prices, especially during the World Wars. The Emma-Albion mine is believed to be the largest producer.

The Antimony district lies in the southeastern corner of the Marysvale volcanic field in the transition zone from the Basin and Range Province on the west to the Colorado Plateau on the east. The Sb deposits occur as irregular lenses, rosettes, and veinlets (USGS Model 27d) in two limey sandstones of the Paleocene Flagstaff Formation near the base of the overlying Oligocene and Miocene Bullion Canyon Volcanics (Doelling, 1975). The ore zones typically range from 5 to 20 ft thick. The primary ore mineral is stibnite which occurs as masses of acicular crystals perpendicular to the attitude of the veinlets/lenses. Gangue minerals include pyrite, realgar, orpiment, fluorite, quartz, kaolinite, and probably arsenopyrite. The average grade from 486 U.S. Bureau of Mines channel samples is 0.79% Sb, although a 500 lb mine dump sample had 3.7% Sb, 600 ppm As, 4.1 ppm Ag, and 79.2% SiO_2 (Traver, 1949). Doelling (1975) suggests a subeconomic inferred resource based on the channel samples near the old mines of about 14 million tons at an average grade of 0.75% Sb. The deposits are hydrothermal sandy carbonate replacements associated with Tertiary volcanism.

Doelling, H.H., 1975, Geology and mineral resources of Garfield County, Utah: Utah Geological and Mineral Survey Bulletin 107, 172 p.

Traver, W.M., 1949, Investigation of the Coyote Creek antimony deposits, Garfield County, Utah: U.S. Bureau of Mines Report of Investigation 4470, 18 p.

ARGENTA DISTRICT

The Argenta mining district is located 6 mi east of Mountain Green in northern Morgan County. Argenta is a modest Pb-Ag producer that was initially discovered in the early 1880s and was intermittently productive from about 1905 to 1917. Total district metal production at modern metal prices is estimated at $958,000. The Carbonate Gem underground mine was probably the largest producer.

The Argenta district is in the Wasatch Range of the Middle Rocky Mountain province. Mineralization in the district occurs as small vein and carbonate replacement deposits in the Paleozoic sedimentary rocks. The Carbonate Gem is hosted in the Middle Cambrian Maxfield Limestone. Mineralization in the district is weakly zoned with more Mn on the northwest and more Cu in the south (Gloyn and others, 1995). The primary recognized ore/sulfide minerals are pyrite, galena, sphalerite, and barite. In addition to Pb-Ag, the ores are strongly anomalous in Zn, Ba, Cd, As, Sb, Cu, Mo, Mn, and weakly anomalous in Au, Bi, and Te. No intrusive rocks have been recognized in the district.

Gloyn, R.W., Shubat, M.A., and Mayes, B., 1995, Mines and prospects in and around the Farmington Complex, northern Utah: Utah Geological Survey Open-File Report 325, 36 p.

ASHBROOK DISTRICT

The Ashbrook mining district is in extreme northwestern Box Elder County, 60 mi west of Snowville. The district was initially prospected in the 1860s and 1870s, becoming a significant Ag-Au producer in the 1920s and also had minor production as late as the 1980s. Total district metal production at modern metal prices is estimated at $61 million. The Vipont underground Ag-Au mine is the only important producer.

Geologically, the Ashbrook district is situated in the northern Goose Creek Mountains on the west flank of the Albion-Raft River-Grouse Creek metamorphic core complex. The area has a long and complex geologic history. The strata near the Vipont mine consist of a sequence of Paleozoic orthoquartzites, carbonates, shales, and sandstones. These units were subjected to Late Jurassic to Early Cretaceous thrusting, folding, and low-grade metamorphism followed by severe Eocene to Miocene extension and intrusion by Miocene (about 13 Ma) granite and rhyolite porphyry plugs, dikes, and sills. Mineralization is apparently related to these late felsic intrusive bodies (possibly the rhyolite plug at Twin Peaks 2 mi to the south), so the orebodies have not undergone significant deformation (Gloyn and Krahulec, 2006).

Mineralization at the Vipont mine primarily consists of Ag-rich veins, mantos, and stratiform disseminated ores hosted primarily by the Mississippian Vipont (Tripon Pass?) limestone near the base of the Chainman-Diamond Peak Formations in a gently southwest-plunging syncline. The orebodies are formed along favorable northeast-trending crenulations and faults within this syncline. A typical individual high-grade Ag orebody may be 500 ft long, 100 ft wide, and 8 ft thick. Mineralization extends down-plunge for about a half mile and was developed by stopes from numerous underground mine levels (Peterson, 1942).

The Vipont orebodies are northeast-elongate, lensoidal, stratiform zones of void-filling, disseminated, replacement, and veinlet-style sulfide mineralization. The total sulfide content of the ore probably averages less than 10 wt.%. The primary hypogene minerals associated with Vipont ore, in addition to quartz and rhodochrosite, are pyrite, arsenopyrite, galena, sphalerite, chalcopyrite, pyrargyrite, tennantite, pearceite, covellite, and argyrodite. Supergene argentite is the most common ore mineral exploited in the oxidized zone (Peterson, 1942). The Vipont deposit may represent a transitional stage between a polymetallic vein/replacement deposit (USGS Model 22c) and a distal disseminated Ag-Au deposit (USGS Model 19c). In addition to Ag and Au, the Vipont ores are strongly anomalous in As, moderately anomalous in Pb, and weakly anomalous in Zn.

Gloyn, R.W., and Krahulec, K., 2006, History, geology, production, and resources of the Vipont mine and Ashbrook mining district, Box Elder County, Utah, in *Harty, K.M., and Tabet, D.E., editors, Geology of northwest Utah: Utah Geological Association Publication 34, CD-ROM, 14 p.*

Peterson, V.E., 1942, A study of the geology of the Ashbrook silver mining district: Economic Geology, v. 37, p. 466–502.

BEATTY MOUNTAIN DISTRICT

The Beatty Mountain district is in the southern Goose Creek Mountains along the Utah-Nevada border in westernmost Box Elder County, roughly 100 mi west of Brigham City. The area has no known mines or historical prospects and no history of production. However, the Beatty Mountain district has been explored for Au by major mining companies intermittently for roughly the last three decades.

The Goose Creek Mountains are a structurally complex area just off the western flank of the Albion-Raft River-Grouse Creek metamorphic core complex in the Basin and Range Province. Geologically, the Beatty Mountain district has Lower to Middle Permian sedimentary strata cut by a series of imbricate low-angle detachment faults and is unconformably overlain by Miocene Salt Lake Formation sedimentary rocks and volcanics (Miller and others, 2012). The Permian strata are mostly members of the Park City Group, principally the Murdock Mountain Formation and the Phosphoria Formation. The Salt Lake Formation consists of thousands of feet of middle Miocene conglomerate and limestone overlain by about a thousand feet of middle to late Miocene tuffs and rhyolites. The volcanics are porphyritic rhyolite tuff and flows belonging to the Rhyolite of Granite Creek, about 13 Ma (Miller and others, 2012).

Mineralization in the Beatty Mountain district is likely related to the intrusion of the Rhyolite of Granite Creek. Prospects in adjoining parts of Nevada include quartz-calcite-adularia Au veins and hot springs Au mineralization. The area of most intense mineralization in Utah is south of Beatty Mountain along Straight Fork and is hosted in the Murdock Mountain Formation of the Park City Group. The Murdock Mountain Formation consists primarily of chert, limestone, and sandstone. The Au-Hg mineralization is associated with jasperoids and "punky" decalcification along Straight Fork. This mineralization is thought to have affinities to sedimentary rock-hosted Au-Ag deposits (USGS Model 26a).

Miller, D.M., Clark, D.L., Wells, M.L., Oviatt, C.G., Felger, T.J., and Todd, V.R., 2012, Progress report geologic map of the Grouse Creek 30' x 60' quadrangle, Box Elder County, Utah and Cassia County, Idaho: Utah Geological Survey Open-File Report 598, 25 p., scale 1:100,000.

BEAVER LAKE DISTRICT

The Beaver Lake mining district is in the Beaver Lake Mountains about 10 mi northwest of Milford in central Beaver County. Mineralization was initially discovered in 1870 and the district became a significant Cu producer in the 1960s and 1970s with another brief period of production in 2012–18. Total district metal production at modern metal prices is estimated at $50 million. The OK underground/open pit mine is the only significant producer.

The Beaver Lake district lies on the Wah Wah-Tushar mineral belt in the Basin and Range Province in southwestern Utah (Krahulec, 2015). The northern Beaver Lake Mountains are composed of a complexly faulted sequence of Paleozoic sedimentary rocks intruded by a large quartz monzonite stock on the south and east. The southern Beaver Lake Mountains are primarily Oligocene Horn Silver Andesite (about 33 Ma) intruded and domed by the approximately coeval OK biotite-hornblende granodiorite stock (about 31 Ma) (Best and others, 1989). The district is metallogenically zoned from distal Pb-Zn-Ag on the north to Cu in the south.

The OK Cu mine is the principal ore deposit in the Beaver Lake district and it developed a small, sub-vertical, magmatic-hydrothermal, pegmatitic breccia pipe hosted by the 1.8-sq-mi Cactus granodiorite plug (Wray, 2006). Mineralization occurs as blebs of chalcopyrite along with molybdenite flakes and minor pyrite in a N. 80° W.-striking, steeply north-dipping mineralized zone cutting across the granodiorite. At the surface, the breccia pipe is roughly 100 by 50 ft in plan and plunges about 65° north-northeast. The known, higher grade Cu-Au-Mo-Ag mineralization occurs mostly along the footwall of the breccia and was mined by a combination of underground and open-pit methods. Scheelite has also been reported locally in the pegmatitic OK Cu ore (Wray, 2006).

Immediately southeast of the OK mine and just north of the old Beaver Harrison shaft, a west-northwest-trending zone of sheeted fracturing with bornite, chalcopyrite, native copper, and molybdenite occurs on joints in the granodiorite (Krahulec, 2015). In summary, the OK-Beaver Harrison mine area is an unusual low-sulfidation, small porphyry Cu-Au-Mo system (USGS Model 17).

Best, M.G., Lemmon, D.M., and Morris, H.T., 1989, Geologic map of the Milford quadrangle and east half of the Frisco quadrangle, Beaver County, Utah: U.S. Geological Survey Miscellaneous Investigations I-1904, scale 1:24,000.

Krahulec, K., 2015, Tertiary intrusion-related copper, molybdenum, and tungsten mining districts of the eastern Great Basin, in Pennell, W.M., and Garside, L.J., editors, New Concepts and Discoveries: Geological Society of Nevada 2015 Symposium Proceedings CD, p. 219–250.

Wray, W.B., 2006, Mines and geology of the Rocky and Beaver Lake districts, Beaver County, Utah, in Bon, R.L., Gloyn, R.W., and Park, G.M., editors, Mining districts of Utah: Utah Geological Association Publication 32, p. 183–285.

BIG AND LITTLE COTTONWOOD DISTRICT

The Big and Little Cottonwood mining district lies in easternmost Salt Lake County about 17 mi southeast of Salt Lake City. The district was a large Pb-Ag producer active intermittently between 1867 and 1976. Total district metal production at modern metal prices is estimated at $618 million. Although the Big Cottonwood and Little Cottonwood mining districts are sometimes reported separately, the division is completely arbitrary and the ore in both sub-districts is the result of a single, complex, magmatic-hydrothermal episode related to the intrusion of the Alta quartz monzonite porphyry stock along their common border. Approximately 60% of the past production has come from the Little Cottonwood subdistrict with the remainder from the Big Cottonwood subdistrict. The South Hecla and Cardiff underground mines are thought to be the most productive in the district, and the South Hecla is also the largest Bi producer in Utah.

The Big and Little Cottonwood district is geologically situated on the Bingham-Park City mineral belt in the Middle Rocky Mountain province. The ore deposits are clustered around the margins of the east-northeast-trending Oligocene stocks (35 Ma to 33 Ma), in particular the high-K, calc-alkaline, Alta quartz monzonite porphyry stock (~34 Ma). Dikes and veins parallel this east-northeast intrusive trend. The porphyritic phase of the Alta stock may be near the center of the district metal zoning pattern. Thrust faulting, domed by the intrusives, has played an important role in the localization of the replacement deposits, acting as a pathway for hydrothermal fluids. The Mississippian Fitchville and Humbug Formations are the preferred host rocks although the Cambrian Ophir Formation and Maxfield Limestone also acted as important hosts (Calkins and Butler, 1943; James, 1979).

Most of the major polymetallic replacement (USGS Model 19a) producers are clustered where all of these factors—intrusive trend, dikes, thrust faults, fissure veins, and favorable carbonate strata—come together and include the Flagstaff Mountain-Alta area Cardiff mine (Big Cottonwood), Emma, South Hecla, Michigan-Utah, and Flagstaff mines (Little Cottonwood). The primary ore/sulfide minerals are galena, sphalerite, tetrahedrite, pyrite, chalcopyrite, argentite, molybdenite, bornite, siderite, rhodochrosite, and enargite. Tetrahedrite is the main primary Cu ore mineral in the replacement deposits. Rare gold, tungstenite, scheelite, stolzite, bismuthinite, aikinite, jamesonite, dufrénoysite, dyscrasite, wulfenite, and huebnerite are found in some deposits (Calkins and Butler, 1943; James, 1979).

The porphyritic quartz monzonite phase of the Alta stock is potentially the bottom of a very deeply eroded porphyry Cu cupola (USGS Model 17), probably eroded down to a paleodepth of very roughly 4 mi, far below the Cu ore zone.

Calkins, F.C., and Butler, B.S., 1943, Geology and ore deposits of the Cottonwood-American Fork area, Utah: U.S. Geological Survey Professional Paper 201, 152 p.

James, L.P., 1979, Geology, ore deposits, and history of the Big Cottonwood mining district, Salt Lake County, Utah: Utah Geological and Mineral Survey Bulletin 114, 98 p.

BINGHAM DISTRICT

The Bingham (West Mountain) mining district is located 22 mi southwest of Salt Lake City in southwest Salt Lake County. Bingham is the oldest and largest district in Utah and hosts a giant porphyry Cu-Au-Mo deposit. The Bingham Canyon open pit porphyry Cu-Au-Mo mine is the largest mine in the U.S. and the Bingham district is the largest Cu, Mo, Au, Ag, Pb, and Zn producer in Utah. The district's total historical metal production at modern metal prices is valued at approximately $174 billion and the Bingham Canyon mine is still in production.

The Bingham district forms a lynchpin in the Bingham-Park City mineral belt in the Basin and Range Province. The district is centered on a giant, high-K, calc-alkaline, porphyry Cu-Mo-Au-Ag deposit (USGS Model 17). This deposit is associated with a small, composite monzonite stock dated at about 38 Ma. This stock intrudes a thick, intercalated sequence of Pennsylvanian-Permian marine quartz sandstones and limestones. A 400- to 1000-ft-wide quartz monzonite porphyry dike and a swarm of narrower, east-northeast-trending dikes cut the north flank of the early monzonite stock. The hypogene porphyry mineralization is concentrically zoned around the quartz monzonite porphyry dike from a deep, inner, low-sulfide core through progressively overlapping hypogene molybdenite, bornite-chalcocite, chalcopyrite, and pyrite zones. The inverted cup-shaped Cu shell is largely coincident with potassic alteration and garnet Cu-Au skarns (USGS Model 18a). The surrounding pyrite halo is spatially associated with propylitically-altered rocks. Each of three major phases of porphyry intrusion is followed by cycles of fracturing, alteration, veining, and metal deposition. This cyclic vein formation resulted in complex vein relationships partly constrained by age dates and crosscutting relations. The quartz monzonite porphyry dike and younger dikes are spatially coincident with the highest grades of Cu and Au in the orebody (Porter and others, 2012). The exposed quartz monzonite porphyry stock is too small to have provided the fluids and metals for the district, necessitating a connection to a far larger magma chamber at depth.

The outermost fringe of the pyrite halo is overprinted by the inner margin of a 3000-ft-wide, intermediate-sulfidation, sphalerite-galena ±tetrahedrite manto-vein zone where alteration is largely confined to the immediate vein walls (USGS Model 19a). The outer perimeter of the Pb-Zn veins locally contains rhodochrosite and/or barite. The Barneys Canyon and Melco distal disseminated Au deposits (USGS Model 19c) lie 4 mi north-northeast of the center of the district and outside Bingham's megascopically recognizable sulfide and alteration system, but on the outer fringe of a weak As-Au geochemical halo (Babcock and others, 1995).

Babcock, R.C., Jr., Ballantyne, G.H., and Phillips, C.H., 1995, Summary of the geology of the Bingham district, Utah, in *Pierce, F.W., and Bolm, J.G., editors, Porphyry Copper Deposits of the American Cordilleran: Tucson, Arizona, Arizona Geological Society Digest 20, p. 316–335.*

Porter, J.P., Schroeder, K., and Austin, G., 2012, Geology of the Bingham Canyon Porphyry Cu-Mo-Au Deposit, Utah, in *Hedenquist, J.W., Harris, M., and Camus, F., editors, Geology and genesis of major copper deposits and districts of the world—A tribute to Richard H. Sillitoe: Society of Economic Geologists Special Publication 16, p. 127–146.*

BLAWN MOUNTAIN DISTRICT

The Blawn Mountain mining district is in southwestern Beaver County approximately 30 mi southwest of Milford. Mineralization was first discovered in the district in the 1880s and the district became a modest U-F and kaolinite producer. Total district metal production at modern metal prices is estimated at $1.2 million. The Staats underground U-F mine is the only significant metal mine along with a nearby kaolinite clay open pit.

The Blawn Mountain district is in the southern Wah Wah Mountains in the Basin and Range Province. The mineralization at the Staats mine is associated with one of several small, high-silica, Miocene rhyolite porphyry plugs known to be associated with the Miocene Blawn Formation volcanic rocks. These plugs include the Pine Grove porphyry, Staats rhyolite, and the smaller Blawn Wash plugs. The Staats topaz rhyolite plug (20.2 Ma) intrudes a sequence of Silurian and Devonian carbonates and is adjacent to the U-F mineralization at the Staats mine (Mehnert and others, 1978).

The Staats fluorite mine was worked by a small open cut and has an estimated 800 ft of underground workings (USGS Model 26b). Some 4855 tons of fluorite were mined from 1935 to 1951. During the 1950s, uranium was discovered at the Staats mine and an additional 1994 tons of 0.26% U_3O_8 hand-sorted ore were shipped. The area was heavily explored for U again in the early 1970s and then for Mo in the late 1970s and early 1980s, following the discovery of the deep, Climax-type porphyry Mo deposit at Pine Grove 7 mi to the northwest.

The Staats fluorite ore zones, grading approximately 75% to 90% CaF_2, are typically a few ft in width, a few tens to just over 100 ft in length, and occur near the rhyolite contact. The autunite and uranophane after uraninite occur as small flakes and coatings in gouge zones adjacent to the fluorite with typical grades of less than 0.2% U_3O_8. Lindsey and Osmonson (1978) report the occurrence of very low-level geochemical anomalies for Be, Mo, and Sn associated with the rhyolite stock. D.A. Lindsey (retired USGS, written communication, July 2007) notes the occurrence of good crystalline cassiterite in a fluorspar breccia near the Staats mine.

Between 2003 and 2010 about 500,000 tons of high alumina (about 30% Al_2O_3) kaolinite clay was recovered from a ridge top open-pit mine on Blawn Mountain. The clay was hauled to the Leamington cement plant as a premium alumina feed to boost kiln throughput. The clay was valued at about $30/ton. The kaolinite was found along a fault contact between altered Ordovician dolomite and Tertiary intrusive rhyolite. Mining operations ceased due to cement plant concerns about the high Hg content of the clay.

Lindsey, D.A., and Osmonson, L.M., 1978, Mineral potential of altered rocks near Blawn Mountain, Wah Wah Range, Utah: U.S. Geological Survey Open-File Report 78-114, 18 p.

Mehnert, H.H., Rowley, P.D., and Lipman, P.W., 1978, K-Ar ages and geothermal implications of young rhyolites in west-central Utah: Isochron/West, no. 21, p. 3–7.

BLUE BELL DISTRICT

The Blue Bell mining district is in extreme southeastern Tooele County, about 15 mi west of Eureka. The initial discoveries in the district were made in the 1890s and the district became a small intermittent Pb-Ag producer operating until 1922. Total district metal production at modern metal prices is estimated at $367,000. The most productive mines in the district were the Black Hawk and Morgan.

The Blue Bell district covers a portion of the east flank of the Sheeprock Mountains and adjoining portions of the West Tintic Mountains of the Basin and Range Province. The Sheeprock Mountains are composed of a thick sequence of northeast-dipping Neoproterozoic Sheeprock Group quartzite, metaconglomerate, and slate (Cohenour, 1959). To the west, these rocks have been intruded by the Miocene (20.9 Ma) Sheeprock granite. The intrusion is an aluminous, anorogenic (A-type), high-silica granite (Christiansen and others, 1988). The Sheeprock Mountains have been rotated eastward by post-intrusive listric extensional faulting so that a deeper level of the Blue Bell paleo-hydrothermal system is exposed on the west and shallower levels are exposed on the east. The Blue Bell district is located 6 mi due east of the granite.

The Blue Bell district has produced about 250 tons of Pb-Ag ore (USGS Model 22c) from veins hosted in the Sheeprock Group quartzite and tillite. The primary ore minerals are argentiferous galena, sphalerite, pyrite, barite, and bismuthinite. In addition to Pb-Ag, the ores may be anomalous in As, Ba, Bi, Mo, and Sb.

In the 1980s and 1990s, jasperoids in windows of Mississippian carbonates along Vernon Creek on the east side of the district were prospected for distal disseminated Ag-Au (USGS Model 19c), particularly from Sabie Mountain to J Hill, without success. These occurrences are associated with silicification principally in the Mississippian Great Blue Limestone and may have orpiment, realgar, and cinnabar. In addition to strong As, Hg, and Sb, these jasperoids may have weak Au and Ag.

Christiansen, E.H., Stuckless, J.S., Funkhouser, M.J., and Howell, K.A., 1988, Petrogenesis of rare-metal granites from depleted crustal sources—an example from the Cenozoic of western Utah, USA, in *Taylor, R.P, and Strong, D.F., editor, Recent advances in the geology of granite-related mineral deposits: Canadian Institute of Mining and Metallurgy Special Volume 39, p. 307–321.*

Cohenour, R.E., 1959, Sheeprock Mountains, Tooele and Juab Counties—Precambrian and Paleozoic stratigraphy, igneous rocks, structure, geomorphology, and economic geology: Utah Geological and Mineralogical Survey Bulletin 63, 201 p.

BLUE MOUNTAIN DISTRICT

The Blue Mountain district is in south-central Beaver County about 25 mi southwest of Milford. The district is a minor Fe-Mn producer with a history of just a few iron ore shipments for flux, possibly totaling 500 tons. Total district metal production at modern metal prices is estimated at $24,000. The Emma mine was probably the largest operation, where small Fe gossans were exploited along high-angle faults.

The Blue Mountain district lies astride the east-trending, Miocene, Blue Ribbon lineament of Rowley and others (1978) in the Basin and Range Province. The district encompasses the Blue Mountain, Jockey Road, Iron Mountain, and Iron Mine Wash areas. The primary structure on Blue Mountain proper is a north-south-trending doubly plunging anticline with a window through upper plate Cambrian strata of the Blue Mountain thrust into lower plate Navajo Sandstone, Chinle Formation, and Moenkopi Formation (Weaver and Hintze, 1993). An aeromagnetic high correlates with the crest of the dome indicating an intrusive at depth. The Jockey Road area flanks Blue Mountain to the northwest and consists of rolling hills underlain by upper Cambrian strata unconformably overlain by Oligocene intermediate tuffs and flows.

Mineralization at Blue Mountain proper consists of weak Mo-Cu-Zn skarn/replacement mineralization in the core of the anticline. The Jockey Road and Iron Mine Wash areas have jasperoids and weak sedimentary and volcanic rock-hosted Au mineralization. Several groups have explored the Jockey Road area mostly for low-grade, disseminated Au (USGS Model 19c) over the past three decades. The best sedimentary rock-hosted mineralization occurs in the lower portion of the Middle Cambrian strata including the Chisholm Formation, Dome Limestone, Whirlwind Formation, and the Swasey Limestone just above the Blue Mountain thrust.

The strongest alteration and Au mineralization occur in the center of a northwest-trending graben in clay-silica altered Oligocene volcanic rocks and in heavily silicified rocks of the lower Middle Cambrian sedimentary strata (Weaver and Hintze, 1993). The best Au prospects are a gray, sucrose, vuggy, and brecciated jasperoid with trace pyrite and Au, which occurs not far above the Blue Mountain thrust and about 3.8 mi northwest of the apex of the Blue Mountain dome. In addition to Au and Ag, the area is anomalous in As, Hg, Mo, and Sb.

The iron ore production has come from gossanous Fe-Mn fault zones cutting Cambrian carbonate in the Iron Mountain area on the west end of the district. The polymetallic veins at the Cobolt #1 prospect have very high Fe, Mn, Ni, and Co.

Rowley, P.D., Lipman, P.W., Mehnert, H.H., Lindsey, D.A., and Anderson, J.J., 1978, Blue Ribbon lineament, an east-trending structural zone within the Pioche mineral belt of southwestern Utah and eastern Nevada: Journal of Research of the U.S. Geological Survey, v. 6, no. 2, p. 175–192.

Weaver, C.L., and Hintze, L.F., 1993, Geologic map of the Blue Mountain quadrangle, Beaver County, Utah: Utah Geological Survey Map 146, scale 1:24,000.

BLUFF–BUTLER WASH DISTRICT

The Bluff–Butler Wash district of the Monticello U mining area is in southeastern San Juan County about 10 mi south of the White Mesa U-V mill near Blanding. The poorly documented Bluff–Butler Wash district is a small U-V producer, and total district metal production at modern metal prices is estimated at $1.6 million. The largest mines are the Hole in the Rock and Tree.

The Bluff–Butler Wash district is situated in the Paradox Basin on the Colorado Plateau. The uranium deposits of the district are generally hosted in the flat lying Upper Jurassic Salt Wash Member of the Morrison Formation; however, the Hole in the Rock mine is hosted in the overlying Westwater Canyon Member (USGS Model 30c). Mineralization is localized where permeable channel sandstones are interbedded with carbonaceous trash and mudstone lenses. The ore deposits are unoxidized below the water table and are dominantly composed of intergranular uraninite and montroseite. Ore grades in the district average about 0.24% U_3O_8 and 0.26% V_2O_5 (Doelling, 1969, 1974).

Doelling, H.H., 1969, Mineral resources, San Juan County, Utah and adjacent areas, Part II—Uranium and other metals in sedimentary host rocks: Utah Geological and Mineralogical Survey Special Study 24, 64 p.

Doelling, H.H., 1974, Uranium-vanadium occurrences of Utah: Utah Geological and Mineral Survey Open-File Report 18, unpaginated.

BOX ELDER DISTRICT

The Box Elder mining district is located about 5 mi north of Brigham City in extreme eastern Box Elder County. Mineralization was initially discovered in 1889 with the main period of production from 1908 to 1917. District production has been small and is estimated at roughly 1000 tons of Sb ore likely making this the second largest Sb producer in Utah. Total district metal production at modern metal prices is estimated at $360,000. Box Elder also has some minor production of Cu-rich polymetallic ore (Doelling, 1980). The Dry Lake Sb mine is the largest producer in the district.

The Box Elder district is situated on the steep western face of the Wellsville Mountains of the Middle Rocky Mountain province. The Dry Lake Sb mine (incorrectly labeled the Copper Blossom mine on the U.S. Geological Survey Brigham City 7.5′ topographic map) lies on the south end of the district and accounts for over 70% of the Box Elder district's estimated production value. The mineralization occurs along a steeply north-dipping, N. 85° E.-trending quartz vein in a fault zone cutting northeast-dipping Middle Cambrian Blacksmith Formation carbonates just beneath the overlying Hodges Shale Member of the Bloomington Formation. The host carbonate is white and gray, fine-grained limestone overlain by thin-bedded limy shales (Jensen and King, 1999). The main ore zone is a few feet wide and extends about 50 ft along strike. The primary ore averages about 10% Sb as stibnite, which is typically fresh in the quartz vein, but has been oxidized (stibiconite?) in the vein walls and adjoining carbonate wallrocks (USGS Model 27d). The deposit also contains trace Cu, Pb, As, Ag, and Au (Doelling, 1980).

The main base metal occurrences, the Baker mine (Cu-Pb-Ag) and Copper Blossom mine (Cu-Pb-Zn-Ag), are both on the same northeast-trending, southeast-dipping fault zone about a mile north of the Dry Lake Sb mine. The Baker mine is farther east and up section in the Ordovician Garden City Formation and the Copper Blossom is lower on the mountain in the Cambrian Nounan Formation. These deposits are principally associated with Fe-oxide-stained brecciated zones and calcite veins. Toward the north end of the district the Cataract Canyon (Pb-Zn) prospects are also located along northeast-trending fault zones in the Cambrian to Silurian carbonates (Doelling, 1980; Jensen and King, 1999). No intrusive igneous rocks are recognized in the district.

Doelling, H.H., 1980, Geology and mineral resource of Box Elder County, Utah: Utah Geological and Mineral Survey Bulletin 115, 251 p.

Jensen, M.E., and King, J.K., 1999, Geologic map of the Brigham City 7.5-minute quadrangle, Box Elder and Cache Counties, Utah: Utah Geological Survey Map 173, 46 p.

BRADSHAW DISTRICT

The Bradshaw mining district occupies the southwestern slopes of the Mineral Mountains in southeastern Beaver County, about 15 mi west-southwest of Beaver. The district was discovered in the 1870s and was a modest intermittent Ag-Au-Pb producer for nearly a century. Total district metal production at modern metal prices is estimated at $9 million. The largest mines in the district are the Cave and Hecla mines.

The Bradshaw district lies on the Wah Wah-Tushar mineral belt in the Basin and Range Province. The Mineral Mountains expose a large (78 sq mi), composite Oligocene-Miocene (25 to 17 Ma) granite, monzonite, and syenite batholith, the largest exposed batholith in Utah. The main granitic phase of the Mineral Mountains batholith has an interpreted age of about 18 to 17 Ma. The batholith has been strongly rotated to the east (40°–85°), so that the east side of the mountain is near the paleo-top of the batholith. This rotation is evident from the steep easterly dip of the Bullion Canyon Volcanics (29–22 Ma) on the east flank of the range (Rowley and others, 2005).

The Bradshaw district production has come primarily from cave-filling or replacement deposits in the Devonian and Mississippian carbonates at the Cave and Hecla mines, respectively (USGS Model 22c), just south of the southern margin of the Mineral Mountain granite batholith. Production has been approximately 11,000 tons averaging a recovered grade of about 926 ppm Ag, 9.6 ppm Au, 4.5% Pb, and minor Cu-Zn. The primary metallic minerals are pyrite, galena, chalcopyrite, sphalerite, argentite, and locally scheelite (Earll, 1957).

Earll, F.N., 1957, Geology of the central Mineral Range, Beaver County, Utah: Salt Lake City, University of Utah, Ph.D. dissertation, 112 p.

Rowley, P.D., Vice, G.S., McDonald, R.E., Anderson, J.J., Machette, M.N., Maxwell, D.J., Ekren, E.B., Cunningham, C.G., Steven, T.A., and Wardlaw, B.R., 2005, Interim geologic map of the Beaver 30' x 60' quadrangle, Beaver, Piute, Iron, and Garfield Counties, Utah: Utah Geological Survey Open-File Report 454, scale 1:100,000 map, 27 p.

BROKEN RIDGE DISTRICT

The Broken Ridge mining district is located about 40 mi northwest of Cedar City in northwestern Iron County. The area's mineral potential was not recognized until the 1970s. Broken Ridge has no history of mineral production, but the area has been prospected for alunite, U, Mo, and Sn.

Broken Ridge is situated in a low range of mountains northwest of the Escalante Desert in the Basin and Range Province. Mineralization is related to Miocene bimodal magmatism and the onset of extension and continental rifting. This magmatism, in conjunction with a series of northeast-trending normal and strike-slip faults, developed in a northeast-trending zone from Modena to Milford. This zone, which includes the Bible Springs fault zone, has coeval rhyolitic plugs, dikes, and flow domes of the Steamboat Mountain Formation (~12 Ma) which unconformably overlies tilted/rotated Oligocene volcanics and older rocks. Geochemical levels of Mo, Sn, and other lithophile elements are reported from stream sediment samples covering a 19-sq-mi area around Broken Ridge (Tucker and others, 1981; Duttweiler and Griffitts, 1989).

A 3-mi-diameter, cauldron-like depression, covering the southern end of Broken Ridge is filled with Steamboat Mountain Formation rhyolite. The large Mountain Spring rhyolite dome straddles the southern margin of this cauldron-like feature. Steamboat Mountain rhyolite phenocrysts at Broken Ridge are typically smoky quartz, sanidine, plagioclase, and minor biotite. Compositionally, the leucocratic alkali rhyolites average just over 75% SiO_2, 4.8% K_2O, and 1100 ppm F, and are garnet- and topaz-bearing. The petrochemistry of these rhyolites is like that of Climax porphyry Mo systems. Scattered areas of argillic and advanced argillic alteration of the Steamboat Mountain Formation occur along the Bible Springs fault zone and on Broken Ridge, particularly near the Mountain Spring dome. Rock-chip samples from the Broken Ridge area, chiefly near the Mountain Spring dome, are strongly anomalous in Mo, Sn, W, B, Be, Bi, F, Li, Mn, Pb, Sb, Th, U, and Zn (Tucker and others, 1981; Duttweiler and Griffitts, 1989).

The Broken Ridge area displays some of the characteristics expected at the top of a porphyry Mo system including: (1) the petrochemistry of the rhyolites on Broken Ridge, (2) a strong rock-chip lithophile geochemical signature, (3) extensive hydrothermal alteration at the surface, and (4) the presence of the large Mountain Spring dome suggesting a cupola at depth.

Duttweiler, K.A., and Griffitts, W.A., 1989, Geology and geochemistry of the Broken Ridge area, southern Wah Wah Mountains, Iron County, Utah: U.S. Geological Survey Bulletin 1843, 32 p.

Tucker, J.D., Miller, W.R., Motooka, J.M., and Hubert, A.E., 1981, A geochemical investigation of a known molybdenum-tin anomaly in southwestern Utah: U.S. Geological Survey Open-File Report 81-576, 77 p.

BROWNS HOLE-UPPER KANE CREEK DISTRICT

The Browns Hole-Upper Kane Creek mining district is in northern San Juan County about 14 mi southeast of Moab. Little has been written on the deposits in the Browns Hole-Upper Kane Creek district; it is one of several districts that make up the Moab U mining area. The Browns Hole-Upper Kane Creek district was a significant U-V producer and accounted for 85%–90% of the Morrison production from the Moab U area. Total district metal production at modern metal prices is estimated at $26 million. Nearly 60% of this production came from the Yellow Circle group (Doelling, 1974).

The Browns Hole-Upper Kane Creek district lies in the Hatch syncline section of the Colorado Plateau province. The district is separated from the Brumley Ridge district to the northeast by the Spanish Valley collapsed salt anticline. The Browns Hole-Upper Kane Creek mine workings are primarily rim cuts and inclines in the Salt Wash Member of the Upper Jurassic Morrison Formation, which is exposed around three sides of Black Ridge. Most of the U-V orebodies are found about 100 to 180 ft above the base of the Salt Wash Member with the best deposits in the thickest sections of Salt Wash sandstone (USGS Model 30c). Ore is typically associated with masses of carbonized vegetal matter and the principal ore minerals are carnotite and vanoxite (Doelling, 1969, 1974).

Production records for the Upper Kane Creek-Browns Hole district are difficult to compile because most production summaries combine production from the whole Moab U mining area. Nonetheless, the district is estimated to have produced approximately 74,000 tons of ore containing 415,000 pounds U_3O_8 and 2,250,000 pounds V_2O_5 at an average grade of 0.28% U_3O_8 and 1.52% V_2O_5 (Doelling, 1974).

Doelling, H.H., 1969, Mineral resources, San Juan County, Utah and adjacent areas, Part II—Uranium and other metals in sedimentary host rocks: Utah Geological and Mineralogical Survey Special Study 24, 64 p.

Doelling, H.H., 1974, Uranium-vanadium occurrences of Utah: Utah Geological and Mineral Survey Open-File Report 18, unpaginated.

BROWNS PARK DISTRICT

The Browns Park (Red Creek) mining district lies on the northeasternmost corner of the Uinta Mountains, 12 mi east of Dutch John, Daggett County. Copper mineralization in the Browns Park–Red Creek area was recognized as early as the John Wesley Powell survey (Powell, 1876). The poorly documented district is characterized by a series of small Cu and Cu-U prospects having no recorded production. The Jessie Ewing Canyon claim has the most extensive workings.

The Uinta Mountains are geologically situated in the Middle Rocky Mountain province. The Browns Park district lies on the East Uinta arch and mineralization is hosted in the Red Creek Quartzite. The Red Creek Quartzite spans the Archean-Proterozoic boundary and primarily contains metaquartzite, mica schist, and amphibolite (Sprinkel, 2006). Sparse Cu mineralization occurs in veins, faults, and fractures. The primary Cu mineral is probably chalcopyrite, but oxidation has resulted in malachite, azurite, brochantite, bornite, and chalcocite. Mineralization may be accompanied by quartz, calcite, and hematite (Butler and others, 1920). The Cu ores in the Jessie Ewing Canyon area near Band Box Butte have anomalous Ag, Au, and Bi. The Yellow Canary Cu-U prospect has carnotite and tyuyamunite (Wilmarth, 1953).

Butler, B.S., Loughlin, G.F., Heikes, V.C., and others, 1920, The ore deposits of Utah: U.S. Geological Survey Professional Paper 111, 672 p.

Powell, J.W., 1876, Geology of the eastern portion of the Uinta Mountains and a region of country adjacent thereto: U.S. Geological and Geographical Survey of the Territories, 218 p.

Sprinkel, D.A., 2006, Interim Geological map of the Dutch John 30'x 60' quadrangle, Daggett and Uintah Counties, Utah, Moffat County, Colorado, and Sweetwater County, Colorado: Utah Geological Survey Open-File-Report 491DM.

Wilmarth, V.R., 1953, Yellow Canary uranium deposits, Daggett County, Utah: U. S. Geological Survey Circular 312, 8 p.

BRUMLEY RIDGE DISTRICT

The Brumley Ridge district lies 14 mi southeast of Moab in northernmost San Juan County. The district lies on the west flank of the La Sal Mountains and is part of the larger Moab U mining area. The history of the district is poorly documented. Brumley Ridge has been a small U-V producer with total district metal production at modern metal prices is estimated at $826,000. The largest mines are the Red Devil and Renegade (Doelling, 1969, 1974).

Brumley Ridge lies in the Paradox Basin on the Colorado Plateau. The U-V ores of the district are hosted in the Upper Jurassic Salt Wash Member of the Morrison Formation (USGS Model 30c). The strata generally dip west, away from the Oligocene (~28.5 Ma), calc-alkaline, La Sal Mountain laccolithic complexes. Although the area is highly faulted, the faults are post-mineral, related to laccolithic emplacement.

As with other Salt Wash-hosted districts, the thickest sandstone channels typically contain the largest deposits, and orebodies are associated with gray and brown reduced zones and accumulations of carbonaceous trash. The orebodies are oxidized, and the principal ore minerals are carnotite and tyuyamunite, which are often associated with celadonite and malachite. The average grades are 0.39% U_30_8 and 1.8% V_2O_5 (Doelling, 1969, 1974).

Doelling, H.H., 1969, Mineral resources, San Juan County, Utah and adjacent areas, Part II—Uranium and other metals in sedimentary host rocks: Utah Geological and Mineralogical Survey Special Study 24, 64 p.

Doelling, H.H., 1974, Uranium-vanadium occurrences of Utah: Utah Geological and Mineral Survey Open-File Report 18, unpaginated.

BULL VALLEY DISTRICT

The Bull Valley mining district is in the rugged Bull Valley Mountains of northwestern Washington County, about 26 mi north-northwest of St. George. The district was organized in 1903 but no production has been recorded. However, some exploration was carried out by the U.S. Bureau of Mines in the 1940s with some additional drilling by U.S. Steel in the 1950s. Little work has been reported in the last half century. The Pilot Fe deposit has had the bulk of the exploration and has the largest known Fe resource in the district (Bullock, 1970).

The Bull Valley district lies on the Miocene-age, east-northeast-trending Iron axis of the Basin and Range Province. The Iron axis is a Sevier-age anticline intruded by Miocene quartz monzonites. In broad terms, the geology of the district is Jurassic and Cretaceous sedimentary strata overlain by a series of Miocene volcanic rocks. The sedimentary rocks in the district are passively intruded by an east-northeast-trending series of three small, Miocene (22 Ma) quartz monzonite porphyry stocks. This whole package is cut by a series of east-west-trending strike-slip faults, mostly having right-lateral displacement. The units exposed in the district are predominantly the Jurassic Carmel Formation carbonate and sandstone including the Homestake Limestone Member, Cretaceous Iron Springs Formation sandstone and shale, and Miocene Rencher Formation quartz latitic, welded, crystal-rich, ash-flow tuff and tuff breccia. The Homestake Limestone Member is the main host in the large Iron Springs Fe district to the northeast. The Bull Valley quartz monzonite porphyry stock, the largest of the three stocks, is a fine-grained quartz monzonite having phenocrysts of plagioclase, hornblende, and augite in a groundmass of quartz, K-spar, magnetite, apatite, zircon, and titanite. The stock domed the sedimentary rocks until it ultimately erupted violently producing a finer grained vent phase and the coeval Rencher Formation volcanics (Bullock, 1970; Biek and others, 2009).

The Bull Valley Fe orebodies are principally contact metasomatic deposits, breccia fillings and replacements, and veins associated with the porphyry stocks. The most important deposit in the district, the Pilot orebody, is a contact metasomatic-hydrothermal replacement of volcanics with thin intercalated limestones adjacent to the Bull Valley stock. The ores occur in volcanic xenoliths and limestone and volcanic replacements along the northeast margin of the stock. The ore zone dips north at about 20°. The Pilot orebody is an irregularly shaped zone, 400 ft thick and 1000 ft wide, and has been followed 900 ft or more down dip. Drill intersections range from 10% to 60% Fe. The main reported ore mineral is hematite with lessor magnetite and martite in a gangue of quartz, calcite, and apatite. A magnetic high covers the down dip extension of this orebody, despite the predominance of hematite in the orebody. The Pilot deposit has a subeconomic inferred resource of 15 to 20 million tons at 30.7% Fe (Bullock, 1970).

Biek, R.F., Rowley, P.D., Hayden, J.M., Hacker, D.B., Willis, G.C., Hintze, L.F., Anderson, R.E., and Brown, K.D., 2009, Geologic map of the St. George and east part of the Clover Mountains 30' x 60' quadrangles, Washington and Iron Counties, Utah: Utah Geological Survey Map 242, 2 plates, 101 p., scale 1:100,000.

Bullock, K.C., 1970, Iron deposits of Utah: Utah Geological and Mineralogical Survey Bulletin 88, 101 p., l plate.

CALF MESA DISTRICT

The Calf Mesa district of the San Rafael Swell U mining area is 29 mi west of Green River in central Emery County. Mineralization was initially discovered in the late 1940s and the district became a minor U producer with operations continuing into the 1970s. Total district metal production at modern metal prices is estimated at $73,000. The largest producer was the Dexter #7 underground mine.

Calf Mesa is geologically situated in the northern San Rafael Swell of the Colorado Plateau. The San Rafael Swell is an asymmetric, doubly plunging anticline, having a very steeply dipping east limb. Mineralization in the Calf Mesa district is predominantly hosted in the Upper Triassic Moss Back Sandstone Member of the Chinle Formation (USGS Model 30c). The Chinle consists of three fining-upward, fluvial-lacustrine sandstone sequences of which the Mossback Sandstone is the middle member. Sedimentological work on the Chinle suggests northwest-trending transport from a braided-stream environment in the southeast to floodplain and lacustrine environments progressively further to the northwest (Mickle and others, 1977).

The U ±V ores of the district occur in the very gently (1° to 4°) northerly dipping Chinle Formation. The major host is the Moss Back Member, but U prospects are also found elsewhere in the Chinle. Mineralization is typically developed in tabular lenses in the basal parts of paleochannels, and orebodies are mostly less than 2000 tons. The primary ore minerals are uraninite, "asphaltite", pyrite, and chalcopyrite occurring interstitial to sand grains and associated with bleaching of the sandstone and mudstone. In addition to U-V, the ores may also be anomalous in Ag, As, Cu, and Mo (Mickle and others, 1977; Gloyn and others, 2003).

Gloyn, R.W., Tabet, D.E., Tripp, B.T., Bishop, C.E., Morgan, C.E., Gwynn, J.W., and Blackett, R.E., 2003, Energy, mineral, and ground-water resources of Carbon and Emery Counties, Utah: Utah Geological Survey Bulletin 132, 161 p., 14 plates, scale 1:855,000 approximately.

Mickle, D.G., Jones, C.A., Gallagher, G.L., Young, Patti, and Dubyk, W.S., 1977, Uranium favorability of the San Rafael Swell area, east-central Utah: U.S. Department of Energy Report GJBX-72(77), 120 p., 3 plates.

CANNONVILLE DISTRICT

The Cannonville district is in north-central Kane County, 12 mi south-southeast of Tropic. The district encompasses three small sediment-hosted Cu and Pb prospects and had an insignificant amount of Pb production in the 1930s (Doelling and others, 1989).

The Cannonville district is situated in the Grand Staircase section of the Colorado Plateau. All prospects are hosted in the Thousand Pockets Tongue of the Middle Jurassic Page Sandstone. The Rock Springs Pb ±Cu deposit is the site of the minor historical Pb production in the district. The workings consist of a short shaft and adit. The mineralization was in small, limonite-stained, irregular pods in the yellow sandstone. A select sample of mineralized material at Rock Springs contained >2% Pb, 1.9% Zn, and 20 ppm Ag (U.S. Geological Survey National Geochemical Database). The total recorded production was just 850 lbs of Pb (Doelling and others, 1989). At the Ridge Copper prospect, spotty Cu mineralization covers a 50 by 1500 ft area. A high-grade sample of mineralized rock contained 10.4% Cu, 1.1% Pb, and 5.3 ppm Ag (Brown and Hannigan, 1986). The Bullet Shafts area has a couple of shafts and a small prospect pit. A select sample from a small stockpile contained 6.3% Cu, 9.7% Pb, and 5.9 ppm Ag (Brown and Hannigan, 1986). Mineralization at these small mines and prospects generally consists of limonite-stained sandstone with iron nodules, galena, anglesite, cuprite, malachite, and Cu pitch (Doelling and others, 1989).

Brown, S.E., and Hannigan, B.J., 1986, Mineral investigations of a part of the Paria-Hackberry Wilderness Study Area (UT-040-247), Kane County, Utah: U.S. Bureau of Mines Open-File Report MLA 34-86, 25 p.

Doelling, H.H., Davis, F.D., and Brandt, C.J., 1989, The geology of Kane County, Utah—geology, mineral resources, geologic hazards: Utah Geological and Mineral Survey Bulletin 124, 192 p., 10 plates, scale 1:100,000.

CARBONATE DISTRICT

The Carbonate mining district is in northern Uintah County, about 25 mi north of Vernal. The mineral deposits in the district were initially discovered in the late 1880s. The district was a significant Cu-Ag producer in the 1890s and early 1900s. In the 1940s and 1950s, some Pb-Zn-Ag ore was produced from the district. Total district metal production at modern metal prices is estimated at $9 million. Most of the workings occur above an elevation of 9000 ft.

The Carbonate district is geologically situated on the southeastern flank of the Uinta Mountains of the Middle Rocky Mountain province. The district consists of a few small mines and several prospects in a thin, gently (5° to 20°) south-southeast-dipping section of Cambrian and Mississippian carbonate rocks sitting on top of Neoproterozoic Uinta Mountain Group sandstones. Major faulting and igneous rocks are not recognized in the district.

Most of the ores are replacement deposits in silty-sandy limestone of the Lower Mississippian Madison (?) Limestone. The largest producer was the Dyer Cu mine which accounted for several hundred tons of 50% Cu with some byproduct Ag. The orebodies are small, irregular "pockets" of primary chalcocite and possibly bornite with little pyrite. In addition to Cu-Ag, the ore is anomalous in F, Zn, Pb, As, Sb, Hg, and Mo, in decreasing order of importance (Conn, 2005).

The Pope Fe mine is located a few hundred feet downslope from the Dyer at the contact between the Cambrian Lodore Formation limestone and the underlying Uinta Mountain Group sandstone and shale. The Pope ores are red hematite to specularite with minor magnetite.

The Silver King mine, a mile to the south of the Dyer, produced a few tons of hand cobbed, Pb-Zn-Cu-Ag-Au ore from a replacement deposit in a higher section of the Madison Limestone. The primary ore minerals are galena and sphalerite with little pyrite. Silver King ore samples are also anomalous in As, Sb, and Hg (Conn, 2005).

Conn, G.R., 2005, Potential economic mineralization in the Uinta Mountains, northeastern Utah, in *Dehler, C.M., Pederson, J.L., Sprinkel, D.A., and Kowallis, B.J., editors, Uinta Mountain Geology: Utah Geological Association Publication 33, p. 369–384.*

CEDAR MOUNTAIN DISTRICT

The Cedar Mountain mining district is on the north end of the San Rafael Swell in Emery County about 25 mi east-northeast of Castle Dale. The district is a poorly documented series of small U, Mn, and Cu prospects. Cedar Mountain is an insignificant U-V producer and a total of about 20 tons of ore has been shipped. The only producers are the Cottonwood No. 1 and Cedar Ridge #2 U-V mines.

The Cedar Mountain district is geologically situated in the San Rafael Swell on the Colorado Plateau. The sandstone U-V deposits (USGS Model 30C) are primarily hosted in the Upper Jurassic Morrison Formation. The principal ore minerals are tyuyamunite and carnotite. The sedimentary Mn deposits (USGS Model 34B) are all in the Cretaceous Cedar Mountain Formation (Baker and others, 1952). The main ore minerals are pyrolusite and psilomelane with minor limonite, hematite, and barite. The small Cu vein and stratabound replacement deposits are either in the Jurassic Navajo Sandstone or the overlying Carmel Formation. The Cu-bearing faults trend N. 70° E. to N. 80° E. and the only reported ore minerals are malachite and azurite. Few references to these prospects are found outside the Utah Mineral Occurrence System (UMOS).

Baker, A.A., Duncan, D.C., and Hunt, C.B., 1952, Manganese deposits of southeastern Utah: U.S. Geological Survey Bulletin 979-B, p. 63–157.

CIRCLE CLIFFS DISTRICT

The Circle Cliffs district, part of the Henry Mountains U mining area, is located about 27 mi east of Escalante in east-central Garfield County. The district is a modest U-V producer with a poorly documented history. The district was in production from about 1956 to 1965. Total district metal production at modern metal prices is estimated at $2.4 million. The largest operation is the Rainy Day underground mine on the east side of the district, which accounts for about 70% of the district's production. The Horsehead and Centipede mines account for most of the rest.

The Circle Cliffs district is geologically situated in the Escalante Canyons section of the Colorado Plateau in south-central Utah. The district's mines flank the doubly plunging, north-northwest-trending Circle Cliffs anticline. The west limb of the fold dips gently (5° to 10°) west and the eastern limb, known as the Waterpocket fold, is steeper (10° to 35°). The anticline plunges gently to the northwest and southeast. The exposed rocks range from Permian in the eroded core of the fold to Cretaceous around the rim (Doelling, 1974).

The bulk of the Circle Cliffs' U-V ±Cu prospects and production is associated with the Upper Triassic Chinle Formation, although there are also U-V occurrences in the Upper Jurassic Morrison Formation on the east flank of the district (USGS Model 30c). The Triassic-hosted ores are primarily in basal Shinarump Conglomerate Member of the Chinle Formation channels where it has cut down into the underlying Moenkopi Formation. The Shinarump channels snake northward across the district. Mineralized rock typically ranges from 0.05% to 0.20% U3O8, 0.15% V2O5, and 0.5% to 0.3% Cu (Doelling, 1974).

Most of the deposits are small and irregular in shape, and the largest mine in the district, the Rainy Day mine, is a remarkable shoestring-shaped orebody of less than 6 square ft in cross-sectional area but mined for an extraordinary 1800 ft in length along the steep, southern Shinarump channel-fill and Moenkopi shale contact. No ore occurs in the adjoining large, open Shinarump channel despite abundant carbonaceous trash. The primary ore and sulfide minerals include uraninite, roscoelite, sphalerite, chalcopyrite, pyrite, marcasite, and galena (Davidson, 1959). Both the Rainy Day and Colt Mesa mines have the pink Co mineral erythrite. The Mo mineral ilsemannite is reported from the Rainy Day mine. In addition to U-V ±Cu, the Circle Cliffs district ores are geochemically anomalous in Ag, Co, Mo, Pb, Zn, Y, and Yb.

Much of the southern and eastern parts of the Circle Cliffs district is in Capital Reef National Park, Glen Canyon National Recreation Area, and Grand Staircase Escalante Canyons National Monument.

Davidson, E.S., 1959, Geology of the Rainy Day uranium mine, Garfield County, Utah: Economic Geology, v. 54, p. 436–448.

Doelling, H.H., 1974, Uranium-vanadium occurrences of Utah: Utah Geological and Mineral Survey Open-File Report 18, unpaginated.

CITY CREEK DISTRICT

The City Creek (Hot Springs) mining district is in southeastern Davis and northeastern Salt Lake Counties about 8 mi northeast of Salt Lake City. Little geological information is available on the district. The district was organized in 1870 and became an insignificant Fe producer with some nominal Pb-Ag production. The district's peak production was likely before 1900. The Burro Fe mine is believed to be the largest producer (Huntley, 1885; Butler and others, 1920).

The City Creek district is situated in the Wasatch Range of the Middle Rocky Mountain province. While most of the mines and prospects exploit small, oxidized Pb-Zn-Ag deposits, the Burro Fe mine is reportedly the principal producer. According to Gloyn and others (1995) dump samples from the base and precious metal mines in the district contained anomalous to ore-grade Pb-Zn-Ag; ranging up to 10% Pb, 20% Zn, and 205 ppm Ag. Prospects on the southwest side of the City Creek district contained up to 0.8% Cu. The district's ores occur as veins in the Neoproterozoic Farmington Canyon Complex or as vein and replacement deposits in Cambrian, Devonian, or Mississippian carbonate strata. The primary ore minerals are Fe oxides, galena, sphalerite, and chalcopyrite (Gloyn and others, 1995).

Butler, B.S., Loughlin, G.F., Heikes, V.C., and others, 1920, The ore deposits of Utah: U.S. Geological Survey Professional Paper 111, 672 p.

Gloyn, R.W., Shubat, M.A., and Mayes, B.H., 1995, Mines and prospects in and around the Farmington Canyon Complex, northern Utah: Utah Geological Survey Open-File Report 325, 30 p.

Huntley, D.B., 1885, The mining industries of Utah, in *Emmons, S.F., and Becker, G.F., Statistics and Technology of the Precious Metals, Tenth U. S. Census—1880, v. 13, p. 405–422.*

CLEAR CREEK DISTRICT

The Clear Creek mining district lies in northwestern Box Elder County, about 29 mi west of Snowville. The district is an insignificant Ag-Pb producer. Ginza Mines is the only known producer.

The Clear Creek mining district lies on the northeastern flank of the Albion-Raft River-Grouse Creek metamorphic core complex of the Basin and Range Province. The geology of the district is complex, and the bulk of the old mine workings are scattered across a northerly trending ridge about 1.5 mi south-southwest of Clear Creek village. Doelling (1980) reports a series of short adits driven into Neoarchean Green Canyon Complex quartzite, schist, and amphibolite. The primary mineralization is chalcopyrite-bornite in small quartz veins. These veins occur on the margins of a leucocratic trondhjemite (quartz-sodium plagioclase "granite"). This intrusive is of indeterminate age with dates ranging from Neoarchean to Cretaceous. Most of the mineralization (Cu-Au-Ag) consists of minor Cu- and Fe-stained veins along a schist-quartzite contact (Doelling, 1980).

Another short adit, a mile northwest of Clear Creek village, is driven into a gossan developed in a brecciated marble. The host rock is believed to belong to either the Ordovician Pogonip Group or Pennsylvanian Oquirrh Group. The mineralized zone is just a few feet thick (Doelling, 1980).

Doelling, H.H., 1980, Geology and mineral resources of Box Elder County, Utah: Utah Geological and Mineral Survey Bulletin 115, 251 p.

COAL CLIFFS DISTRICT

The Coal Cliffs district is in west-central Emery County, about 5 mi southeast of Emery. The district has no recorded production but hosts a series of very poorly explored Ti-Zr black sand paleoplacer deposits (Dow and Batty, 1961; Gloyn and others, 2003).

The Coal Cliffs district is geologically situated on the west flank of the San Rafael Swell on the Colorado Plateau. The deposits are hosted in the basal Ferron Sandstone Member of the Upper Cretaceous Mancos Shale. Seven small, flat lying, beach paleoplacer deposits occur on two parallel northwest-trending belts across sections 29, 30, and 32, T. 22 S., R. 7 E. The deposits are exposed on a cliff and have an average thickness of 5 ft, widths of 90 to 280 ft, and their lengths are indeterminant due to overlying cover. The deposits are dark purple, fine-grained, and well cemented with hematite and carbonate. The mineralogy is believed to be ilmenite, zircon, magnetite, quartz, and monazite (USGS Model 39c). Three samples from the exposed paleoplacer deposits average 12.6% TiO_2, 1.8% ZrO_2, 33.4% Fe, and 0.1% ThO_2 (Dow and Batty, 1961). The radiometric anomaly associated with the deposits continues on the same trend northwest into sections 18 and 19, T. 22 S., R. 7 E. and section 13, T. 22 S., R. 6 E. There has been no reported drill testing of the deposits or their potential extensions (Gloyn and others, 2003).

Dow, V.T. and Batty, J.V. 1961, Reconnaissance of titaniferous sandstone deposits of Utah, Wyoming, New Mexico, and Colorado: U.S. Bureau of Mines Report of Investigations 5860, 52 p.

Gloyn, R.W., Tabet, D.E., Tripp, B.T., Bishop, C.E., Morgan, C.E., Gwynn, J.W., and Blackett, R.E., 2003, Energy, mineral, and ground-water resources of Carbon and Emery Counties, Utah: Utah Geological Survey Bulletin 132, 161 p.

COLUMBIA-EAST ERICKSON DISTRICT

The Columbia-East Erickson mining district is in southeastern Tooele County, about 22 mi west of Eureka. The district has been a modest Pb-Mn producer. The Columbia-East Erickson mining district produced a small tonnage of Pb-Ag, Mn, and Fe ores sporadically from about 1871 to 1917, and total metal production at modern metal prices is estimated at $2.3 million. The Sharp Pb-Ag underground mine is the primary producer.

The Sheeprock Mountains are geologically situated in the Basin and Range Province of west-central Utah. The range is composed of a thick sequence of northeast-dipping Neoproterozoic Sheeprock Group quartzite, metaconglomerate, and slate on the northeast flank of the range intruded by the Miocene (20.9 Ma) Sheeprock granite on the southwest flank. The intrusion is a high-silica granite (Christiansen and others, 1991). The range has been rotated eastward by post-intrusive listric extensional faulting so that a deeper level of the early Miocene Sheeprock mineralizing system is exposed on the southwest and higher levels are exposed on the northeast. In general, the "lower" (southwest) half of the granite is medium grained porphyritic and the "upper" (northeast) half is fine-grained porphyritic (Richardson, 2004).

The 7.8-sq-mi, red, oxidized Sheeprock granite has a 1.4-sq-mi highly differentiated "white facies" core containing smoky quartz and blue beryl (Christiansen and others, 1991; Richardson, 2004). The granite has ilmenite, magnetite, muscovite, zircon, apatite, monazite, thorite, uraninite, fluorite, samarskite, and topaz as accessory minerals. There are also small pegmatites and aplite dikes. The "white facies" is known to be enriched in Be, Th, and heavy rare earth elements (Richardson, 2004). Beryl occurs as (1) disseminated grains, (2) rosettes of radiating crystals as much as 2 ft in diameter, (3) in tiny, but massive seams/veins, and (4) in small aplite dikes and quartz veins. Minor danalite is also reported.

Narrow, northeasterly trending greisen veins (quartz, muscovite, fluorite, hematite, magnetite, galena, sphalerite, and rare topaz) host weak Sn-W (cassiterite-wolframite-huebnerite) mineralization cutting the granite (USGS Model 15c) (Christiansen and others, 1991). The northwest and southeast sides of the granite have been prospected for Cu-F-U ±W mineralization, and the area northeast of ("above") the granite has primarily produced minor Pb-Zn-Ag-Mn (specularite) mineralization. Seven U.S. Geological Survey National Geochemical Database samples near the Sheeprock Granite assay over 100 ppm Sn.

Christiansen, E.H., Wu, L.M., and Rogers, J.R., 1991, Crystallization conditions for a Be- and Y-rich granite—the Sheeprock granite of west-central Utah: Utah Geological and Mineral Survey Contract Report 91-6, 105 p.

Richardson, P.D., 2004, Pluton zonation unveiled by gamma ray spectrometry and magnetic susceptibility—the Sheeprock granite, western Utah: Provo, Utah, Brigham Young University, M.S. thesis, 72 p.

CONFIDENCE DISTRICT

The Confidence (Eagle Valley district, Nevada) mining area lies in the southern White Rock Mountains of northwesternmost Iron County, about 61 mi northwest of Cedar City. No production has been recorded in the Confidence district (Tingley and Castor, 1991); however, the district has been prospected for Au-Ag. The Utah portion of the Confidence district was drilled on three separate occasions in the 1980s and 1990s.

The Confidence district lies on the Blue Ribbon lineament in the Basin and Range Province. The area is underlain by a series of Oligocene-Miocene volcanic rocks. The main mineralized feature is the west-northwest-trending Confidence Au-Ag vein with the largest development at the Confidence mine, some 600 ft into Lincoln County, Nevada. The old Bergin Au-Ag mine lies on the southeastern projection of the Confidence vein in Utah (USGS Model 25c). Mineralization at the Bergin mine is associated with an 80° southwest dipping quartz-calcite vein cutting Miocene-age rhyolite.

Tingley, J.V., and Castor, S.B., 1991, Mineral resources inventory, Bureau of Land Management, Schell resource area, Ely district, Nevada: Nevada Bureau of Mines and Geology Open-File Report 91-1, 138 p.

COTTON THOMAS BASIN DISTRICT

The Cotton Thomas Basin mining area is in the northern Goose Creek Mountains of northwestern Box Elder County, about 57 mi west of Snowville. The district has no recorded production but has been prospected for Pb-Zn-Ag.

The Cotton Thomas Basin prospects are situated in Tom Sherry Canyon in the Goose Creek Mountains of the Basin and Range Province. Cotton Thomas Basin is named after William P. (Cotton) Thomas, the first white settler/cattle rancher in the area. Virtually no published literature is available on the property, although a few newspaper accounts mention its initial development in 1900.

Mineralization at Cotton Thomas Basin consists of spotty, pyritic Pb-Zn-Ag vein/replacements (USGS Model 22c) in a small, structurally complex window of Paleozoic carbonates (Ordovician Pogonip Group and/or Pennsylvanian Oquirrh Group?). Much of the area is covered by a veneer of Tertiary and Quaternary alluvial cover. The mineralization has been explored by several short adits up to 150 ft in length and scattered prospect pits (Doelling, 1980). Gossanous, high-grade, dump-rock samples average about 200 ppm Ag, 8.4% Zn, and 3.3% Pb. As in the Ashbrook district, to the northwest, mineralization is probably related to Miocene (~13 Ma) granite and rhyolite porphyry intrusions and would likely postdate the major, older structural complexities of the Albion-Raft River-Grouse Creek metamorphic core complex.

Doelling, H.H., 1980, Geology and mineral resource of Box Elder County, Utah: Utah Geological and Mineral Survey Bulletin 115, 251 p.

COTTONWOOD WASH DISTRICT

The Cottonwood Wash district of the Monticello U mining area is in central San Juan County, about 6 mi west of Blanding. The district is a significant U-V producer. The U:V ratio averages 1:10 and the U grade runs just 0.16% U_3O_8 (Doelling, 1969). Gloyn and others (1995) list production for the Cottonwood Wash district at 896,000 pounds U_3O_8 and 5,664,000 pounds V_2O_5. Total district metal production at modern metal prices is estimated at $61 million. The largest producers are the Royal Flush and Simpatico underground mines.

The Cottonwood Wash district is geologically situated in the Paradox Basin section of the Colorado Plateau. The U deposits are hosted in the Upper Jurassic Morrison Formation, which is exposed in a north-south band between the Pennsylvanian-cored Monument Uplift to the west and the Blanding Basin to the east. The largest deposits all fall in an east-west-trending belt centered on the confluence of Cottonwood Wash and Brushy Basin Wash.

The U-V ores are hosted in the 210- to 245-ft-thick Salt Wash Member sandstones. The uranium deposits in the Cottonwood Wash district average 2 ft thick by 50 ft wide by 100 ft long. Mineralization occurs where permeable sandstone is interbedded with carbonaceous trash and mudstone lenses (USGS Model 30c). The ore deposits are unoxidized below the water table and are dominantly composed of intergranular uraninite and montroseite with an average lime (CaO) content of 6% (Doelling, 1969).

Doelling, H.H., 1969, Mineral resources, San Juan County, Utah and adjacent areas, Part II—Uranium and other metals in sedimentary host rocks: Utah Geological and Mineralogical Survey Special Study 24, 64 p.

Gloyn, R.W., Morgan, C.D., Tabet, D.E., Blackett, R.E., Tripp, B.T., and Lowe, M, 1995, Mineral, energy, and ground-water resources of San Juan County, Utah: Utah Geological Survey Special Study 86, 24 p., 14 plates, scale 1:500,000.

CRATER BENCH DISTRICT

The Crater Bench (Abraham or Baker Hot Spring) mining district is in south-central Juab County, about 19 mi north-northwest of Delta. The district was a small Mn producer in 1929–30. Total district metal production at modern metal prices is estimated at $246,000. The Iron King is the only mine known to have shipped ore from the district (Crittenden, 1951).

The Crater Bench district lies along the broader Deep Creek–Tintic mineral belt in the Basin and Range Province of western Utah. The district lies on the east flank of Crater Bench, a 7-mi-diameter, 600-ft-high, Pleistocene (0.9 Ma), basaltic shield volcano (Crittenden, 1951).

The mineralization at the Iron King mine occurs as a discrete Mn layer in an otherwise barren calcareous tufa mound about 1600 ft in diameter and 15 ft high (Callaghan and Thomas, 1939). The Mn occurs as a single thin lens interbedded with the barren porous calcite near the top of the tufa dome (USGS Model 25g). Average shipped grades are 20.8% Mn. The principal ore minerals are psilomelane and pyrolusite (Callaghan and Thomas, 1939). The mine workings consist of very shallow pits and trenches.

Callaghan, A.L., and Thomas, H.E., 1939, Manganese in a thermal spring in west-central Utah: Economic Geology, v. 34, p. 905–920.

Crittenden, M.D., Jr., 1951, Manganese deposits of western Utah: U.S. Geological Survey Bulletin, 979-A, 62 p.

CRATER ISLAND DISTRICT

The Crater Island mining district is in the northernmost Silver Island Mountains of southwestern Box Elder County, about 25 mi northeast of Wendover. The district has had a limited production of Au-Cu mostly from 1934 to 1948. Total district metal production at modern metal prices is estimated at $180,000. The Copper Blossom mine is the only recognized producer. The northern portion of Crater Island was explored for W in the 1970s, but there is no record of any production (Doelling, 1980). In the 1990s, the southern part of the district was explored by Franco Nevada Mining Corp. and Kennecott Exploration Co.

Crater Island consists of northerly trending Paleozoic sedimentary rocks cut by a series of north-trending normal faults and has Jurassic plutons (about 152 Ma) on both the north end (Sheepwagon porphyritic biotite granodiorite) and southern end (Crater Island quartz monzonite) of the range. The southern Crater Island stock has an extensive aeromagnetic high (especially in the pediment to the west of Donner-Reed Pass), while the magnetic expression of the northern Sheepwagon stock is much more subdued. These two plutons and associated dikes have produced broad zones of bleaching and recrystallization up to a half mile wide with narrow zones of calc-silicate development. Typical mineralization is associated with narrow, anhydrous, prograde, garnet-epidote ±diopside skarns adjacent to the Jurassic plutons (Miller and others, 1990). Skarn mineralization consists of either Cu-Au-Ag near the Crater Island stock (USGS Model 18b) or weak W-Mo adjoining the Sheepwagon stock (USGS Model 14a). Chalcopyrite and bornite are the primary Cu minerals in the Copper Blossom mine which averages about 0.5% Cu, 12 ppm Ag, and 0.3 ppm Au over a couple of feet. Doelling (1980) reports scheelite, powellite, molybdenite, and chalcopyrite in the northern skarns and grades of 0.13% to 0.34% WO_3 over 3 to 4 ft. One sample of ore from the Copper Blossom mine reported 0.61% Cu, 20.6 ppm Ag, and 686 ppb Au.

Argillization, silicification, and disseminated pyrite occur locally with granodiorite dikes along the northerly trending Sheepwagon fault zone (east-central Crater Island). Small jasperoids in this zone host weak Au-Ag-As-Bi-Sb-Te mineralization in the Mississippian Joana Limestone and Chainman Shale (Doelling, 1980; Miller and others, 1990).

Doelling, H.H., 1980, Geology and mineral resource of Box Elder County, Utah: Utah Geological and Mineral Survey Bulletin 115, 251 p.

Miller, D.M., Jordan, T.E., and Allmendinger, R.W., 1990, Geologic map of the Crater Island quadrangle, Box Elder County, Utah: Utah Geological and Mineral Survey Map 128, scale 1:24,000, 16 p.

CRICKET MOUNTAINS DISTRICT

The Cricket Mountains are in south-central Millard County, about 40 mi southwest of Delta. The mining district is a minor Pb-Ag producer and total recorded production for the area is just 60 tons of ore containing 17,000 pounds of Pb and 76 ounces of Ag. Total district metal production at modern metal prices is estimated at $18,000. The Rogers mine is the largest producer.

The Cricket Mountains are a north-northeasterly trending range in the Basin and Range Province of west-central Utah. Geologically, the range is primarily a moderately east-dipping (~25°) homoclinal sequence of Cambrian quartzites and carbonates. The weak Pb-Ag mineralization is hosted in the Middle Cambrian Howell Limestone. The ore consists of irregular blebs, replacements and stringers of galena in recrystallized massive limestone. Generally, fine- to medium-grained galena occurs as narrow hairline zones, veinlets, and in white, vuggy calcite veinlets. The ore is confined to moderately to strongly Fe-stained, massive limestone along minor fractures or narrow breccia zones that strike N. 50° E. and dip 70° NW. These mineralized structures do not parallel the main fault zones but are at angles of 30° to 50° to them and may represent tensional fractures. The in-place ore may contain as much as 8% to 10% galena, but mining usually produces much lower grades (Hintze, 1984). There are no intrusive igneous rocks recognized in the district and the ores do not have the high Ag:Pb ratio typical of intrusive-related ores.

Ferruginous quartzite is exposed as thin, discontinuous, horizons traceable for 2 to over 13 mi. These ferruginous beds occur in the quartzitic lower member of the Lower Cambrian Pioche Formation about 160 ft above the base (Hintze, 1984). Bullock (1970) reported that the ferruginous quartzite varies from 5 to more than 25 ft thick with an average thickness of about 18 ft, but Hintze (1984) reports thicknesses of only 3 to 6 ft for the most strongly hematitic portions. The ferruginous quartzite consists of fine- to coarse-grained, detrital quartz with hematite as grain coatings and void fillings. Thin-bedded quartzite is richer in Fe and contains more hematite as cement and as thin layers than the thicker bedded, more massive quartzite. The ores typically average about 20% Fe as hematite (Bullock, 1970).

Bullock, K.C., 1970, Iron deposits of Utah: Utah Geological and Mineralogical Survey Bulletin 88, 101 p., l plate.

Hintze, L.F., 1984, Geology of the Cricket Mountains, Millard County, Utah: U.S. Geological Survey Open-File Report 84-683, 23 p.

DAGGETT DISTRICT

The Daggett mining district is in northernmost Daggett County, just south of Manila and the Wyoming state line. The poorly documented district stretches east-west for about 40 mi along the north flank of the Uinta Mountains, but is only 4 mi wide. The first known mineral location in the district was made in 1897 and sporadic exploration continued into at least the 1920s. The district consists of a series of Fe and Mn occurrences and a lone Cu prospect, all having no recorded production. The Terry Cu mine is the most significant prospect (Hansen, 1965).

The Uinta Mountains are geologically situated in the Middle Rocky Mountain province. The Daggett district is elongated roughly along the Uinta fault zone, a major south-dipping thrust fault emplacing Neoproterozoic Uinta Mountain Group and older metamorphic rocks over Mississippian and younger sedimentary strata (Sprinkel, 2006). Most of the prospects are small, discontinuous, and irregular Fe and Mn replacements associated with faulting. Ore minerals include limonite, goethite, hematite, pyrolusite, and psilomelane (Bullock, 1970). The Terry Cu mine is developed in fine-grained sandstone of the Upper Triassic Chinle Formation in the lower plate of the Uinta fault zone. The Terry property has two older collapsed adits and one vertical and two inclined shafts up to 50 ft deep. The exposed Cu mineralization is malachite and azurite having minor limonite and hematite as thin coatings along overturned bedding planes dipping 60° S. (Hansen, 1965). The ore is strongly anomalous in As, Mo, Pb, Zn, and Ag.

The Daggett district is partially within the U.S. Forest Service Flaming Gorge National Recreation Area.

Bullock, K.C., 1970, Iron deposits of Utah: Utah Geological and Mineralogical Survey Bulletin 88, 101 p., l plate.

Hansen, W.R., 1965, Geology of the Flaming Gorge area, Utah-Colorado-Wyoming: U.S. Geological Survey Professional Paper 490, 196 p., 3 plates.

Sprinkel, D.A., 2006, Interim Geological map of the Dutch John 30' x 60'quadrangle, Daggett and Uintah Counties, Utah, Moffat County, Colorado, and Sweetwater County, Colorado: Utah Geological Survey Open-File-Report 491DM.

DEER FLAT DISTRICT

The Deer Flat mining district is located on the Monument Upwarp in central San Juan County, between the White Canyon district to the west and Elk Ridge district to the east. Copper prospecting began in the White Canyon area in the 1880s but led to little development. Uranium exploration and development began in the late 1940s with the first production from the Hideout No.1 mine in 1949. Total district metal production at modern metal prices is estimated at $45 million. Deer Flat is a significant U ±Cu producing district and Hideout No.1 is believed to be the largest producer.

The rocks of the Monument Upwarp, west of the Comb Ridge monocline, generally dip gently west at about 5°; however, very gentle monoclinal flexures may have influenced the location of ore at Deer Flat. The host stratum in the Deer Flat district is the Upper Triassic Shinarump Conglomerate Member of the Chinle Formation. Mineralization is typically associated with westerly flowing stream channels down-cutting into the underlying Moenkopi Formation mudstone (USGS Model 30c). Deposits are in the basal sandstone, tabular to lenticular, associated with carbonaceous trash, and contain from a few tons to more than 15,000 tons of ore. Productive orebodies are 2 to 10 ft thick, 50 to 150 ft wide, and 300 to 500 ft long (Doelling, 1974).

The ore minerals are fine grained, in the interstices of the sandstone, and associated with asphaltite and carbonaceous trash. The unoxidized ore/sulfide minerals are uraninite, chalcopyrite, bornite, domeykite, tennantite, pyrite, and less common galena and sphalerite. Vanadium only occurs in trace amounts. Gangue minerals include calcite, dolomite, manganosiderite, jarosite, limonite, gypsum, and barite. Ore grades average approximately 0.26% U_3O_8, 0.06% V_2O_5, and about 0.7% Cu. The underlying Moenkopi Formation mudstone is often bleached near orebodies (Finnel and others, 1963).

Doelling, H.H., 1974, Uranium-vanadium occurrences of Utah: Utah Geological and Mineral Survey Open-File Report 18, unpaginated.

Finnel, T.L., Franks, P.C., and Hubbard, H.A., 1963, Geology, ore deposits, and exploratory drilling in the Deer Flat area, White Canyon district, San Juan County, Utah: U.S. Geological Survey Bulletin 1132, 114 p.

DESERT MOUNTAIN DISTRICT

The Desert Mountain mining district is located 27 mi west-southwest of Eureka in central Juab County. The district has two parts, Desert Mountain itself and the Coyote Knoll and Allison Knolls area to the northeast. The district is a minor Ag-Cu producer. Total district metal production at modern metal prices is estimated at $15,000. The largest producers are the Rockwell Ag-Cu underground mine and Coyote Knoll Ag-Au open pit.

The Desert Mountain district lies on the Deep Creek–Tintic mineral belt of the Basin and Range Province. Desert Mountain proper is underlain by an exposed 14 sq mi, Oligocene granodiorite and granite intrusive complex, but aeromagnetic surveys suggest it is at least 30 sq mi. The early granodiorite is dark, fine-grained, with abundant plagioclase, biotite, and magnetite. The younger granite is light-colored, fine-grained, porphyritic, with abundant K-spar and quartz. The eastern margin of the Desert Mountain intrusive complex is cut by an arcuate caldera margin with down-dropped volcanic rocks to the east (Krahulec, 1996).

Ore deposits in the Desert Mountain district are generally small and mineralization is sporadic with little production. Minor production has come from the narrow Rockwell Ag-Cu vein on the west flank of Desert Mountain where a north-striking, moderately west-dipping vein is associated with a dike in granitic country rock. The Rockwell mine produced some 200 short tons of ore around 1905 and the best grade of ore contained approximately 5% Cu, 275 ppm Ag, and 0.17% U_3O_8. The ore/sulfide minerals include pyrite, chalcopyrite, barite, and possibly tetrahedrite and fluorite (USGS Model 22c). These ores are also anomalous in Au, Bi, Pb, and Zn. There are also some small, but intense areas of pervasive, greisen-like, quartz-muscovite-pyrite alteration in the intrusive complex, but no mineralization has been identified with these peculiar, texturally destructive alteration zones (Rees and others, 1973).

The Allison Knolls area to the northeast of Desert Mountain has had significant exploration drilling and limited development at the Coyote Knoll Ag-Au prospect. This prospect produced a few thousand tons of high-grade, low-sulfidation, Ag-Au quartz vein or strongly silicified pebble dike ore (USGS Model 25c) in and/or near the caldera margin fault from a small open cut. The vein averages about 10 ft thick, strikes east-northeast, and dips moderately to the north. Alteration is primarily silicification transitioning outward to argillic alteration of the host volcanics. Ore minerals include native silver, horn silver, native gold, and covellite. The ore is estimated to average about 330 ppm Ag and 1.9 ppm Au and is only weakly anomalous in Sb, Cu, Pb, As, and Zn.

Krahulec, K., 1996, Geology and geochemistry of the Southwest Tintic porphyry copper system, Tintic mining district, Juab County, Utah, in *Green S.M., and Struhsacker, E., editors, Geology and ore deposits of the American Cordillera: Reno, Geological Society of Nevada Field Trip Guidebook Compendium, p. 62–78.*

Rees, D.C., Erickson, M.P., and Whelan, J.A., 1973, Geology and diatremes of Desert Mountain, Utah: Utah Geological and Mineralogical Survey Special Studies 42, 12 p.

DRUM MOUNTAIN DISTRICT

The Drum Mountain (Detroit) mining district straddles the Juab–Millard County line in west-central Utah, 28 mi northwest of Delta. The district was organized in 1872 and had intermittent production from about 1879 to 2000. The district is a large Au and Mn producer with lesser Cu. The district has a long history of exploration and development. The total value of district production is about $144 million dollars, at modern metal prices. The district is the largest Mn and second largest Bi producing district in Utah. The Drum Au open pit mines in the south are the largest producers in the district.

The Drum Mountains are broadly part of the east-west-trending Deep Creek–Tintic mineral belt in the Basin and Range Province in west-central Utah. The Drum Mountains are a small range consisting of moderately west- to southwest-dipping Proterozoic-Ordovician sedimentary strata overlain by a series of Eocene and Oligocene volcanic rocks. Mineralization in the district is related to the Eocene (~36 Ma) Mt. Laird quartz monzonite porphyry stocks and dikes. The district contains a small, subeconomic porphyry Mo-Cu system (USGS Model 21b) and a series of adjoining small Cu-Au-Ag carbonate replacement deposits in the Cambrian strata to the west. The porphyry Mo-Cu deposit has a small, low-grade, supergene chalcocite blanket. The Cu-Au-Ag replacement deposits are believed to have a primary mineralogy of chalcopyrite, pyrite, tetrahedrite, native bismuth, argentite, and possibly pyrrhotite. The Cu-Au-Ag ores are also anomalous in As, Bi, Hg, Sb, Sn, and Te.

The central Mo-Cu and Cu-Au-Ag deposits are flanked to the south by the Drum distal disseminated Au mines (USGS Model 19c) and the north by manganese replacement deposits (USGS Model 19b), the first and second most productive mines in the district, respectively. The Drum Au mines are weakly anomalous in As, Bi, and Sb (Krahulec, 2011). The primary ore/sulfide mineral in the Mn replacement deposits are rhodochrosite, mangoan calcite, pyrite, and galena (Crittenden and others, 1961). These Mn ores may be geochemically anomalous in As, Pb, and Zn.

Crittenden, M.D., Jr., Straczek, J.A., and Roberts, R.J.U., 1961, Manganese deposits in the Drum Mountains, Juab and Millard Counties, Utah: U.S. Geological Survey Bulletin 1082-H, p. 493–544.

Krahulec, K., 2011, Sedimentary rock-hosted gold and silver deposits of the northeastern Basin and Range, Utah, in *Steininger, R., and Pennell, B, editors, Great Basin evolution and metallogeny: Geological Society of Nevada 2010 Symposium Proceedings, v. I, p. 31–62.*

DRY VALLEY DISTRICT

The Dry Valley (East Canyon) district of the Monticello U mining area is in northeastern San Juan County, about 40 mi southeast of Moab. The district is a large V-U producer and has reported production from about 1945 to 1980. Total district metal production at modern metal prices is estimated at $122 million. Dry Valley produced about 1,525,000 pounds U_3O_8 and 12,662,000 pounds V_2O_5 at average grades of 0.15% U_3O_8 and 1.30% V_2O_5 through 1980. The Dry Valley district is the third largest V producer in Utah. The largest operations are in the Rim-Columbus-Sunset underground mine area (Doelling, 1969, 1974).

The Dry Valley district is in the Paradox Basin on the Colorado Plateau. The primary host is the Upper Jurassic Salt Wash Member of the Morrison Formation with most of this production from the upper sandstone unit of the Salt Wash. The Salt Wash Member averages about 300 ft thick in the Dry Valley district and consists of a lower, generally continuous sandstone unit averaging about 30 ft thick, a middle unit with several thin (10 to 25 ft thick) discontinuous sandstone lenses, and an upper, generally continuous sandstone unit 15 to over 80 ft thick with occasional 10- to 20-ft-thick shale interbeds. The larger and more concentrated groupings of deposits occur where this upper, continuous sandstone is at least 40 ft thick (Doelling, 1969, 1974).

According to Doelling (1969), the tabular orebodies typically measure 3 ft thick by 30 ft wide by 200 ft long with the elongation dimension generally parallel to the channel (USGS Model 30c). In the major ore producing areas, the lenticular roll deposits are from 3 to 10 ft thick, 50 to 150 ft wide, and 100 to as much as 500 ft long. Both tabular and roll type orebodies can occur at any level within the host channel but are generally near the bottom or sides (Doelling, 1969). In general, the ore minerals fill voids, impregnate the host sandstone, and locally replace carbonaceous material. Within the tabular orebodies, mineralization often consists of a series of irregular, thin, wispy zones of more concentrated ore. The unoxidized ore consists of uraninite, coffinite, montroseite, and vanadium micas; however, most of the ore mined was oxidized and consisted of vanadium mica/vanadium clays, carnotite, tyuyamunite, corvusite, and occasionally volborthite.

Doelling, H.H., 1969, Mineral resources, San Juan County, Utah and adjacent areas, Part II—Uranium and other metals in sedimentary host rocks: Utah Geological and Mineralogical Survey Special Study 24, 64 p.

Doelling, H.H., 1974, Uranium-vanadium occurrences of Utah: Utah Geological and Mineral Survey Open-File Report 18, unpaginated.

DUGWAY DISTRICT

The Dugway mining district covers the northern Dugway Range in south-central Tooele County, about 57 mi west of Eureka. The district was initially discovered in 1869, organized in 1872, and was a modest intermittent Pb-Zn producer until about 1969. Total district metal production at modern metal prices is estimated at $7.5 million. The Four Metals Pb-Zn-Ag underground mine is the leading producer.

The Dugway Range is situated on the Deep Creek–Tintic mineral belt in the Basin and Range Province in west-central Utah. Dugway is an unusual northwest-trending range, composed of gently southwesterly dipping Cambrian to Mississippian strata. The range is structurally dominated by a central northwest-trending horst encompassing the crest of the range (Staatz and Carr, 1964). Aeromagnetic surveys suggest that the embayed northwestern end of the range and possibly the central horst are underlain by intrusive igneous rocks, probably of Miocene age (~20 Ma).

Much of the Cu production in the Dugway district came from the central horst, having predominantly Cu ±Pb ±Zn ±Au veins in lower Cambrian quartzite and Zn-Pb-Ag vein and replacement deposits mainly to the northeast and east in Cambrian and Mississippian limestones and shales (USGS Model 22c). Higher Ag-Au values occur principally on the southeast end of the district. The Early Mississippian Joana Limestone, the host at the Four Metals mine, may be the most important host rock in the district. Fluorite is a common vein mineral and wulfenite is reported from several of the mines in the district (Staatz and Carr, 1964). Numerous shallow mineral exploration drill programs and a few scattered deeper holes have cut intermediate intrusives but failed to define a large intrusive body at depth under the district.

Multi-element lithogeochemistry vectors southeasterly for sedimentary rock-hosted Au-Ag signatures. The most interesting area for sedimentary rock-hosted Au-Ag is the remote Buckhorn mine area where 33 samples averaged 1.1 ppm Au and 67 ppm Ag (Au:Ag 1:60) with weak geochemically anomalous As, Pb, Sb, and Zn and strong Ba as barite (USGS Model 19c). The Buckhorn mine workings occupy an oolitic and silty carbonate horizon in the Middle Cambrian, upper Fish Springs Member of the Trippe Limestone. The 100-ft-thick favorable, slope-forming horizon is only locally silicified, but is commonly weakly Fe-stained and barite is scattered throughout the soil and subcrop (Klatt, 2006).

Klatt, H.R., 2006, Copper-gold and other polymetallic mineralization at the Dugway mining district, northern Dugway Range, eastern Great Basin, Utah, in *Harty, K.M., and Tabet, D.E., editors, Geology of northwestern Utah: Utah Geological Association Publication 34, p 152–187.*

Staatz, M.H., and Carr, W.J., 1964, Geology and mineral deposits of the Thomas and Dugway Ranges, Juab and Tooele Counties, Utah: U.S. Geological Survey Professional Paper 415, 188 p.

EAST HENRY MOUNTAIN DISTICT

The East Henry Mountain (Trachyte, Butler Wash, Taylor Ridge) mining district is in the Henry Mountains U area of eastern Garfield County, about 25 mi south of Hanksville. The district encompasses three subdistricts, from north to south: Butler Wash–Crescent Creek, Cottonwood Wash–Trachyte, and Taylor Ridge. The East Henry Mountain district is a significant U-V producer from a series of small operations which suffered from their remote location (Chenoweth, 1980). Total district metal production at modern metal prices is estimated at $10 million. The most important mines are the Cottonwood Wash, Taylor Ridge, Trachyte Creek, and Woodruff mines.

The East Henry Mountain district is located on the east flank of the Henry Mountains on the Colorado Plateau. The ore is hosted in the Salt Wash Member of the Morrison Formation, which dips gently west into the Henry Mountains syncline (Chenoweth, 1980). The Cottonwood Wash-Trachyte ore occurs 100 to 150 ft above the base of the Salt Wash Member, at a higher stratigraphic horizon than at the Shootaring or Del Monte mines to the south, but it is still associated with a thick, favorable mudstone (USGS Model 30c). Paleo-streams meandered noticeably, but channels in the Salt Wash Member generally trend east-west (Doelling, 1974). Typical orebodies average 50 ft long by 20 ft wide by 2 ft thick and are associated with trash-pocket type accumulations of carbonaceous material. The ore minerals occur interstitially to sand grains (Doelling, 1974).

Uranium production from the East Henry Mountain district through 1978 is estimated at a modest 26,600 tons averaging 0.33% U_3O_8 and 1.48% V_2O_5 for a total of 175,560 pounds U_3O_8 and 787,380 pounds V_2O_5 (Chenoweth, 1980).

Chenoweth, W.L., 1980, Uranium-vanadium deposits of the Henry Mountains, Utah, in *Picard, M.D., editor, Henry Mountains symposium: Utah Geological Association Publication 8, p. 299–304.*

Doelling, H.H., 1974, Uranium-vanadium occurrences of Utah: Utah Geological and Mineral Survey Open-File Report 18, unpaginated.

EAST TINTIC DISTRICT

The East Tintic district, in Utah County 30 mi southwest of Provo, is a subdistrict of the greater Tintic mining area, the second largest district in Utah. East Tintic is a very large Ag-Pb-Au producer and was productive from the early 1900s to the 1970s. The district is about the fifth largest metal mining district in Utah. Total district metal production at modern metal prices is estimated at $3.14 billion. Nearly 6 million tons of ore have been mined from the East Tintic district averaging recovered grades of about 435 ppm Ag, 3.77 ppm Au, 8.5% Pb, 3.0% Zn, and minor amounts of Cu as well as by-product Cd, Bi, and Mn (Krahulec and Briggs, 2006). The district is the third largest Zn producer in Utah. The Burgin Pb-Zn-Ag and the Tintic Standard Ag-Pb underground mines are the two most productive operations.

The East Tintic district is located on the Deep Creek–Tintic mineral belt of the Basin and Range Province in central Utah. Geologically, the district is structurally complex. The thrust-cored East Tintic anticline is unconformably overlain by Eocene-Oligocene volcanic rocks of the East Tintic volcanic field and intruded by Oligocene (~33 Ma) monzonite plugs, andesite porphyries, and numerous pebble dikes. Most of the historical production from the East Tintic subdistrict was derived from Paleozoic sedimentary-rock hosted, vein and replacement deposits (USGS Model 19a) in the upper plate of the East Tintic thrust, except for the Burgin mine in the lower plate (Morris and others, 1979). Some of the deposits, like the Trixie, which are in less reactive quartzite or shale, are generally more Cu-rich with high-sulfidation mineral assemblages with enargite and luzonite (USGS Model 25e).

East Tintic displays a broad pattern of metal zoning, ranging from higher-temperature Cu-Au-Fe in the southwest, through Pb-Ag, to cooler Zn-Mn mineralization in the northeast. The surficial hydrothermal alteration pattern in the volcanic rocks of the district reflects a similar pattern with the most intense and pervasive advanced argillic alteration in two areas in the southwest near the North Lily shaft and a larger one to the south covering Big Hill (Krahulec and Briggs, 2006).

The East Tintic district, like Southwest Tintic, potentially represents a high level lithocap over a deeply buried porphyry Cu (-Mo) system. Intrusions, mineralization, and pervasive porphyry-style alteration are focused in the two areas of advanced argillic alteration.

Krahulec, K., and Briggs, D.F., 2006, History, geology, and production of the Tintic mining district, Juab, Utah, and Tooele Counties, Utah, in *Bon, R.L., Gloyn, R.W., and Park, G.M., editors, Mining districts of Utah: Utah Geological Association Publication 32, p. 121–150.*

Morris, H.T., Lovering, T.S., and others, 1979, General geology and mines of the East Tintic mining district, Utah and Juab Counties, Utah: U.S. Geological Survey Professional Paper 1024, 203 p., 4 plates, various scales.

ELKHORN DISTRICT

The Elkhorn (East Park City) mining district is in the Wasatch Range about 6 mi east-southeast of Park City in northernmost Wasatch County. The district was organized in 1975 and is an insignificant Pb-Ag producer. The Park Konold is the only mine in the district with recorded production.

The Elkhorn district is situated on the Bingham-Park City mineral belt in the Middle Rocky Mountain province. The district is largely underlain by the five phases of the Park Premier stock intruding partly coeval volcanic rocks. The area was explored by the Anaconda Company from the 1950s to 1980s for porphyry Cu and related skarn mineralization. The geology of the area is well described by John (1989). The Park Premier stock exhibits multiple granodiorite porphyry phases, stockwork veining, and large areas of pervasive porphyry-style alteration: hydrothermal biotite ±actinolite, quartz-sericite-pyrite, propylitic, and advanced argillic. Biotite alteration has been dated at about 33.5 Ma (John and others, 1997). Indicated grades of the porphyry mineralization are less than 0.2% Cu, 0.01% Mo, and 617 ppb Au (USGS Model 17). The porphyry mineralization is overprinted by younger high-sulfidation epithermal veins (USGS Model 25e) (John, 1989).

The western part of the Elkhorn district and much of the known porphyry system is now covered by the Jordanelle Reservoir.

John, D.A., 1989, Evolution of hydrothermal fluids in the Park Premier stock, Utah: Economic Geology, v. 84, no. 4, p. 879–902.

John, D.A., Turrin, B.D., and Miller, R.J., 1997, New K-Ar and $^{40}Ar/^{39}Ar$ ages of plutonism, hydrothermal alteration, and mineralization in the central Wasatch Mountains, Utah, in John, D.A., and Ballantyne, G.H., editors, Geology and ore deposits of the Oquirrh and central Wasatch Mountains, Utah: Society of Economic Geologists Guidebook, v. 29, p. 47–57.

ELK RIDGE DISTRICT

The Elk Ridge district is the easternmost district in the White Canyon U mining area on the Monument Upwarp in central San Juan County, 20 mi west of Monticello. Copper prospecting began in the White Canyon area in the 1880s but lead to little development. Uranium exploration and development began in the late 1940s with production from 1951 to 1970. Elk Ridge has been a significant U ±Cu producing district. Total district metal production at modern metal prices is estimated at $68 million. The largest producers are the Betty, Abe, Avalanche Group, King Edward, and Payday underground mines (Chenoweth, 1993).

Geologically, the Elk Ridge district is dominated by the north-trending Comb Ridge monocline on the east, which dips up to 30° east and defines the eastern margin of the Monument Uplift of the Colorado Plateau. The rocks of the Monument Uplift, west of Comb Ridge, generally dip gently west at about 5° (Chenoweth, 1993). The main host stratum in the Elk Ridge district is the Upper Triassic Shinarump Conglomerate Member of the Chinle Formation. In the northern part of the district, some small orebodies occur in the overlying Moss Back Member. The Shinarump Conglomerate is rarely more than 40 ft thick with an erosional unconformity at the base. The westerly flowing Shinarump stream channels are up to 250 ft wide and may scour up to 15 ft into the underlying Moenkopi. Shinarump-hosted mineralization is typically in contact with the underlying Moenkopi Formation mudstones (USGS Model 30c). Deposits occur in the basal sandstone and are tabular to lenticular, associated with asphaltite and carbonaceous trash, and contain on average from 5000 tons to 10,000 tons of ore (Doelling, 1969). The deposits are only up to about 5 ft thick but can be followed for several hundred feet along the channel.

The primary host to uranium mineralization in the Elk Ridge district is the lower section of the Triassic Chinle Formation with lesser ore produced from the Moenkopi Formation (Doelling, 1969). The ore is fine grained, occupies the interstices between sand grains, and is associated with carbonaceous matter and mudstone of the Moenkopi. The primary uranium mineral is uraninite, locally associated with chalcopyrite, bornite, tennantite, domeykite, and pyrite with traces of galena and sphalerite; however, vanadium is uncommon (Doelling, 1969).

Issues associated with the district include the lack of a V byproduct, the high Cu-content can cause metallurgical problems, its relatively remote location, and its location on National Forest System land.

Chenoweth, W.L.,1993, The geology and production history of the uranium-vanadium deposits in the White Canyon district, San Juan County, Utah: Utah Geological Survey Miscellaneous Publication 93-3, 24 p.

Doelling, H.H., 1969, Mineral resources, San Juan County, Utah and adjacent areas, Part II—Uranium and other metals in sedimentary host rocks: Utah Geological and Mineralogical Survey Special Study 24, 64 p.

ERICKSON DISTRICT

The Erickson (Indian Spring) mining district covers the southern and western Simpson Mountains of southern Tooele County about 32 mi west of Eureka. The district was organized in 1894 and became a modest Mn-Pb-Ag-Zn producer. Total district metal production at modern metal prices is estimated at $3.8 million. The Erickson district is the third largest Mn producer in Utah. The Bar X mine is probably the largest producer.

The Simpson Mountains are a small desert mountain range in the Basin and Range Province of western Utah. The range is composed of three structural blocks: (1) a northern block composed of Proterozoic and Lower Cambrian clastic meta-sedimentary rocks; (2) a central, easterly trending graben of Paleozoic sedimentary rocks; (3) and a southern block of folded Proterozoic clastic meta-sedimentary rocks. Mineralization is confined to the two southern blocks. The mineralization in the central graben is dominantly gently-dipping, epithermal Ag-Au veins (USGS Model 25c) with pyrite-tetrahedrite-chalcopyrite that constitute a small percentage of the district's overall production (Thomas, 1958).

Mineralization in the southern block consists of Mn-Pb-Zn-Ag polymetallic veins (USGS Model 22c) in Neoproterozoic quartzites, metaconglomerates, and shales. These metasedimentary rocks are broadly folded into a large northerly trending and plunging anticline centered on Death Canyon. Locally these veins have strongly anomalous Mo and Sn. The southern block also has some small, Miocene-age high-silica rhyolitic intrusive bodies (~16 Ma).

The southern Erickson district mineralization occurs primarily as veins occupying northwesterly and easterly trending fault zones. The northwest-trending faults show greater brecciation and throw (Fry and Wilson, 1949). Mineralization is predominantly Pb-Zn-Ag in the middle reaches of Death Canyon near the Bar X mine, and Mn becomes more dominant in the mines/prospects to the north and east. The veins, generally south and west of the Bar X, have strongly anomalous Mo (1000 ppm), Sn (200 ppm), and weakly anomalous Cu in U.S. Geological Survey National Geochemical Database samples.

Fry, E., and Wilson, S.R., 1949, Investigation of the Huber-Rydalch manganese deposits, Tooele County, Utah: U.S. Bureau of Mines Report of Investigation 4601, 7 p.

Thomas, G.H., 1958, Geology of Indian Springs quadrangle, Tooele and Juab Counties, Utah: Brigham Young University Research Studies, v. 5, no. 4, 35 p.

ESCALANTE DISTRICT

The Escalante district is in southwestern Iron County, about 36 mi west of Cedar City. The district was originally organized in 1896 but did not become a large Ag producer until the 1980s. Total district metal production at modern metal prices is estimated at $277 million. The only important producer is the Escalante underground mine.

The district is in the southern Escalante Desert of the Basin and Range Province of southwestern Utah. The Escalante mine was developed on a single persistent quartz-calcite ±adularia vein cutting middle Miocene rhyolitic volcaniclastic sediments of the "mine series" (690 ft thick), approximately temporally equivalent to the Steamboat Mountain Formation. The main vein is 3600 ft long, 5 to 45 ft wide (average 26 ft), strikes N. 27° E., and dips 70° NW. The main vein reportedly horsetails into multiple smaller veins to the southwest (Fitch and Brady, 1982). Adularia from the vein has been dated at 11.6 ± 0.5 Ma (Siders, 1985).

The main mineralized area is a zone of supergene Ag enrichment from about 200 to 700 ft in depth where grades average about 300 ppm Ag. The Ag is partially leached and sub-ore grade at the surface where the vein is narrower (4 to 10 ft wide) and Ag continues at depth in a primary zone, but the grade also diminishes. The vein is strongly crustiform-banded (repeated mineralizing events), vuggy, white quartz-calcite and dark gray Fe-Mn oxides with minor Cu-As-oxides (USGS Model 25c). The principal Ag minerals in the enriched zone are very fine-grained chlorargyrite and rare native silver. The main ore/sulfide minerals in the primary zone are argentite, galena, sphalerite, pyrite, hematite, jalpaite, and rare native silver and gold. Gangue minerals include several generations of quartz with subordinate calcite, fluorite, barite, and rare adularia. Calcite, fluorite, and galena appear to be increasing with depth (Fitch and Brady, 1982). The vein is surrounded by a 10- to 50-ft-wide zone of silicification having lower Ag grades next to the vein which grades outward to a weak calcitic alteration and minor sericite, calcite, chlorite, and kaolinite. Limited trace element geochemistry shows anomalous Au, Cu, Mo, Pb, and Zn associated with ore in the veins.

Although virtually all production from the Escalante mining district is derived from the Escalante vein; other smaller veins and hydrothermal alteration occur over an area of some 16 sq mi. Much of this alteration occurs on and or near The Point, a knoll some 4 mi north of the Escalante mine (Siders, 1985). At The Point, the volcanic facies of the rhyolite of Beryl Junction (13 to 10 Ma) is locally silicified and Fe-stained in spatial association with intrusives and flow domes of the rhyolite member (Siders, 1985).

Fitch, D.C., and Brady, M.W., 1984, Geology of the Escalante silver mine, Utah, in *Wilkins, J., Jr., editor, Gold and silver deposits of the Basin and Range Province, western U.S.A.: Arizona Geological Society Digest, v. 15, p. 109–116.*

Siders, M.A., 1985, Geologic map of the Beryl Junction quadrangle, Iron County, Utah: Utah Geological and Mineral Survey Map 85, 2 plates, scale 1:24,000.

FARMINGTON DISTRICT

The Farmington mining district is located about 15 mi north of Salt Lake City on the west flank of the Wasatch Range in easternmost Davis County. The district contains scattered old workings that produced an insignificant amount of Cu-Au around 1900. The only reported small producer is the Morning Star Group (Butler and others, 1920).

The Wasatch Range is part of the Middle Rocky Mountain province. The Farmington district prospects occur in the metamorphic gneiss and schist of the Proterozoic Farmington Canyon Complex. The deposits consist of relatively narrow, quartz-chalcopyrite veins or veinlet stringer zones generally cross-cutting the gneissic foliation. Some of these Cu veins also carry modest Au values, mostly those in the northern part of the district (Gloyn and others, 1995). Most of the veins are developed in retrograde, chloritic shear zones. These retrograde shear zones were formed during the Sevier orogeny and are dated between 140 and 110 Ma. The quartz-chalcopyrite veins are believed to be younger than the shearing (Gloyn and others, 1995). The primary metallic vein minerals are pyrite, chalcopyrite, specularite, and possibly bornite. Gold is the only other metal that locally correlates with Cu (Gloyn and others, 1995).

Butler, B.S., Loughlin, G.F., Heikes, V.C., and others, 1920, The ore deposits of Utah: U.S. Geological Survey Professional Paper 111, 672 p.

Gloyn, R.W., Shubat, M.A., and Mayes, B.H., 1995, Mines and prospects in and around the Farmington Canyon Complex, northern Utah: Utah Geological Survey Open-File Report 325, 30 p.

FERBER DISTRICT

The Ferber mining district lies in the Ferber Hills of westernmost Tooele County about 34 mi south of Wendover and immediately south of Utah Peak. Mineralization was discovered in the Ferber district in 1880 in Elko County, Nevada (Hill, 1916). The district had intermittent production from the 1890s until 1957 and all the reported production came from the Nevada side of the district. The total recorded production, all from Nevada, is approximately 2000 tons of Cu, Pb, and Ag ore (Hill, 1916; Smith, 1976). The Martha Washington Cu-Pb mine (Nevada) is the largest producer.

The Ferber Hills are geologically situated in the east-central Basin and Range Province. The mineralization in the Ferber district is associated with a roughly 1-sq-mi porphyritic quartz monzonite stock and gabbro (?) dikes that lie mostly in Nevada. Although the stock is undated, it is mapped as Cretaceous in age by Coats (1987). The stock and mineralization are both elongate in an east-northeast direction. The mineralization includes small skarns and veins. The main Cu-Pb-Ag ores were locally anomalous in As, Bi, Sn, and Zn (Smith, 1976). Mineralization in the Utah section of the district is limited to a few prospect pits and short shafts exploring weakly altered and mineralized Paleozoic carbonates, possibly Pennsylvanian Ely Limestone or Permian Fergus Mountain Formation (Coats, 1987). Reported ore minerals from the Utah prospects include malachite, limonite, jarosite, and scorodite. No references to the Utah prospects are found outside the Utah Mineral Occurrence System (UMOS).

Coats, R.R., 1987, Geology of Elko County, Nevada: Nevada Bureau of Mines and Geology Bulletin 101, 112 p.

Hill, J.M., 1916, Notes on some mining districts in eastern Nevada: U.S. Geological Survey Bulletin 648, 214 p.

Smith, R.W., 1976, Mineral resources of Elko County, Nevada: U.S. Geological Survey Open-File Report 76-56, 201 p.

FISH SPRINGS DISTRICT

The Fish Springs mining district is in the northern Fish Springs Range of northwestern Juab County about 72 mi west of Eureka. The district was organized in 1891 and was a significant Ag-Pb producer continuing into the early 1960s. Total district metal production at modern metal prices is estimated at $60 million. The Utah and Galena Pb-Ag underground mines are by far the largest historical producers in the district. The large West Desert (Crypto) Zn-In skarn was discovered at depth by drilling in the late 1950s and early 1960s.

The district is located on the Deep Creek–Tintic mineral belt in the Basin and Range Province in west-central Utah. Mineralization at Fish Springs is associated with west-northwest-trending fracture zones and trachyte dikes near the Juab fault and a concealed, Eocene-age, equigranular to weakly porphyritic, monzonite-syenite stock dated at 38.5 ±1.0 Ma (Staargaard, 2009). Previously mined mineralization is primarily Pb-Ag vein and replacement ores in the Silurian Laketown Dolomite (USGS Model 19a). These replacement ores are strongly anomalous in As, B, Cd, Mn, Mo, V, and Zn.

Bleaching and recrystallization of the carbonate rocks along the northwestern range front in the Fish Springs district and a very strong magnetic high in the pediment led to drill testing and the discovery of a pair of unexposed stocks and a deep magnetite-sphalerite skarn (Christiansen, 1977). The common magnesian skarn consists of medium- to coarse-grained humite, magnetite-magnesioferrite, and phlogopite along with subordinate spinel, periclase, actinolite/tremolite, and forsterite (USGS Model 18c). The sulfide phases present in the deep skarn include sphalerite, chalcopyrite, molybdenite, pyrite, and lesser pyrrhotite and roquesite (Staargaard, 2009). The main ore hosts are the Ordovician Ely Springs Dolomite and Pogonip Group and deeper mineralization in the Cambrian Orr Formation. In 1993, Cyprus Minerals reported two separate subeconomic inferred resource estimates at Crypto: 3.1 million tons of 7.0% Zn as an oxide deposit and 6 million tons of 8.7% Zn in a deeper sulfide deposit (Staargaard, 2009). Reportedly, Cu grades increase near the stock which also hosts some Mo mineralization at the intrusive-skarn contact. More recent drilling at the deposit by Lithic Resources has revealed economically interesting indium associated with some of the sphalerite skarn mineralization, including 78.3 ft assaying 4.22% Zn and 184.9 ppm In in hole C-07-01 (Dyer and others, 2010).

Christiansen, W.J., 1977, Geology of the Fish Springs mining district, Juab County, Utah: Salt Lake City, University of Utah, M.S. thesis, 66 p.

Dyer, T.L., Tietz, P.G., and Austin, J.B., 2010, Technical report on the West Desert zinc-copper-indium-magnetite project preliminary economic assessment, Juab County, Utah: unpublished Canadian national instrument (NI) 43-101 technical report prepared for InZinc Mining Ltd., 188 p.

Staargaard, C.F., 2009, Geology and exploration at the Crypto zinc-indium-copper-molybdenum skarn deposit, Fish Springs mining district, Juab County, Utah, in Tripp, B.T., Krahulec, K., and Jordan, J.L., editors, Geology and geologic resources and issues of western Utah: Utah Geological Association Publication 38, CD, p. 139–151.

FORTUNA DISTRICT

The Fortuna mining district is situated on the north end of Beaver Valley, near Gillies Hill, in Beaver County about 12 mi north of Beaver. The Fortuna district is a little recognized and minor historical Au producer, mainly active from about 1906 to 1936. Total district metal production at modern metal prices is estimated at $56,000. The Fortuna mine is the only known producer.

The Fortuna district is on the west flank of the Tushar volcanic field in the eastern Basin and Range Province of southwestern Utah. Butler and others (1920) first mentioned the district and described the mineralization as having northwest-trending, banded quartz-carbonate ±adularia veins cutting easterly dipping, propylitized Oligocene Bullion Canyon Volcanics rhyodacite porphyry host rocks. The rhyodacite porphyry wallrocks are silicified immediately adjacent to the veins (USGS Model 25c). Native gold reportedly occurs with limonite after pyrite in the veins (Butler and others, 1920) and grades of over 10 ppm Au are reported. In addition to Au and Ag, the veins are also anomalous in As, Sb, and Hg.

The mine workings consist of scattered shafts and a very small open cut (1000 tons?) at the Fortuna mine. The rhyodacite porphyry host rocks are also cut by a series of Miocene-age felsite porphyry dikes (9.1 Ma) and may be related to the Rhyolite of Gillies Hill, some of which are high-silica rhyolites (Evans and Steven, 1982). The district has undergone sporadic exploration and drill testing, including numerous drill holes by Cordex Exploration south and southwest of the Fortuna main shaft area in the early 1990s and exploration holes well north of the main shaft by Kinross Gold in the 2010s.

Butler, B.S., Loughlin, G.F., Heikes, V.C., and others, 1920, The ore deposits of Utah: U.S. Geological Survey Professional Paper 111, 672 p.

Evans, S.H., and Steven, T.A., 1982, Rhyolites in the Gillies Hill-Wood Tick Hill area, Beaver County, Utah: Geological Society of America Bulletin, v. 93, p. 1131–1141.

FREE COINAGE DISTRICT

The Free Coinage (Timpie Canyon) district is in the northern Stansbury Mountains in northeastern Tooele County, about 17 mi northwest of Tooele. The district is a small Pb-Ag producer organized in 1895 and operated sporadically from 1917 into the 1970s. Total district metal production at modern metal prices is estimated at $556,000. The Monte Carlo and Utah Bunker Hill underground mines in the upper reaches of Miners Canyon were the largest operations (Stein and others, 1989).

The Free Coinage district is situated on the north flank of the Bingham–Park City mineral belt in the Basin and Range Province of northwestern Utah. The district lies on the east limb of the north-northeast-trending Deseret anticline. An Eocene-age monzonite porphyry dike is present in the southeastern part of the district. The polymetallic vein and replacement deposits are hosted by faulted Lower Mississippian carbonates, particularly the Gardison Limestone (Rigby, 1958). In addition to Pb-Zn-Ag, the replacement ores may be anomalous in As, Au, Cd, and Cu (USGS Model 19a).

Furthermore, a small quantity of cinnabar was reportedly mined in the 1950s from the Halladay Hg property south of Timpie Valley. The unusual coarse-grained cinnabar occurs as stringers along a fault breccia in nearly vertical, north-striking, Lower Mississippian Gardison Limestone (Rigby, 1958). Limited geochemistry suggests that the Hg ore has associated Ag, As, Au, Cu, Pb, Sb, and Zn.

The most economically important mining operations in the district are industrial mineral quarries that produced substantial quantities of limestone and dolomite (USGS Model 32g) for lime production, for use as flux in Cu smelting, and for cement raw material (Tripp and others, 1989).

Rigby, J.K., 1958, Geology of the Stansbury Mountains, eastern Tooele County, Utah, in *Rigby, J.K., editor, Guidebook to the geology of Utah, no. 13, Geology of the Stansbury Mountains, Tooele County, Utah: Utah Geological Society, p. 1–134.*

Stein, H.J., Bankey, V., Cunningham, C.G., Zimmerman, D.R., Brickey, D.W., Shubat, M., Campbell, D.L., and Podwysocki, M.H., 1989, Tooele 1° x 2° quadrangle, northwest Utah—a CUSMAP preassessment study: U.S. Geological Survey Open-File Report 89-0467, 134 p.

Tripp, B.T., Bishop, C.E., Shubat, M.A., and Blackett, R.E., 1989, Mineral occurrences of the Tooele 1° x 2° quadrangle, west-central Utah: Utah Geological and Mineral Survey Open-File Report 153, 85 p.

FREEMONT DISTRICT

The Freemont (Miners Mountain) mining district is in western Wayne and Garfield Counties about 30 mi west-southwest of Hanksville. The earliest locations in the district date back to at least 1901 for the Oyler U mine. The Freemont district is a small U-V producer. Total district metal production at modern metal prices is estimated at $917,000. The two most productive operations are the U3O8 and Billy's Dream V-U mines.

The Freemont district is in the Teasdale anticline–Waterpocket monocline section of the western Colorado Plateau. The Teasdale anticline trends roughly N. 70° W. and is doubly plunging to the northwest and southeast with the apex of the fold in the Miners Mountain area. The Waterpocket monocline is east of the anticline, strikes approximately N. 50° W., and the beds dip from 10° to 35° NE. (Smith and others, 1963).

The Freemont district's mineralization shows an unusual, large-scale district zoning from Cu-hosted deposits in the Triassic Sinbad Member of the Moenkopi Formation near the apex of the anticline on Miners Mountain outward to sandstone-hosted U ores. The U-hosted ores in the Triassic Shinarump Member of the Chinle Formation wrap around the doubly plunging Teasdale anticline and then farther outward the V-U deposits hosted in the Jurassic Salt Wash Member of the Morrison Formation are exposed along the Waterpocket monocline to the northeast. The primary sulfide minerals in the sediment-hosted Cu deposits (USGS Model 30B) are disseminated chalcopyrite and rare galena. The deposits are small and generally low-grade, although select grab samples can run up to 5% to 10% Cu. In addition to Cu, these ores can be anomalous in Ag, As, Co, Mo, Pb, and Zn. The U ores in the Shinarump Member are controlled by paleo-stream channels and accumulations of carbonized wood. The principal ore mineral in the U deposits is metatorbernite. The Salt Wash Member V-U ores are similarly controlled by paleo-stream channel scours. The main ore minerals in these deposits are corvusite and carnotite. The U_3O_8:V_2O_5 ratio in the Salt Wash ores probably averages 1:2 to 1:3. Both the previously mentioned U3O8 and Billy's Dream U-V mines are hosted by the Salt Wash Member. In addition to U and V, the sandstone-hosted ores (USGS Model 30C) are anomalous in Co, Cu, Mo, Pb, and Zn (Smith and others, 1963).

Smith, J.F., Jr., Huff, L.C., Hinrichs, E.N., and Luedke, R.G., 1963, Geology of the Capitol Reef area, Wayne and Garfield Counties, Utah: U.S. Geological Survey Professional Paper 363, 102 p.

FRY CANYON DISTRICT

The Fry Canyon district is in remote southwestern San Juan County. Fry Canyon is in the south-central part of the White Canyon U mining area, 45 mi southwest of Monticello. The area is part of the deeply incised Red Rock Plateau/White Canyon Slope, sandwiched between the Colorado River on the west and the Monument Uplift on the east. The White Canyon mining area as a whole is credited as Utah's second largest uranium producer (Chenoweth, 1993). Total district metal production at modern metal prices is estimated at $5.3 million. The largest producers in the Fry Canyon district are the Gizmo and Fry underground mines.

Fry Canyon is geologically situated in the Paradox Basin on the Colorado Plateau. The uranium ores of the Fry Canyon district are hosted in the basal Shinarump Conglomerate Member of the Triassic Chinle Formation (USGS Model 30c). Mineralization is associated with channel scours and sandstone pinch-outs against mudstone, and the grade is directly proportional to the amount of carbonaceous material available (Doelling, 1969). The generally unoxidized orebodies average 3.5 ft thick and range from 10 to 500 ft wide and 50 to 1000 ft long (Doelling, 1969). Ore grades average about 0.2% U_3O_8 (Chenoweth, 1993). The low-lime ore is primarily uraninite with low vanadium, but commonly over 1% Cu values, as chalcopyrite, and Co and Mo are locally associated with the ore.

Chenoweth, W.L., 1993, The geology and production history of the uranium-vanadium deposits in the White Canyon district, San Juan County, Utah: Utah Geological Survey Miscellaneous Publication 93-3, 24 p.

Doelling, H.H., 1969, Mineral resources, San Juan County, Utah and adjacent areas, Part II—Uranium and other metals in sedimentary host rocks: Utah Geological and Mineralogical Survey Special Study 24, 64 p.

GATEWAY DISTRICT

The Gateway (Beaver Mesa, Polar Mesa) district is in eastern Grand County about 25 mi east-northeast of Moab. The district is a significant U-V producer. Total district metal production at modern metal prices is estimated at $66 million. The U mineralization in the Gateway district extends into adjoining portions of Colorado as the northern Uravan mineral belt. The largest producers are the Effie F., Petrified Tree, F.W. #3, and Thompson C underground mines. These deposits are all clustered in the northwest corner of the district.

Gateway lies in the Paradox Basin on the Colorado Plateau on the very gently dipping, southwest limb of the Sagers Wash syncline. The Upper Jurassic Salt Wash Member of the Morrison Formation is the primary U-V host in the district (USGS Model 30c). The Salt Wash Member here is slightly over 300 ft thick and ore occurs predominantly in the light-brown to light-gray, 10- to 80-ft thick, "Payoff" sandstone horizon in the upper portion of the unit (Doelling, 1974). Minor mineralization also occurs in the basal Brushy Basin Member and at the base of the Upper Triassic Chinle Formation.

Mineralization is associated with fossilized logs, carbonized vegetal matter, and seams of mudstone. Individual orebodies are small, tabular, amoeboid-shaped, elongated in a northeast direction and range in size from 100 to 5700 tons, and the deposits tend to cluster into larger ore zones (Doelling, 1974). Both oxidized and unoxidized ores are known, but unoxidized ores are the most important producers. Pyrite is abundant in the ores along with uraninite, coffinite, montroseite, and doloresite (Doelling, 1974). The ores typically average about 0.3% U_3O_8 and 1.2% V_2O_5. The Whirlwind mine along the Colorado border has a permitted resource of 169,129 tons at 0.3% U_3O_8 and 0.7% V_2O_5.

Doelling, H.H., 1974, Uranium-vanadium occurrences of Utah: Utah Geological and Mineral Survey Open-File Report 18, unpaginated.

GOLD CITY DISTRICT

The Gold City (Little Willow) mining district is in Salt Lake County about 12 mi south-southeast of Salt Lake City. The district began with the discovery of gold in the Wasatch foothills which led to the Gold City mining boom from about 1894 to 1901. This boom resulted in the location of many mining claims followed by some mine development, construction of mills, and minor Au production primarily in the early 1900s. As with many Utah Au districts, the properties were closely reexamined during the depths of the Great Depression in the 1930s. The New State and adjoining Wasatch Utah Au mines were the primary producers (James, 1979).

The Gold City district is on the west flank of the Wasatch Range of the Middle Rocky Mountain province. The district is situated in Proterozoic metamorphic rocks near the northern contact of the 50-sq-mi Oligocene Little Cottonwood quartz monzonite batholith. A small, isolated body of quartz monzonite lies about a mile and a half to the north of the batholith in the Gold City district. These metamorphic rocks primarily belong to the Paleoproterozoic Little Willow Formation and Mesoproterozoic Big Cottonwood Formation (James, 2006). The most productive mines are in the Little Willow Formation. The principal rock types are gray quartz-feldspar-biotite gneiss with thin intercalated mafic actinolite schist and quartz-sericite-chlorite schist.

There are two primary types of ore in the Gold City district: steeply dipping, Au-Ag-Cu bull quartz veins with minor chalcopyrite and pyrite; and a few W-bearing quartz veins with pyrite, huebnerite, and scheelite. The precious metal-rich bull quartz veins have provided virtually all of the district's mineral production. Most of the area developed for Au-Ag also contains thin quartz-sericite-chlorite schist units, but the actinolite schists are the primary host for the Au-Ag-Cu quartz veins. The Wasatch Utah glory hole, for example, produced a few thousand tons of ore from this schist (James, 1979). The ore mineral is native gold or electrum (James, 2006).

James, L.P., 1979, Geology, ore deposits, and history of the Big Cottonwood mining district, Salt Lake County, Utah: Utah Geology and Mineral Survey Bulletin 114, 98 p., 4 plates in pocket.

James, L.P., 2006, Big and Little Cottonwood (Alta) mining districts, Salt Lake County, Utah, in *Bon, R.L., Gloyn, R.W., and Park, G.M., editors, Mining districts of Utah: Utah Geological Association Publication 32, p. 42–66.*

GOLD HILL DISTRICT

The Gold Hill (Clifton) mining district lies near the Nevada state line, 40 mi south of Wendover in west-central Tooele County. Gold Hill is a large As-Au-Ag-Pb-Cu district and is the largest As and W producing district in Utah. Gold Hill's production peaked during World War I immediately after the arrival of a railroad from Wendover. Total district metal production at modern metal prices is estimated at $111 million. The two largest producers in the district are believed to be the Gold Hill (Western Utah) and U.S. arsenic mines.

The Gold Hill district lies on the north end of the Deep Creek Range in the Basin and Range Province of west-central Utah. The Gold Hill district is structurally very complex and hosts at least three ages of mineralization: Jurassic, Eocene, and Miocene. The district also hosts an unusual suite of ore deposits including polymetallic pipe, skarn, vein, and replacement deposits. Most of the Gold Hill ore deposits are associated with a large (22 sq mi) Jurassic granodiorite plug (about 152 Ma). The polymetallic pipes are small, irregular, W-Cu-Mo-bearing chimneys of very coarse grained actinolite-tourmaline-orthoclase formed within the Jurassic granodiorite (e.g., Yellow Hammer mine). The skarns (Cu-W-As-Mo-Pb-Zn-Bi-Sb-Au) form in carbonate rock adjacent to the granodiorite stock and occur as prograde garnet-diopside and retrograde hornblende-actinolite-tourmaline skarns. These skarns include several small Au skarns like the Midas and Cane Springs orebodies (USGS Model 18f). The largest historical producers in the district are the arsenopyrite polymetallic vein and replacement deposits (Gold Hill and U.S. mines) formed in the Mississippian Ochre Mountain Limestone near the Jurassic granodiorite. These bodies (As-Pb-Cu-Zn-Sb) lie just outboard of the skarns and are controlled by the intersection of mineralizing fissures and favorable host beds (Nolan, 1935). Later mineralizing events in the Gold Hill district include W skarns associated with the Eocene (about 42 Ma) quartz monzonite plug (4 sq mi) north of Gold Hill at the Stardust and Timm mines (USGS Model 14a) and Miocene (~8 Ma) low-sulfidation Au quartz-adularia veins (USGS Model 25c) reported in Rodenhouse Wash at the Kiewit mine (Robinson, 2006).

Small sedimentary rock-hosted Au-Ag prospects (USGS Model 19c) occur at Ochre Springs and Trail Gulch in the west and northwestern portion of the Gold Hill district. The mineralization is reportedly hosted in siltstone/limestone at the contact between the Mississippian Ochre Mountain Formation and Chainman Shale.

The Jurassic-age mineralization in the Gold Hill mining district is primarily low-oxidation-state arsenopyrite replacement deposits and low-sulfidation-state W-Cu-Mo breccia pipe orebodies. These deposits suggest that Jurassic magmatism generated reduced, low-sulfide mineralizing fluids.

Nolan, T.B., 1935, The Gold Hill mining district, Utah: U.S. Geological Survey Professional Paper 177, 172 p.

Robinson, J.P., 2006, Gold Hill, Utah—polyphase, polymetallic mineralization in a transverse zone, in *Bon, R.L., Gloyn, R.W., and Park, G.M., editors, Mining districts of Utah: Utah Geological Association Publication 32, 16 p.*

GOLD MOUNTAIN DISTRICT

The Gold Mountain (Kimberly) mining district lies on the northeast flank of the Tushar Mountains about 20 mi northeast of Beaver in northern Piute County of southwestern Utah. The mineralization in the Gold Mountain district was discovered in 1888 when prominent Au-bearing veins were located between 8000 and 10,600 ft elevation. The district was organized in 1889 and remained intermittently productive into the 1950s. Total district metal production at modern metal prices is estimated at $180 million. Due to the rugged terrain, the mines were primarily accessed by a series of adits (Lindgren, 1906). The district was a large Au producer and the Annie Laurie and Sevier mines were the largest producers.

The Gold Mountain district lies on the north flank of the Marysvale volcanic field of the transition zone between the Basin and Range Province and the Colorado Plateau. The district is localized around the Kimberly quartz monzonite plug (about 24 Ma) that intrudes the coeval Oligocene-Miocene Bullion Canyon Group volcanic rocks just north of the Mount Belknap caldera. The Kimberly quartz monzonite is a medium-grained, equigranular to strongly porphyritic plug.

There are two main mines in the Gold Mountain district: the Annie Laurie on the east and the Sevier about a mile to the west. These mines host north-northwest-trending vein sets that appear to outline a northwest-trending graben in the host quartz monzonite. The Annie Laurie vein trends about N. 20° W., 55° SW. and the Sevier trends roughly N. 15° W., 65° NE. The orebodies are low-sulfidation, epithermal, white, quartz-carbonate ±adularia veins with minor fluorite and barite (USGS Model 25b). The veins are primarily oxidized where they have been exploited. Primary ore minerals are rarely visible except for a little argentite and some fine native gold seen upon crushing and panning the ore (Lindgren, 1906; Park and Krahulec, 2009).

A series of three exploration programs from 1981 to 1996 attempted to evaluate the remaining Au resources in the district, primarily at the Annie Laurie and Sevier mine areas. A total of 38 holes were drilled during these programs. These exploration programs partially delineated two subeconomic inferred resources: about 200,000 tons of 0.55 ppm Au and 62 ppm Ag in the lower Kimberly mill tailings and a crudely estimated 100,000 tons of 5.14 ppm Au and 51.4 ppm Ag in the lower Annie Laurie mine (Park and Krahulec, 2009). In addition to Au and Ag, the veins are anomalous in Pb, Zn, and Cu. While all past metal mining and documented exploration in the Gold Mountain district has been directed toward Au-Ag, other potential exploration targets may exist. The central area of pervasive argillic alteration in the Kimberly quartz monzonite (about 0.14 sq mi) and the elevated Mo rock-chip anomalies (to 434 ppm Mo) could indicate a porphyry Mo (-Cu) system at depth (Park and Krahulec, 2009).

Lindgren, W., 1906, The Annie Laurie mine, Piute County, Utah: U.S. Geological Survey Bulletin 285, p. 87–90.

Park, G., and Krahulec, K., 2009, Gold Mountain mining district, Piute County, Utah, in *Tripp, B.T., Krahulec, K., and Jordan, J.L., editors, Geology and geologic resources and issues of western Utah: Utah Geological Association Publication 38, p. 171–180.*

GOLD SPRINGS DISTRICT

The Gold Springs mining district (Pike's Diggings) lies along the Nevada border about 55 mi west-northwest of Cedar City in northwestern Iron County. The district is a modest Au producer totaling about 9300 ounces, some of which came from Nevada, between 1897 and 1948 (Perry, 1976). Total district metal production at modern metal prices is estimated at $11 million. The largest producers in the district are the Jennie and the Jumbo underground mines.

The Gold Springs district is situated in the Paradise Mountains of the Basin and Range Province. Gold-silver production was derived from a series of generally northerly trending, moderately east-dipping, epithermal, low-sulfidation, banded or crustiform, quartz-carbonate-adularia ±pyrite veins cutting Miocene-age volcanic rocks (USGS Model 25c). From oldest to youngest, the volcanic sequence consists of andesitic flows, ash-flow tuffs, and rhyolitic flows. These volcanic rocks are cut by coeval porphyritic rhyolite intrusives (16.5 Ma) associated with the Gold Springs depression (cauldron). The porphyritic rhyolite plug, which lies in the depression just across the state line in Nevada, is phyllically to argillically altered (Williams and others, 1997). Veins near the Gold Springs depression are higher in Au and the more distal veins carry higher Ag. Ferrimolybdite is reported from the Jumbo lode in Utah. Geochemical sampling of the Au-Ag veins indicates elevated Mo, F, Pb, Cu, Mn, Te, Hg, and U. A shaft near the center of the porphyritic rhyolite (on Bull Hill, NV) is developed on a Au-Ag-rich, fluorite-hematite-clay pipe (Perry, 1976). The Charley Ross mine (Nevada), immediately south of the Gold Springs depression, intersected a body of "talc" 40 ft wide containing locally high Au-Ag values, apparently as sylvanite.

The Gold Springs district is being actively explored for exploitable Au-Ag mineralization. This work has defined a measured and indicated resource on the Jumbo Au-Ag stockwork of 13,591,000 tons of 0.53 ppm Au and 13.6 ppm Ag at a 0.3 ppm Au cutoff. The preliminary economic assessment calls for a 15,000 ton per day, open-pit, heap leach operation with a 2:1 stripping ratio (Lane and others, 2015).

Lane, T., Moritz, R., and Katsura, K., 2015, Preliminary economic assessment update, Gold Springs property, Utah/Nevada, USA: unpublished Canadian National Instrument (NI) 43-101 technical report prepared for TriMetals Mining Inc., 194 p.

Perry, L.I., 1976, Gold Springs mining district, Iron County, Utah, and Lincoln County, Nevada: Utah Geological and Mineral Survey, Utah Geology, v. 3, no. 1, p. 23–49.

Williams, V.S., Best, M.G., and Keith, J.D., 1997, Geologic map of the Ursine-Panaca Summit Deer Lodge area, Lincoln County, Nevada, and Iron County, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-2479, scale 1:50,000.

GOLDSTRIKE DISTRICT

The Goldstrike mining district is located 26 mi northwest of St. George in northwestern Washington County. The district is a large Au producer and had its most prolific period in the late 1980s and early 1990s. Total district metal production at modern metal prices is estimated at $235 million. Goldstrike's largest mines were the Hamburg and Main Zone open pits.

The Goldstrike district is situated along the East Fork of Beaver Dam Wash on the northwest flank of the Bull Valley Mountains of the Basin and Range Province of southwestern Utah. The district is elongated to the northeast and lies on the N. 60° E. projected trend of the Iron Springs and Bull Valley mining districts (22 to 21 Ma) to the northeast. The Goldstrike district has a complex structural history; however, most of the structural events occurred before Au-Ag mineralization. The oldest structures recognized in the district are folding and faulting of the Paleozoic and Mesozoic sedimentary rock, probably related to the Sevier orogeny in the Late Cretaceous. This complex package is unconformably overlain by Paleocene to Eocene Claron Formation. The Claron Formation is a section 150 to 500 ft thick of variegated sandstone, conglomerate, limestone, and tuff. The Claron has been divided into seven members by Adair (1986), and the basal clastic member is the primary ore host at Goldstrike. This lower member is a white to yellow conglomerate and sandstone and is generally silicified where mineralized. These Tertiary units are cut by several periods of northeast-, east-west-, and northwest-trending high-angle faults. Small dikes and sills up to 50 ft thick occur west of Hamburg Peak (Willden and Adair, 1986). In the central part of the district, these intrusive bodies are strongly altered; however, farther west some dikes are recognizable as andesite porphyries (Adair, 1986).

Mineralization at Goldstrike occurs in an arcuate, northeast-trending zone over about 5 mi. The largest deposits lie in the east-northeast-trending Goldstrike graben on the eastern end of the belt, and mineralization continues to the southwest in a series of smaller deposits. Mineralization in the Goldstrike district is disseminated Au-Ag located along or near structures in, or near, the basal member of the Claron Formation (USGS Model 19c). Of the twelve pits ultimately mined, eight lie along the boundaries of the Goldstrike graben and four occur at intersections of northwest- and northeast-trending faults farther southwest. Hydrothermal alteration associated with the mineralization is primarily decalcification of carbonate rocks and silicification. The orebodies are generally gently dipping and tabular replacements of favorable strata, with narrow, more steeply dipping zones along faults. An aggressive exploration/definition drilling program is currently underway (May 2018).

Adair, D.H., 1986, Structural setting of the Goldstrike district, Washington County, Utah, in *Griffen, D.T., and Phillips, W.R., editors, Thrusting and extensional structures and mineralization in the Beaver Dam Mountains, Southwestern Utah: Utah Geological Association Publication 15, p. 129–136.*

Willden, R., and Adair, D.H., 1986, Gold deposits at Goldstrike, Utah, in *Griffen, D.T., and Phillips, W.R., editors, Thrusting and extensional structures and mineralization in the Beaver Dam Mountains, Southwestern Utah: Utah Geological Association Publication 15, p. 137–148.*

GRANITE DISTRICT

The Granite (North Granite) mining district is situated on the southeast flank of the Mineral Mountains 9 mi northwest of Beaver in east-central Beaver County. The district was organized in 1863 and became a small Zn-Cu-Pb-W producer, but the most productive period was from 1911 to 1932. Total district metal production at modern metal prices is estimated at $263,000. The largest producer was probably the Beaver Tungsten Mines, including the Garnet and Contact mines.

The Granite district is on the Wah Wah-Tushar mineral belt in the Basin and Range Province of southwestern Utah. The Mineral Mountains expose a large, mostly gray, alkalic, high-silica, composite Oligocene-Miocene (25 to 18 Ma) granite, monzonite, and syenite batholith (78 sq mi), the largest exposed batholith in Utah. The main granitic phase of the Mineral Mountains batholith has an interpreted age of about 18 to 17 Ma. The batholith has been strongly rotated to the east (40°–85°), so that the east side of the mountain is near the paleo-top of the batholith. The Granite district covers an 8-mi-long by 1-mi-wide contact on the east side (paleo-top) of the Mineral Mountains granite.

The district shows a broad, but poorly defined zonation from Pb-Zn-rich ores on the north and south to W, Sn, and Mo in the center, near the Garnet and Contact mines. Mineralization is developed in prograde, anhydrous, tabular garnet-vesuvianite-epidote ±diopside ±tremolite ±wollastonite W skarns (USGS Model 14a) formed near the contact of the quartz monzonite porphyry and the Mississippian Deseret Limestone (?). The porphyry is finer grained at this contact and there are numerous minor pegmatitic phases and quartz veins associated with the border facies. The carbonate rocks are broadly conformable with the porphyry contact and are skarnified within a couple hundred yards of the batholith and marbleized or bleached for a few hundred yards more (Sibbett and Nielson, 1980).

Weakly mineralized skarn may be up to 800 ft long, 30 ft wide, and 100 ft deep, although the ore mined to date occurs in much smaller, higher-grade, structurally controlled, brecciated pods unevenly distributed within these broader, low-grade zones (Everett, 1961). The skarns range from dark brown, massive garnet lenses near the granite to pale yellow-green banded epidote-zoisite marble beds in the outer contact zone. The ore minerals are scheelite, galena, sphalerite, argentite, molybdenite, chalcopyrite, and bismuthinite, typically found with pyrite, fluorite, and barite. Nearly all of the scheelite fluoresces cream-yellow instead of the normal blue-white, which indicates isomorphous substitution of Mo for W. Everett (1961) reports a W ore sample from the district as running 0.53% WO_3 and 0.15% Mo. Some U.S. Geological Survey National Geochemical Database rock samples from the Granite district also run up to 450 ppm Sn and 70 ppm Mo.

Everett, F.D., 1961, Tungsten deposits in Utah: U.S. Bureau of Mines Information Circular 8014, 44 p.

Sibbett, B.S., and Nielson, D.L., 1980, Geology of the central Mineral Mountains, Beaver County, Utah: University of Utah Earth Science Laboratory, 42 p.

GRANITE PEAK DISTRICT

The Granite Peak (Granite Range) mining district is located about 85 mi west of Provo in south-central Tooele County. The district is an insignificant Pb-Ag producer with some fluorite production. The El Dorado mine is believed to be the largest producer.

Granite Peak is an isolated mountain located in the Great Salt Lake Desert of the Basin and Range Province of west-central Utah. Granite Peak is principally composed of an exposed 25 sq mi Jurassic (about 149 Ma) granite-granodiorite complex (Clark and others, 2009). The upper part of the complex is a foliated granodiorite underlain by a less strained and more leucocratic granite. Both intrusive phases are cut by pegmatite and aplite dikes and quartz veins.

Pegmatite dikes are common throughout the Granite Peak intrusive complex and are estimated to form up to 10% to 15% of the intrusive rock volume, being more prevalent in the upper foliated granodiorite. The pegmatite dikes typically strike approximately N. 35° E. and dip 55° to 70° W. The pegmatites range from small stringers, to pods, to larger tabular, zoned dikes and some individual dikes can be traced for up to half a mile. Accessory minerals generally constitute about 1% of the pegmatites and the minerals include garnet, tourmaline, beryl, samarskite, zircon, apatite, and hematite. Three zones are recognized in the pegmatites: borderwall, intermediate, and core. Samarskite and beryl occur in greatest abundance at the inner margin of the intermediate zone, adjoining the quartz-dominant core. The core is reportedly 97% quartz and 2% microcline. The Desert Queen prospect on the west side of Desert Peak was briefly examined by the Mica Corporation of America in the 1940s for muscovite, some of which had books reaching 6 inches across.

Mineralization at the El Dorado mine occurs in a north-trending, steeply east-dipping quartz vein. The vein is in a fault which it shares with a green, medium-grained, “diorite” dike. The dike is altered to chlorite-sericite-pyrite (Butler and others, 1920). Both the hanging wall and footwall of the fault are leucocratic granite. Butler and others (1920) believe that the dike predates the vein and Clark and others (2009) date the dike as Miocene (~8 Ma). The quartz vein is banded and contains galena, chalcopyrite, fluorite, and some Ag-Au values (Butler and others, 1920).

The area is in the southern part of the U.S. Army Dugway Proving Ground with no public access.

Butler, B.S., Loughlin, G.F., Heikes, V.C., and others, 1920, The ore deposits of Utah: U.S. Geological Survey Professional Paper 111, 672 p.

Clark, D.L., Biek, R.F., Willis, G.C., 2009, Geologic map of the Granite Peak and Sapphire Mountain area, U.S. Army Dugway Proving Ground, Tooele County, Utah: Utah Geological Survey Map 238, scale 1:24,000.

GREASEWOOD DRAW DISTRICT

The Greasewood Draw mining district of the San Rafael Swell U mining area is located 16 mi west of Green River in east-central Emery County. Mineralization was initially discovered in the mid-1950s and the district became an insignificant U-V producer. All the mines are small, but the largest producers were the Black Dragon, Uneva, and Cliff Dweller.

Greasewood Draw is geologically situated on the east flank of the San Rafael Swell of the Colorado Plateau. The Swell is an asymmetric, doubly plunging anticline, having a steeply dipping east limb. Mineralization in the San Rafael Swell district is predominantly hosted in the Upper Triassic Chinle Formation. The Chinle consists of three fining-upward, fluvial-lacustrine sandstone sequences. Sedimentological work on the Chinle suggests northwest-trending transport from a braided-stream environment in the southeast to floodplain and lacustrine environments progressively to the northwest.

The U ±V ores of the district are hosted in the moderately east-dipping (10° to 60°) Upper Triassic Chinle Formation (USGS Model 30c). The major host is the Moss Back Member, but U prospects are also found in the Temple Mountain and Monitor Butte Members. Orebodies in the Moss Back Member are hosted in tabular sandstones and conglomerates, typically within 40 ft of the base of the member and orebodies are typically less than 2000 tons. The principal ore minerals are uraninite and uranophane interstitial to sand grains and associated with bleaching. In addition to U-V, the ores may also be anomalous in As, Cu, and Mo (Mickle and others, 1977; Gloyn and others, 2003).

Gloyn, R.W., Tabet, D.E., Tripp, B.T., Bishop, C.E., Morgan, C.E., Gwynn, J.W., and Blackett, R.E., 2003, Energy, mineral, and ground-water resources of Carbon and Emery Counties, Utah: Utah Geological Survey Bulletin 132, 161 p., 14 plates, scale 1:855,000 approximately.

Mickle, D.G., Jones, C.A., Gallagher, G.L., Young, P., and Dubyk, W.S., 1977, Uranium favorability of the San Rafael Swell area, east-central Utah: U.S. Department of Energy Report GJBX-72(77), 120 p., 3 plates.

HARDSCRABBLE DISTRICT

The Hardscrabble (Mill Creek) mining district is located along Hardscrabble Creek about 8 mi south of Morgan in southwestern Morgan County. The Queen of the West Fe mine was located in the 1870s and became an infrequent producer from 1879 to 1923 and was examined again in the 1960s (Butler, 1920; Bullock, 1970). Total district metal production at modern metal prices is estimated at $20,000. The district is a small iron ore producer with the Queen of the West the only recorded producer.

The Hardscrabble district is on the east flank of the Wasatch Range of the Middle Rocky Mountain province. Mineralization at the Queen of the West Fe mine is along steeply dipping, northeasterly trending fracture filling and replacements in east-dipping Middle Cambrian Maxfield Limestone. The ore is brown, limonitic and goethitic gossans with small masses of magnetite, trace chalcopyrite, and abundant calcite (Bullock, 1970). The mineralization occurs as small lenses and pods a few feet thick. Bullock (1970) collected seven samples that averaged about 50% Fe.

Adams (1969) reported a prospect in migmatized granite gneiss of the Paleoproterozoic Farmington Canyon Complex in Arthurs Fork of Hardscrabble Creek (exact location uncertain). The Arthurs Fork prospect reportedly contains some uraninite, molybdenite, monazite, and xenotime (Adams, 1969). Nearby National Uranium Resource Evaluation (NURE) stream sediment samples contain anomalous rare earth elements (REE) Ce, La, and Y.

Adams, J.W., 1969, Thorium and rare earths, in Mineral and water resources of Utah: Utah Geological and Mineralogical Survey Bulletin 73, p. 115–119.

Bullock, K.C., 1970, Iron deposits of Utah: Utah Geological and Mineralogical Survey Bulletin 88, 101 p., 1 plate.

Butler, B.S., Loughlin, G.F., Heikes, V.C., and others, 1920, The ore deposits of Utah: U.S. Geological Survey Professional Paper 111, 672 p.

HENRY DISTRICT

The Henry mining district is in the Antelope Range about 18 mi south-southwest of Richfield in southwestern Sevier County. The district was organized in 1883 and has been a modest Au-Ag producer with insignificant Fe (960 tons) and alunite (500 tons) production (Butler and others, 1920; Callaghan, 1973). Total district metal production at modern metal prices is estimated at $1.35 million. The largest producers are believed to be the Antelope Au-Ag, Yellow Jacket Au-Ag, and Krotke (Iron Cap) Fe mines.

The Henry district is located on the northeast flank of the Oligocene-Miocene Marysvale volcanic field in the transition zone between the Basin and Range Province to the west and the Colorado Plateau to the east. The district is underlain by a thick sequence of volcanic rocks and about the eastern one-third of the district is mapped within the early Miocene Monroe caldera. The intracaldera volcanic rocks strike N. 20° W. and dip moderately east. The area inside the caldera wall is mostly altered Monroe Peak tuffs and andesites recognized as a 2 sq mi, 22.5 Ma advanced argillic Yellow Jacket hydrothermal cell. The upper levels of this alteration consist of massive silica replacements ("silica cap"), alunite ±dickite, and locally hydrothermal breccias (Cunningham and others, 1984). This texturally destructive alteration gradually fades laterally outward into zones of weaker chloritic propylitic alteration. The advanced argillic alteration zone is one of several cells surrounding the 23 Ma quartz monzonitic Central intrusive (Cunningham and others, 1984). This area has been explored for volcanic-hosted, epithermal Au-Ag deposits (USGS Model 25e). Rock-chip samples in the area are extremely erratic, but in addition to Au-Ag, are anomalous in As, Bi, Cu, Hg, Mo, Pb, Sb, Te, Tl, and Zn. The highest values are typically found in or near the Antelope or Krotke mines and associated with silicified, hematitic, hydrothermal breccias. The district was unsuccessfully explored for Au-Ag in the late 1980s and early 1990s. This work included nine holes totaling 3450 ft. A 505-ft vertical hole collared at the Yellow Jacket quarry cut a 10-ft interval at 200 ft of 0.36 ppm Au and 21.5 ppm Ag within a zone of quartz veinlets and pyrite associated with argillically altered andesite. The Antelope Au-Ag mine to the west, outside of the caldera, developed a small Au-Ag quartz vein (USGS Model 25c) in altered Oligocene Mount Dutton Formation dacites (Callaghan, 1973).

Butler, B.S., Loughlin, G.F., Heikes, V.C., and others, 1920, The ore deposits of Utah: U.S. Geological Survey Professional Paper 111, 672 p.

Callaghan, E., 1973, Mineral resource potential of Piute County, Utah and adjoining area: Utah Geological and Mineralogical Survey Bulletin 102, 135 p.

Cunningham, C.G., Rye, R.O., Steven, T.A., and Mehnert, H.H., 1984, Origins and exploration significance of replacement and vein type alunite deposits in the Marysvale volcanic field, west-central, Utah: Economic Geology, v. 79, p. 50–72.

HENRY MOUNTAINS DISTRICT

The Henry Mountains mining district is in eastern Garfield County about 25 mi south of Hanksville. The Henry Mountains is a small district that has had minor, sporadic production from the initial discoveries made in the 1880s. Total district metal production at modern metal prices is estimated at $25 million. The largest producer was the Bromide Au-Cu-Ag mine (about 500 oz Au) on Mount Ellen; however, the Crescent Creek Au placers downstream to the east were also nominal producers (Hunt and others, 1953).

The Henry Mountains are a series of north-northwest-trending, Oligocene (about 28 Ma), calc-alkaline stocks and laccoliths intruded into the Henry Basin on the Colorado Plateau. Compositionally the stocks are diorite to quartz monzonite porphyry and the adjoining laccoliths are mostly diorite porphyry. The stocks are often surrounded by shatter zones of brecciated igneous and sedimentary rocks (Hunt and others, 1953). Mineralization in the district is largely associated with the three central intrusive stocks near Mount Ellen, Mount Pennell, and Mount Hillers, from north to south, and is typically not associated with the surrounding laccoliths. The best mineralization occurs in the Bromide Basin cirque on the southeast side of Mount Ellen (Hunt and others, 1953). The dominant igneous rocks in Bromide Basin are equigranular diorite and feldspar-hornblende porphyry with small dikes and plugs of andesite porphyry, crowded feldspar porphyry, and quartz porphyry. These intrusives are largely subvertical and have been subjected to weak propylitic alteration with the development of epidote-chlorite-calcite.

At Bromide Basin, a series of scattered, small, north-northeasterly (N. 5°–25° E.) trending, very steeply dipping, native gold-bearing breccia veins cut the Mount Ellen stock. The veins range from a few inches to about 10 ft in width and average about 2 ft. These breccia veins have narrow zones of weak propylitic and argillic alteration. In addition to visible native gold, the primary metallic minerals are pyrite, chalcopyrite, bornite, pyrrhotite, specularite, magnetite, and rare molybdenite. The small, high-grade ore shoots in the Bromide vein can reportedly average about 68 ppm Au, 100 ppm Ag, and 8.5% Cu (Hunt and others, 1953). Other veins are primarily magnetite, chalcopyrite, and Au. The results of about 70 rock samples from Bromide Basin show no other element consistently correlates with Au, the best correlation for Au is with Cu-Fe-La, and there is no significant correlation to As, Ba, Cd, Hg, Mo, Pb, Sb, or W. Similar, albeit even smaller veins, also occur in the Pennell monzonite porphyry stock and the Mount Hillers diorite porphyry stock. Most of the more recent work has focused on extracting very small tonnages of high-grade Au ore from these old mines (Doelling, 1975). About 300 to 350 ounces of placer gold have been produced from the Crescent Creek placers downstream from Bromide Basin (USGS Model 39a). The gold occurs as fine flakes in black, sandy streaks at the base of surface gravels.

Doelling, H.H., 1975, Geology and mineral resources of Garfield County, Utah: Utah Geological and Mineral Survey Bulletin 107, 172 p.

Hunt, C.B., Averitt, P., and Miller, R.L., 1953, Geology and geography of the Henry Mountain region, Utah: U.S. Geological Survey Professional Paper 228, 234 p.

HONEYCOMB HILL DISTRICT

The Honeycomb Hill mining district is about 59 mi northwest of Delta in west-central Juab County. The area has no recorded production but has been prospected intermittently since the 1950s for lithophile elements including U, Be, Li, and rare earth elements (REE). The Honeycomb Hills is part of a low range of hills between the southern Deep Creek Range to the west and the Fish Springs Range to the east.

The Honeycomb Hills is an isolated series of rhyolite flow domes in the Basin and Range Province. Volcanic-hosted U mineralization was discovered in the Honeycomb Hills by H.P. Bertelsen in 1950, but grades are below typical ore grades (<0.1% U_3O_8). In 1961, C.R. Sewell discovered Be mineralization in the area while working for The Dow Chemical Company. Dow drilled a series of 15 exploration holes totaling 2930 ft and cut some dozer trenches. Assays reportedly ran from 0.05% to 0.85% Be (McAnulty and Levinson, 1964). Later, Anaconda held a property position in the district from 1977 to 1979 while exploring for uranium. ATW Gold Corp. acquired the Honeycomb Hills as a REE project in 2010. ATW Gold reported surface samples running up to 1000 ppm Be, 1690 ppm Li, 1270 ppm Rb, and 1043 ppm total rare earth oxides, but has dropped their property position.

The Honeycomb Hills is the westernmost Miocene to Pliocene (22 to 4 Ma) topaz rhyolite along the greater Deep Creek–Tintic mineral belt. This belt includes the famous Spor Mountain Be-F district 20 mi to the east. The Honeycomb Hills volcanic complex consists of a 40-ft-thick, Pliocene lithic, fluorite-bearing, air-fall (?) tuff, immediately underlain by older volcanic rocks, and overlain by two small coeval topaz rhyolite flow domes that erupted about 4.7 Ma. The rhyolite is gray, vesicular, strongly flow-banded, and contains about 40% phenocrysts of smoky quartz, sanidine, plagioclase, and biotite. Topaz crystals commonly line the vesicles. The rhyolite also contains globular topaz- and fluorite-bearing inclusions (Christiansen and others, 1986). Paleozoic carbonate rocks (Devonian?) lie beneath the rhyolite domes at an estimated depth of about 200 ft (McAnulty and Levinson, 1964). Low-grade Be, Li, Cs, and Rb occurs in an approximately 3-ft-thick zone in the uppermost tuff immediately underlying the capping massive Bell Hill (northwestern) rhyolite dome (McAnulty and Levinson, 1964). Some samples also contain anomalous Mo and Sn (Christiansen and others, 1986). Honeycomb Hills is also anomalous in Lu, Tb, Y, and Yb with a low light REE/heavy REE ratio (i.e., it is relatively enriched in heavy REE).

Christiansen, E.H., Sheridan, M.F., and Burt, D.M., 1986, The geology and geochemistry of Cenozoic topaz rhyolites from the western United States: Geological Society of America Special Paper 205, 82 p.

McAnulty, W.N., and Levinson, A.A., 1964, Rare alkali and beryllium mineralization in volcanic tuffs, Honey Comb Hills, Juab County, Utah: Economic Geology, v. 59, p. 768–774.

INDIAN CREEK DISTRICT

The Indian Creek district is part of the Moab U mining area, San Juan County, and is located about 30 mi south of Moab. The district has been a significant U-V producer. Total district metal production at modern metal prices is estimated at $543,000. The largest operations have been the Jean #1 and Moki underground mines in the southern part of the district (Doelling, 1969, 1974).

The Indian Creek district is in the Paradox Basin on the Colorado Plateau. The mining history and geology of the Indian Creek district are poorly documented. The mines exploit sandstone U orebodies (USGS Model 30c). The larger mines, in the southern Indian Creek district, produced from the Upper Triassic Moss Back Member of the Chinle Formation, and the small mines in the northern part of the district produced from the underlying Lower Permian Cutler Formation. The mines in the Moss Back Member have more Cu than the ore in the Cutler Formation. The Moss Back orebodies are associated with carbonaceous trash and clay gauls in paleochannels. The Cutler ores are hosted in bleached arkosic sandstones of the Bogus Tongue Member of the Cutler Formation. The overall ore grades for Indian Creek district ores are about 0.3% U_3O_8 and 0.1% V_20_5. No Cu analyses are available (Doelling, 1974; Gloyn and others, 1995).

Doelling, H.H., 1969, Mineral resources, San Juan County, Utah and adjacent areas, Part II—Uranium and other metals in sedimentary host rocks: Utah Geological and Mineralogical Survey Special Study 24, 64 p.

Doelling, H.H., 1974, Uranium-vanadium occurrences of Utah: Utah Geological and Mineral Survey Open-File Report 18, unpaginated.

Gloyn, R.W., Morgan, C.D., Tabet, D.E., Blackett, R.E., Tripp, B.T., and Lowe, M, 1995, Mineral, energy, and ground-water resources of San Juan County, Utah: Utah Geological Survey Special Study 86, 24 p., 14 plates, scale 1:500,000.

INDIAN PEAK DISTRICT

The Indian Peak mining district lies about 48 mi west of Milford in the Indian Peak Range in western Beaver County. The district is located north of the larger Washington F-Pb-Zn district. The Indian Peak district is a poorly documented series of small Cu and Ag-Au prospects and has no recorded production. However, the Blue Jay Cu mine, which was active well before 1900 and possibly 1890, has the most extensive mine workings in the district and probably has made some very small shipments of high-grade Cu-Ag-Au-Pb ore.

The Indian Peak Range lies in the east-central Basin and Range Province. The Indian Peak district is geologically situated astride the northern margin of the large, early Oligocene (29.5 Ma) Indian Peak caldera. Mineralization in the district is probably related to this important magmatic event. The bulk of the mineralization in the district was derived from fissured and replaced Paleozoic sedimentary rocks; however, Oligocene volcanic rocks are ore hosts locally. The Indian Peak Range was rotated eastward during Miocene-age extension so that the Oligocene units dip moderately eastward, but mid-Miocene volcanic units only dip gently (Best and others, 1987).

Two clusters of alteration and mineralization occur in the district, one near Miners Cabin Wash in the southwest and the other near Sawtooth Peak in the northeast. Both areas had some exploration drilling in the late 1990s. The Blue Jay Cu mine and Miners Cabin Cu shafts in the southwest are associated with a small, dark-gray, magnetic granodiorite porphyry (east-central section 13, T. 29 S., R. 19 W.) that has weakly chloritized mafic minerals. The Cambrian and Lower Ordovician carbonates in this area are altered and locally mineralized (Steven and Morris, 1987). The Blue Jay mine developed a small Cu-Au-Ag-Pb garnet skarn (USGS Model 18B) on about eight patented mining claims. The ore is also anomalous in As, Mn, Sb, and Zn. This area was unsuccessfully drill tested by Breccia Development and Royal Gold, who drilled about 12 shallow holes primarily for Au. The mineralization to the northeast near Sawtooth Peak is primarily Ag-Au hosted in Fe-stained silicified Lower Ordovician limestone along a northerly trending normal fault just west and south of the Elephant Back ridge (Steven and Morris, 1987). This property was also unsuccessfully drilled in the late 1990s by West Hills Excavating; about 10 holes were drilled for Au.

Best, M.G., Grant, S.K., Hintze, L.F., Cleary, J.G., Hutsinpiller, A., and Saunders, D.M., 1987, Geologic map of the Indian Peak (southern Needle) Range, Beaver and Iron Counties, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-1795, scale 1:50,000.

Steven, T.A., and Morris, H.T., 1987, Summary mineral resource appraisal of the Richfield 1° x 2° quadrangle, west-central Utah: U.S. Geological Survey Circular 916, 24 p.

INTER-RIVER DISTRICT

The Inter-River district is a part of the Green River U mining area located about 10 mi west of Moab just above the confluence of, and between the Green and Colorado Rivers on the Grand and San Juan County line. The Inter-River area is quite rugged with difficult access and the district has been a small U producer, with no large mines. Total district metal production at modern metal prices is estimated at $397,000.

The Inter-River district is situated in the Paradox Basin section of the Colorado Plateau. Nearly all mineralization is in flat-lying, stratabound deposits hosted in the lower Moss Back Member of the Upper Triassic Chinle Formation (USGS Model 30c). Mineralization occurs in conglomeratic sandstone channels cut into the underlying Moenkopi Formation. Bleaching of both the Moss Back and Moenkopi occur near ore. Some of the Inter-River ore is associated with carbonaceous trash in the sandstone. Primary ore/sulfide minerals include uraninite, chalcopyrite, bornite, chalcocite, covellite, pyrite, galena, sphalerite, and barite. The lack of a V by-product and the deleterious metallurgy resulting from the high Cu content were both detrimental to the Inter-River district's production. Ilsemannite and erythrite have both been reported locally, suggesting at least geochemically anomalous Mo and Co associated with the ore. Ore grades are approximately 0.2% U_3O_8 and 0.02% V_2O_5 (Doelling, 1969, 1974).

The area of the Inter-River district includes portions of Dead Horse Point State Park and Canyonlands National Park.

Doelling, H.H., 1969, Mineral resources, San Juan County, Utah and adjacent areas, Part II—Uranium and other metals in sedimentary host rocks: Utah Geological and Mineralogical Survey Special Study 24, 64 p.

Doelling, H.H., 1974, Uranium-vanadium occurrences of Utah: Utah Geological and Mineral Survey Open-File Report 18, unpaginated.

IRON PASS DISTRICT

The Iron Pass mining district is in south-central Millard County about 18 mi northwest of Milford. Bullock (1970) estimates that a few tons of Fe ore have been shipped based on the mine workings in the district.

The Iron Pass district lies in the northern San Francisco Mountains of the Basin and Range Province. The prospects and mine workings are primarily along a gravel road through Iron Mine Pass. Most of the Fe workings are south of the pass and are referred to as the Iron Pass mine (NE¼NE¼ section 23 and NW¼NW¼ section 24, T. 25 S., R. 12 W.). These shallow prospects consist of a series of short inclined shafts, adits, dozer cuts, and a small open cut. The workings all follow minor normal faults cutting Neoproterozoic metasedimentary strata including Black Rock Canyon Limestone and Caddy Canyon Quartzite. Mineralization is generally localized at fault contacts between brown dolomitic limestone and gray quartzite or purplish gray argillite. Mineralization occurs as scattered, narrow 0.5- to 4-ft-wide, massive hematite or goethite pods developed along the faults, fractures, or as thin replacements of favorable carbonate beds. Mineralization includes some Mn (Bullock, 1970). Bullock (1970) reports two samples from these workings average 53.8% Fe and 2.52% Mn. The district also has a couple of smaller, less well described prospects north of the pass.

Bullock, K.C., 1970, Iron deposits of Utah: Utah Geological and Mineralogical Survey Bulletin 88, 101 p., 1 plate.

IRON PEAK DISTRICT

The Iron Peak mining district is located on the Markagunt Plateau about 26 mi northeast of Cedar City in northeastern Iron County. The district covers a few small Fe prospects; there has been no recorded production, but the area has been repeatedly staked and reexamined by prospectors. The Iron Peak Group prospect has the largest area of surface disturbance.

The Iron Peak district lies on the early Miocene Iron Axis mineral belt in the Markagunt Plateau of the transition zone from the Basin and Range Province on the west to the Colorado Plateau on the east. The Iron Peak district lies in the Iron Peak graben. The graben contains Miocene Brian Head volcaniclastic strata and Bear Valley ash-flow tuff intruded by the Iron Peak laccolith. The intrusive is a calc-alkaline, diorite-gabbro porphyry laccolith (20.2 Ma) with an exposed base at an elevation of about 7500 ft and an apex at 8158 ft on Iron Peak. The laccolith is the most mafic and easternmost intrusive on the Iron Axis. A series of feeder dikes to the laccolith are exposed in a canyon to the south and below the base of the intrusion. The Iron Peak diorite-gabbro porphyry is primarily composed of augite, plagioclase, and has 8% opaque minerals, mostly magnetite (Biek and others, 2015). Slope wash deposits around Iron Peak have abundant resistant magnetite fragments.

Iron Peak mineralization occurs as magnetite veins mostly less than an inch wide, but ranging up to 10 ft thick (Spurney, 1984). Bullock (1970) describes three small Fe prospects near Iron Peak: a shallow shaft southwest of the peak, a prospect near the peak, and the Iron Peak Group dozer scape north of the peak. He reports the ore is magnetite with minor hematite and gives the average of 14 samples collected in the district as 62.4% Fe, 4.9% SiO_2, 0.36% Mn, 0.03% P, and 0.006% S. Minor specularite has also been reported.

Biek, R.F., Rowley, P.D., Anderson, J.J., Maldonado, F., Moore, D.W., Hacker, D.B., Eaton, J.G., Hereford, R., Sable, E.G., Filkorn, H.F., and Matyjasik, B., 2015, Geologic map of the Panguitch 30' x 60' quadrangle, Garfield, Iron, and Kane Counties, Utah: Utah Geological Survey Map 270DM, 3 plates, 162 p., scale 1:62,500.

Bullock, K.C., 1970, Iron deposits of Utah: Utah Geological and Mineralogical Survey Bulletin 88, 101 p., l plate.

Spurney, J.C., 1984, Geology of the Iron Peak intrusion, Iron County, Utah: Kent, Ohio, Kent State University, M.S. thesis, 84 p., 8 plates, scale 1:16,500.

IRON SPRINGS DISTRICT

The Iron Springs (Pinto) mining district is located about 15 mi west of Cedar City in south-central Iron County. The district was organized in 1871, is the most productive Fe district in the western U.S. (about 100 million long tons), and is estimated to be the fourth largest district in Utah by production value. Total district metal production at modern metal prices is estimated at $6.7 billion. The most productive mine in the district is the Comstock–Mountain Lion (CML) open pit on the east side of Iron Mountain.

The Iron Springs district covers a 20-mi-long, slightly arcuate, northeast-trending belt of laccoliths along the east-northeast-trending Miocene-age Iron axis of the Basin and Range Province of southwestern Utah. The Iron axis is a Sevier-age anticline intruded by Miocene quartz monzonites. The orebodies are associated with three oval-shaped Miocene (about 22 Ma) calc-alkaline, porphyritic quartz monzonite laccoliths, from southwest to northeast: Iron Mountain, Granite Mountain, and Three Peaks. The three intrusions have nearly identical composition. The porphyritic quartz monzonite is green-gray, fine-grained quartz and K-spar with plagioclase phenocrysts and subordinate hornblende, augite, and biotite with accessory magnetite, ilmenite, apatite, titanite, and zircon (Bullock, 1970).

Three basic types of orebodies are in the Iron Springs district: veins, breccia bodies, and skarn/replacement orebodies. The largest and most important orebodies are the stratabound skarn/replacement ores principally in the Middle Jurassic Homestake Limestone Member of the Carmel Formation draped over the laccoliths (USGS Model 18d). The Homestake Limestone is about 250 ft thick and near ore it is extensively recrystallized and bleached micritic limestone. The Homestake Limestone, equivalent to the Co-op Creek Member regionally, is often separated from the intrusive by a hornfelsed siltstone of the underlying Temple Cap Formation (30 to over 100 ft thick). Stratabound skarn/replacement mineralization begins at the base of the Homestake Limestone where it usually has the best grade (>50% Fe); however, the entire Homestake Limestone may ultimately be replaced. While some of the breccia orebodies constitute significant deposits, the veins are generally only small deposits (Bullock, 1970; Wray and Pedersen, 2009).

All Iron Springs ores are primarily magnetite and have minor hematite. Textures of the magnetite ore indicate cross-cutting veinlets and progressive replacement of the limestone along bedding planes leading to virtually massive magnetite containing only accessory minerals. The gangue minerals include calcite, quartz, dolomite, phlogopite, fluorapatite, quartz, siderite, ankerite, diopside, magnesite, gypsum, barite, epidote, andradite garnet, vesuvianite (idocrase), and scapolite (Bullock, 1970; Wray and Pedersen, 2009).

Bullock, K.C., 1970, Iron deposits of Utah: Utah Geological and Mineral Survey Bulletin 88, 101 p., l plate.

Wray, W.B., and Pedersen, A.D., 2009, Iron resources and geology of the property of Palladon Ventures Ltd. in the Iron Mountain area, Iron County, Utah, in *Tripp, B.T., Krahulec, K.A., and Jordan, J.L., editors, Geology and geologic resources and issues of western Utah: Utah Geological Association Publication 38, p. 152–162.*

JARLOOSE DISTRICT

The Jarloose mining district covers part of the Black Mountains about 15 mi southwest of Beaver, in Beaver County. The district has some reports of weak Ag, Au, Cu, Pb, and Zn, but no production.

The district lies directly on the east-trending, Miocene-age, Blue Ribbon lineament (Rowley and others, 1978) in the eastern Basin and Range Province. The host rocks in the district are primarily late Miocene-age andesites with subordinate younger basalts and alkalic rhyolites. The southwestern Black Mountain peak is an andesite plug (Erickson and Dasch, 1968). The range shows evidence of modest eastward rotation. Mineralization is associated with epithermal quartz veins, local silicification, and moderate argillic alteration of the volcanic host rocks (Erickson and Dasch, 1968). The district has no recorded production, but low Au and Ag values are reported.

Erickson, M.P., and Dasch, E.J., 1968, Volcanic stratigraphy, magnetic data and alteration, geologic map, and sections of the Jarloose mining district southeast of Minersville, Beaver County, Utah: Utah Geological and Mineralogical Survey Map 26, scale 1:24,000.

Rowley, P.D., Lipman, P.W., Mehnert, H.H., Lindsey, D.A., and Anderson, J.J., 1978, Blue Ribbon lineament, an east-trending structural zone within the Pioche mineral belt of southwestern Utah and eastern Nevada: Journal of Research of the U.S. Geological Survey, v. 6, no. 2, p. 175–192.

KAIPAROWITS DISTRICT

The Kaiparowits district spans the Garfield–Kane County line along the Straight Cliffs, south of Escalante. The prospects are in an area with steep-walled canyons and are poorly developed. The district has had no production but encompasses a series of Ti-Zr paleoplacers, a Mn occurrence, and three of U ±V occurrences. The Mn and U-V occurrences are of no consequence. The Ti-Zr paleoplacers were discovered in the 1950s, probably by prospectors during the uranium boom. The occurrences were repeatedly staked and dropped by a series of junior companies primarily driven by high Ti prices prior to the declaration of the Grand Staircase–Escalante National Monument in 1996 (Dow and Batty, 1961; Gloyn and others, 1997).

The Kaiparowits district lies in the Kaiparowits Basin on the Colorado Plateau. At least 14 Ti-Zr occurrences are in the John Henry Member of the Upper Cretaceous Straight Cliffs Formation. The source area for the Straight Cliffs Formation sandstone was to the southwest and open water was to the northeast. The formation records a series of transgressive and regressive marine sandstone interbedded with nonmarine siltstone, fine-grained sandstone, carbonaceous shale, and coal (Gloyn and others, 1997). The better paleoplacer deposits developed in swash zones during regressive phases. The Straight Cliffs Formation has been folded into a series of open, upright, north-northwest-trending anticlines and synclines (Force, 2000).

The heavy mineral concentrations generally occur in small, red-brown, elongate lenses from 3 to 15 ft thick, 100 to 300 ft wide, and 300 to 3500 ft long. The Fe-cement may cause the occurrences to weather as low, resistant ridges. Heavy minerals in the deposits include Ti phases rutile, ilmenite, leucoxene, and titanite and Zr phases zircon, brookite, and anatase. Hematite, garnet, staurolite, and minor allanite, monazite, apatite, tourmaline, aluminosilicates, chromite, and gahnite are also reported from the deposits (Gloyn and others, 1997). The only prospect that has enough drilling on it to provide any grade-tonnage information is the Mann-Longshot deposit. This paleoplacer is estimated at about 300,000 tons at average grade of 9.6% TiO_2 and 3% ZrO_2. Hafnium (Hf) and minor Th, Nb, Ta, U, W, and Y have also been reported from the deposits (Gloyn and others, 1997). This mineral inventory is only a fraction of the size of the average shoreline placer Ti deposit (USGS Model 39c) but is slightly above average grade. The Calf Canyon deposit has not been drilled but may have similar size and grade potential.

Dow, V.T. and Batty, J.V. 1961. Reconnaissance of titaniferous sandstone deposits of Utah, Wyoming, New Mexico, and Colorado: U.S. Bureau of Mines Report of Investigations 5860, 52 p.

Force, E.R., 2000, Titanium mineral resource of the Western U.S.—an update: U.S. Geological Survey Open-File Report 00-442, 37 p.

Gloyn, R.W., Park, G.M., Reeves, R.G., 1997, Titanium-zirconium-bearing fossil placer deposits in the Cretaceous Straight Cliffs Formation, Garfield and Kane Counties, Utah, in *Learning from the land—Grand Staircase-Escalante National Monument Science Symposium Proceedings: Salt Lake City, Bureau of Land Management, p. 293–303.*

KANOSH DISTRICT

The Kanosh (Dog Valley, Gordon) mining district is located on the northwestern slope of the Pavant Range 30 mi north of Beaver in southeast Millard County. The Kanosh district is distinguished from the Sulphurdale district to the south by the Pb-Zn ores in Kanosh and sulfur ores in Sulphurdale some 6 mi to the south. The Kanosh district is a minor producer and extends along the northwest face of Dog Valley Mountain. Lead-zinc was probably discovered in the district around 1910. First production was reported in 1911 and consisted of a small amount of oxidized, Pb-Ag ore. Total district metal production at modern metal prices is estimated at $36,000. Subsequent mining, mostly, if not entirely, from the Blue Bell mine, continued intermittently until 1966.

The Pavant Range is part of the transition zone between the Basin and Range Province to the west and the Colorado Plateau to the east. Geologically the Kanosh district features a northeast-trending thrust fault with overturned lower Paleozoic strata in the northwestern upper plate and upper Paleozoic strata in the lower plate.

The Blue Bell mine workings consist of eight short adits, four shallow shafts, and numerous prospect pits. The host rock is massive, gray to brownish gray, recrystallized dolomite of the Devonian Simonson Dolomite in the immediate hanging wall of the thrust. The Kanosh district Pb-Zn mineralization consists of veins and small replacements along faults and bedding planes in carbonate rocks (USGS Model 22c). The ore on the dumps is completely oxidized and consists of hard, dense siliceous red-brown gossan/jasperoid and vuggy, porous, yellow-brown gossan. A few other mines and prospects occur in the district, but none have reported production (Heyl, 1963; Perry and McCarthy, 1977).

Heyl, A.V., 1963, Oxidized zinc deposits of the United States, pt. 2, Utah: U.S. Geological Survey Bulletin 1135-B, 104 p.

Perry, L.I., and McCarthy, B.M., 1977, Lead and zinc in Utah, 1976: Utah Geological and Mineral Survey Open-File Report 22, 525 p.

KEG DISTRICT

The Keg mining district, on the northwest flank of the Keg Mountains, is located about 44 mi west of Eureka in central Juab County of west-central Utah. The Keg mineral occurrences were not discovered until the 1970s and there has been no recorded production.

The Keg district lies on the Deep Creek–Tintic mineral belt in the Basin and Range Province. Prospecting from the 1970s to the 1990s, primarily by Bob and Terry Steele, located numerous mineral occurrences, which have since been explored by several prospect pits and drill programs. These properties have been investigated by Getty Mining Company, Freeport Minerals, Western Strategic Minerals Company, Kennecott Exploration, Crown Resources, and Inland Explorations since the late 1970s. The eastern part of the district has been explored principally for base metals (Lead Hill area) and the west end for Ag (Dome Hill) (Venable, 2009).

The geology of the Keg Mountain area is quite complex. The oldest exposed units in the area are Lower Cambrian Prospect Mountain Quartzite, thrust over Middle Cambrian carbonate rocks, and overlain by Eocene andesitic and latitic volcanic rocks, volcanic megabreccia, and finally by Miocene Topaz Mountain Rhyolite. During the latest Eocene, a cauldron subsided on the north side of the district and several small porphyry stocks (~36 Ma) were intruded to the southeast (Shubat, 1987). These porphyries range in composition from granodiorite to high-silica rhyolite (>75% SiO_2). Mineralization in the Keg district appears to be related to these porphyry stocks and associated pebble dikes. A zone of pyritic alteration wraps around the northeast side of the northeasternmost granodiorite porphyry. Mineralization may have been deposited by hydrothermal solutions derived from the granodiorite porphyry of Dead Ox Wash (Shubat, 1987).

The Dome Hill Ag prospect has high-grade rock samples assaying to over 1000 ppm Ag and generally low Au values (Au:Ag about 1:150). A low northwest-trending ridge of Prospect Mountain Quartzite occurs as a horst surrounded by Tertiary volcanic rocks and alluvium. Bedding in the quartzite strikes to the northwest and dips moderately to the southwest. Mineralization at Dome Hill consists of a northwest-trending quartz-sulfide stockwork from 2 to 10 ft wide in the Prospect Mountain Quartzite (Venable, 2009).

Shubat, M.A., 1987, Geology and mineral occurrences of northern Keg Mountain, Juab County, Utah: Salt Lake City, Utah, in Kopp, R.S., and Cohenour, R.E., editors, Cenozoic geology of western Utah—sites for precious metal and hydrocarbon accumulations: Utah Geological Association Publication 16, p. 451–462.

Venable, M.E., 2009, Mineral Exploration in the northern Keg Mountains, Juab County, Utah, in Tripp, B.T., Krahulec, K., and Jordan, J.L., editors, Geology and Geologic Resources and Issues of Western Utah: Utah Geological Association Publication 38, p. 175–182.

KINGS CANYON DISTRICT

The Kings Canyon district is located about 60 mi southwest of Delta in west-central Millard County. The Kings Canyon mineral occurrences cover about 70 sq mi but were not discovered until the 1980s and there has been no production. Nonetheless, the area was intensively explored in the late 1980s, early 1990s, and again this century—including the drilling of over 200 exploration holes.

Kings Canyon is situated on the west flank of the Confusion Range in the Basin and Range Province. The Confusion Range is a gently west-dipping homocline of Devonian-age carbonate rocks. The massive, very thickly bedded, Middle to Upper Devonian Guilmette Limestone forms cliffs on the west side of the range. The underlying Middle Devonian Fox Mountain Formation is a poorly mapped and understood carbonate solution breccia/karst cave-fill unit. Most of the recognized Au deposits occur in or near the Fox Mountain Formation. The Fox Mountain is underlain by thickly bedded, ledge-forming, Middle Devonian Simonson Dolomite and the underlying Lower Devonian Sevy Dolomite with a few Au prospects farther east in these units (Krahulec, 2011). The only known intrusive rocks are two small feldspar (latite?) porphyry dikes and several breccias containing clasts of altered intrusive rocks exposed on the west side of the range in and near Boobs Canyon (Krahulec, 2011).

Gold mineralization occurs in cross-cutting, high-angle structures and as stratiform replacement of susceptible horizons (USGS Model 19c). The Au is commonly associated with partial or, more rarely, complete silicification. The alteration locally produces massive jasperoid bodies, but more commonly is selective and only 10% to 50% of the rock is silicified. Gangue minerals in the jasperoid include quartz, calcite, fluorite, and barite. Gold mineralization is also associated with Fe-stained and slightly to moderately decalcified limestone and dolomite along cross-cutting structures and along bedding (Zimmerman, 2009).

Four broad main areas of sedimentary rock-hosted Au mineralization in the Kings Canyon district (from southwest to northeast): Thompson Knoll/Boobs Canyon, Road Canyon, Crown/Royal zones, and King Top/Sunshine (Krahulec, 2011). The southeastern part of the district is within a Wilderness Study Area.

Krahulec, K., 2011, Sedimentary rock-hosted gold and silver deposits of the northeastern Basin and Range, Utah, in *Steininger, R., and Pennell, B, editors, Great Basin evolution and metallogeny: Geological Society of Nevada 2010 Symposium Proceedings, v. 1, p. 31–62.*

Zimmerman, J.E., 2009, Gold mineralization at Kings Canyon, Millard County, Utah, in *Tripp, B.T., Krahulec, K., and Jordan, J.L., editors, Geology and geologic resources and issues of western Utah: Utah Geological Association Publication 38, p. 187–195.*

KINGSTON CANYON DISTRICT

The Kingston Canyon mining district lies about 7 mi east of Junction on the Sevier Plateau in southern Piute County. The Kingston Canyon district is a poorly documented series of small Au-Ag and U prospects and has no recorded production. None of the prospects have notable disturbance, but quartz veins northwest of Blood Mine Spring have the highest reported Au values.

The Kingston Canyon district lies in the southeastern Marysvale volcanic field on the Sevier Plateau in the transition zone from the Basin and Range Province on the west to the Colorado Plateau on the east. The district is largely underlain by the Oligocene-Miocene Mount Dutton Formation (26–21 Ma), which is made up of volcanic mudflows, andesitic flows, and flow breccias (Rowley and others, 2005). The Mount Dutton Formation is intruded and overlain by Pliocene-age high-silica rhyolites belonging to the east-west trending Blue Ribbon transverse zone (Rowley, 1998; Rowley and others, 2005). Phonolite Hill is a gray, crystal-poor, rhyolite volcanic dome/intrusive (5.4 to 4.8 Ma) in the south-center of the Kingston Canyon district. Mineralization in the district appears to be zoned around the Phonolite Hill rhyolite with radial (?) narrow Au-Ag quartz veins near the dome/stock and more distal volcanogenic U deposits (USGS Model 25F). The low-sulfidation Au-Ag veins strike northeast, northeast of Phonolite Hill (Jeep Springs prospects) and roughly N. 30° W. north of Phonolite Hill (Blood mine). The quartz veins are up to about 3 ft wide or locally are smaller, sheeted vein sets. The mineralized veins are Fe-stained and may display bladed quartz after calcite (USGS Model 25C). The Fe-stained veins are consistently anomalous in Au from about 200 ppb to 1.5 ppm Au with low Ag values and very roughly 1 ppm Hg, 10–100 ppm As, and 2–16 ppm Sb (Peter Maciulaitis, written communication, August 1, 2011). The Blood mine vein has low Mo (less than 10 ppm Mo), but the Jeep Springs vein has elevated Mo to 110 ppm Mo. No recent physical exploration is reported from the Blood mine vein, but the Jeep Springs prospect was drilled by Placer Dome in the 1990s. The distal volcanogenic U deposits are mere prospect pits or dozer scrapes and have weak argillic alteration and minor uranophane and autunite (USGS Model 25F). The best reference to the prospects in this district is the Utah Mineral Occurrence System (UMOS).

Rowley, P.D., 1998, Cenozoic igneous and tectonic setting of the Marysvale volcanic field, and its relation to other igneous centers in Utah and Nevada, in *Friedman, J.D., and Huffman, A.C., Jr., coordinators, Laccolith complexes of southeastern Utah—Time of emplacement and tectonic setting—Workshop proceedings: U.S. Geological Survey Bulletin 2158, p. 167–202.*

Rowley, P.D., Vice, G.S., McDonald, R.E., Anderson, J.J., Machette, M.N., Maxwell, D.J., Ekren, E.B., Cunningham, C.G., Steven, T.A., and Wardlaw, B.R., 2005, Interim geologic map of the Beaver 30' x 60' quadrangle, Beaver, Piute, Iron, and Garfield Counties, Utah: Utah Geological Survey Open-File Report 454, scale 1:100,000, 27 p.

KOLOB TERRACE DISTRICT

The Kolob Terrace district is in east-central Washington County about 25 mi northeast of St. George. The district has one mine and three known prospects. The Kolob U mine recorded minor U production. Total district metal production at modern metal prices is estimated at $10,000.

Kolob Terrace encompasses Smith Mesa and adjoining areas in the northwestern corner of the Grand Staircase section of the transition zone from the Basin and Range Province on the west to the Colorado Plateau on the east (Biek and others, 2009). The Kolob mine has autunite and tyuyamunite in brecciated Lower Permian Kaibab Formation limestone. Ore from the mine ran 0.08% U_3O_8 and 0.03% V_2O_5. Mineralization in the other known prospects is primarily stratabound replacements hosted in the nearly flat-lying Upper Triassic Chinle Formation. All three prospects have some Cu mineralization (USGS Model 30b). Petrified wood is also present at one of these sites. Mineralization is present as malachite, azurite, chrysocolla, and vanadium mica. High-grade dump samples collected from the Dry Creek Cu prospect run up to 2% Cu, 250 ppm U, 150 ppm V, and 30 ppm Ag (U.S. Geological Survey national geochemical database), but channel samples are much lower grade. No references to these prospects are found outside the Utah Mineral Occurrence System (UMOS).

Biek, R.F., Rowley, P.D., Hayden, J.M., Hacker, D.B., Willis, G.C., Hintze, L.F., Anderson, R.E., and Brown, K.D., 2009, Geologic map of the St. George and east part of the Clover Mountains 30' x 60'quadrangles, Washington and Iron Counties, Utah: Utah Geological Survey Map 242, 2 plates, 101 p., scale 1:100,000.

LAKE MOUNTAINS DISTRICT

The Lake Mountains (Soldiers Pass) mining district covers the southern Lake Mountains of west-central Utah County, immediately west of Utah Lake. The district produced a small amount of Mn ore between 1930 and 1943. Total district metal production at modern metal prices is estimated at $157,000. The Wildcat underground mine is the only known metal producer, but the district also covers several larger industrial mineral operations (Crittenden, 1951).

The Lake Mountains are positioned in the eastern part of the Basin and Range Province in central Utah. The most prominent structure in the range is the Lake Mountains syncline. The Wildcat Mn mine is located on the west flank of the range in east-dipping Upper Mississippian Manning Canyon Shale. The Manning Canyon Shale is a 1200-ft-thick interbedded sequence of shale, siltstone, sandstone, and limestone. The Mn ore is hosted in a heavily faulted, thin-bedded, shaly limestone. The ore occurs as stringers and veins following both bedding and east-west-trending faults with small Mn replacements a few feet across (USGS Model 19b). The primary ore was spongy masses of cryptomelane having average shipped grades of about 45% Mn (Crittenden, 1951). The Lake Mountains are currently quarried for crushed stone from the Mississippian Deseret Limestone and common clay from the Mississippian Manning Canyon Shale and Tertiary Salt Lake Group.

Crittenden, M.D., Jr., 1951, Manganese deposits of western Utah: U.S. Geological Survey Bulletin, 979-A, 62 p.

LAKESIDE DISTRICT

The Lakeside mining district lies 50 mi west-northwest of Salt Lake City and just west of Great Salt Lake in northeastern Tooele County. The district was organized in 1871 and became a modest Pb producer. The main periods of metal production were the early 1870s, 1917 to 1924, and 1932 to 1948. Total district metal production at modern metal prices is estimated at $2.7 million. The Monarch underground mine at the north end of the district is the largest producer, probably responsible for 90% of the production (Perry and McCarthy, 1977).

The Lakeside district covers the southern half of the Lakeside Mountains of the Basin and Range Province in northwestern Utah. District production has been predominantly Pb ore (about 13,000 tons) in the north and siliceous iron ore in the south. There are no known intrusives in the range or any magnetic anomalies suggesting any intrusive rocks at depth.

The largest producer is the Monarch Pb replacement deposit in Cambrian- and Ordovician-age carbonate rocks. Orebodies in the Monarch mine typically occur along northerly trending fault systems. The ore is mostly oxidized with only remnant galena and sphalerite. There are reports of thick sections of low-grade Pb ore in the workings which have not been shipped due to the lack of associated precious metals. A 100,000 tons low-grade Pb-Zn subeconomic inferred resource is reported at the Monarch mine (Doelling, 1964; Perry and McCarthy, 1977).

The Lakeside district is unlike the many intrusive-centered base metal replacement camps in the eastern Basin and Range because it lacks associated igneous phases and has low precious metal credits. The low Ag:Pb ratios in the Lakeside district are similar to Mississippi Valley-type Pb-Zn ores. The Promontory Zn district on the east side of Great Salt Lake also has very low Ag:Pb ratios.

Doelling, H.H., 1964, Geology of the northern Lakeside Mountains and the Grassy Mountains and vicinity, Tooele and Box Elder Counties, Utah: University of Utah, doctoral thesis, 338 p.

Perry, L.I., and McCarthy, B.M., 1977, Lead and zinc in Utah, 1976: Utah Geological and Mineral Survey Open-File Report 22, 525 p.

LA SAL DISTRICT

The La Sal district of the Moab U mining area is located 24 mi southeast of Moab in northern San Juan County. The district was organized in 1954 and is a large U-V producer. The district is the largest V and second most productive U district in Utah. Total district metal production at modern metal prices is estimated at $368 million. The most productive area is the Energy Queen, Redd Block, Beaver-La Sal, and Pandora group of underground mines.

The La Sal district is situated in the Paradox Basin on the Colorado Plateau. The district contains several significant U-V mines along a 12-mi-long, east-trending channel in the Upper Jurassic Salt Wash Member of the Morrison Formation (USGS Model 30c). Most of the mines were discovered by drilling and orebodies lie at depths of 500 to 800 ft. Little has been written about the deposits; a short article by Kovschak and Nylund (1981) is the best available reference.

Individual Salt Wash channel sandstones average 40 to 50 ft thick and are generally separated by thin mudstones or scour zones. However, in the central part of the main La Sal trend, several channels coalesce to form thick sandstone bodies up to 120 ft thick, over a mile wide, and several miles long. These thicker sandstones host the Energy Queen, Redd Block, Beaver-La Sal, and Pandora orebodies. Kovschak and Nylund (1981) believe that the La Sal channel is a major trunk or distributary channel to the finer-grained, braided-stream deposits of the Uravan mineral belt to the east. The host sandstones in the La Sal district are similar to other Salt Wash sandstone, but are coarser grained, thicker, and more linear. The host sandstones are relatively homogeneous, reduced gray sandstones. The underlying mudstones are greenish-gray in contrast to the normal red-brown color away from ore. Most of the known U-V deposits occur along the southern margin of the channel where gray channel sandstones interfinger with red and pink sandstones and mudstones.

Nearly all of the deposits developed primary, unoxidized ores; the only important oxidized deposit is the Rattlesnake U-V open pit. Primary ore consists of uraninite, coffinite, montroseite, and vanadium clays. Ore coats detrital grains, fills void spaces, and may replace some detrital quartz and feldspar. Carbonaceous material does not appear to be important in most deposits, although Weir and Puffett (1981) reported that at the Rattlesnake mine, U was concentrated in and around plant remains and associated clay pebbles and galls. Although not noted in the literature, there appears to be a regional gradation in vanadium content with higher vanadium orebodies in the eastern part of the main trend.

Kovschak, A.A., Jr., and Nylund, R.L., 1981, General geology of uranium-vanadium deposits of Salt Wash sandstones, La Sal area, San Juan County, Utah, in *Epis, R.C., and Callender, J.F., editors, Western Slope geology-western Colorado and eastern Utah: New Mexico Geological Society 32nd Field Conference, p. 171–175.*

Weir, G.W., and Puffett, W.P., 1981, Incomplete manuscript on stratigraphy and structural geology and uranium-vanadium and copper deposits on the Lisbon Valley area, Utah-Colorado: U.S. Geological Survey Open-File Report 81-0039, 306 p.

LA SAL CREEK DISTRICT

The La Sal Creek mining district lies on the Colorado border about 30 mi southeast of Moab in San Juan County. The district is a significant V-U producer and ranks as the fourth largest V producer in Utah. Total district metal production at modern metal prices is estimated at $63 million. The major mines are the Firefly, Vanadium Queen, and Black Hat underground mines. The Vanadium Queen is one of the largest and highest grade V mines in the state at over 2% V_2O_5.

La Sal Creek district is in the Paradox Basin on the Colorado Plateau in southeastern Utah. Most of the uranium deposits are in the upper sandstone unit of the Upper Jurassic Salt Wash Member of the Morrison Formation (USGS Model 30c). This sandstone ranges from 30 to 100 ft thick and generally consists of multiple, coalescing sandstone lenses, often separated by thin mudstone/siltstone layers and containing thin interbeds of mudstone, siltstone, and mudstone conglomerate. Ore is usually confined to areas having thicker sandstone lenses (>60 ft) and most commonly occurs at the base of the ore sandstone. Ore can also be present near the channel margins where thick relatively clean sandstone grades into sandy mudstone/siltstone. Occasionally the host sandstone is divided into upper and lower parts by shale or mudstone pebble conglomerate layers, up to 10 to 15 ft thick, and ore may be present in both sands (Carter and Gualtieri, 1965).

The V-U deposits in the La Sal Creek area occur mostly as irregular, but generally elongate, amoeboid, tabular- to wedge-shaped bodies or more rarely, as C- or S-shaped rolls or irregular replacement of logs or trash pockets. Most ore occurs in small- to medium-sized pods containing from 10 to 500 tons. Pods commonly occur in clusters along channel or scour trends. Weakly mineralized sandstone is often present between the higher-grade pods. Tabular bodies are 20 to 300 ft wide, 50 to 600 ft long, and from 1 to over 8 ft thick. Orebodies are generally elongate with the long dimension parallel to depositional trends in the host sandstone, typically trending N. 80° W. Rolls may be up to 6 to 8 ft thick and 30 to 50 ft long, but most are considerably smaller. Rolls are generally C-shaped, but "hourglass rolls" consisting of two contrasting C-rolls are also common. Most rolls follow sedimentary depositional trends. Trash pocket and log deposits are smaller but have considerably higher grades than the tabular or roll type. Trash pockets have a circular to elongate shape and are generally only 1 to 2 ft thick and 2 to 10 ft in lateral dimensions. Logs may be 1 to 2 ft in diameter and up to 30 ft long. Near the V-U deposits the sandstone is bleached to white, gray, or light-tan and the siltstones and mudstones are green or gray-green in contrast to their normal reddish-brown color. Hard, barren sandstone, strongly cemented with calcite, may form irregular halos 5 to 15 ft away from the deposit. The V-U minerals occur together, impregnating sandstone and siltstone and replacing accumulations of carbonaceous and mudstone debris. The ore minerals coat sand grains, fill voids, replace carbonaceous material and clay, and rarely replace carbonate cement or quartz and other detrital grains. Reduced deposits are present in the larger and deeper mines and contain uraninite, coffinite, montroseite, roscoelite, and sparse sulfides (Carter and Gualtieri, 1965).

Carter, W.D., and Gualtieri, J.L., 1965, Geology and uranium deposits of the La Sal quadrangle, San Juan County, Utah, and Montrose County, Colorado: U.S. Geological Survey Professional Paper 508, 82 p., 13 plates.

LA SAL MOUNTAIN DISTRICT

The La Sal Mountain mining district is located about 16 mi east of Moab in southeasternmost Grand County. The district was organized in 1897 and became a modest Au producer. None of the individual mines in the district have had notable production. Total district metal production at modern metal prices is estimated at $1.9 million.

The La Sal Mountains are situated in the Paradox Basin on the Colorado Plateau in southeastern Utah. The La Sal Mountains are a series of three Oligocene (about 27 Ma) stocks (North, Middle, and South) and adjoining laccolithic complexes. The stocks are aligned in a northwest direction along the trend of the pre-existing Castle Valley salt-cored anticline. The intrusive rocks range from calc-alkaline diorite to alkaline syenite to peralkaline granite. The laccoliths are typically diorite porphyry and the stocks are syenite or granite. Unlike the laccoliths, the syenite and granite stocks have dike swarms and large associated igneous (?) explosion breccias or breccia pipes (Hunt, 1958; Mutschler and others, 1997). The breccias contain angular syenite porphyry fragments in a quartz-carbonate-rock flower matrix.

Nearly all mineralization in the La Sal Mountains is associated with the North stock near Mineral Mountain, immediately east of Miners Basin. Mineral Mountain is cored by an irregular alkaline syenite porphyry intruding a larger diorite porphyry. The primary ore deposits consist of narrow, glassy, coarsely crystalline, smoky quartz veins or small quartz vein stockworks carrying a little Au-Ag and locally some Cu cutting the intrusive porphyry stocks. The primary minerals are pyrite, chalcopyrite, and bornite with some calcite, siderite, magnetite, quartz, hematite, actinoite, and occasionally fluorite (Hill, 1913; Hunt, 1958; Mutschler and others, 1997). Minor placer gold is reported from Placer Creek below Miners Basin.

Utah International, Cyprus, Exxon, and Freeport Exploration explored the Miners Basin area of the La Sal Mountain district for deep porphyry Cu and porphyry Mo deposits in the late 1970s and early 1980s. Early Freeport work concentrated on porphyry Cu exploration on Mineral and Green Mountains and later porphyry Mo exploration on Pilot Peak (southeast of Miners Basin). The holes ranged from several hundred to 2000 ft deep. However, mineralized intercepts only showed modest intervals of Cu or Mo (e.g., 10 ft of 0.23% Cu and 10 ft of 0.01% Mo). Freeport also conducted some shallow drilling for Au in the Indiana-Tornado area and encountered some wide zones of low grade (e.g., 160 ft of 0.34 ppm Au).

Hill, J.M., 1913, Notes on the northern La Sal Mountains, Grand County, Utah: U.S. Geological Survey Bulletin 530, p. 99–118.

Hunt, C.B., 1958, Structure and igneous geology of the La Sal Mountains, Utah: U.S. Geological Survey Professional Paper 294-I, p. 305–364.

Mutschler, F.E., Larson, E.E., and Ross, M.L., 1997, Potential for alkaline igneous rock-related gold deposits in the Colorado Plateau laccolithic centers, in *Laccolith complexes of southeastern Utah—time of emplacement and tectonic setting—workshop proceedings: U.S. Geological Survey Bulletin 2158, p. 233–252.*

LEAMINGTON DISTRICT

The Leamington mining district is located about 22 mi northeast of Delta in Millard County and some small prospects are in adjoining portions of Juab County. The district was organized in 1886 and is a small Pb-Ag producer. Total district metal production at modern metal prices is estimated at $155,000. The Yellowstone underground mine is believed to be the largest producer.

The Leamington district is situated on the west flank of the northern Canyon Mountains of the Basin and Range Province. The Pb-Ag mineralization consists of disseminated to semi-massive galena replacements of brown, Fe-stained limestone of the Cambrian Howell Formation and as disseminated galena associated with coarse-grained, white calcite veins (USGS Model 22c). Much of the near-surface ore was oxidized to cerussite mixed with remnant galena in a gangue of calcite and ferruginous dolomite (Butler and others, 1920). The mineralization occurs along and adjacent to faults (Arbroath and Yellowstone mines), at intersections of faults and fissures (Yellowstone mine), and at intersections of fissures and bedding (Mine Hollow prospect). Ore guides include coarse-grained, rhombic calcite and brown, limonite-stained gray limestone. The vertical extent of the ore is probably less than 250 to 300 ft since adits driven to intersect the orebodies at depth have no ore on the dumps. Based on limited sampling, the ore contains high concentrations of Pb, Ag, and Mn and low concentrations of Cu, Ba, and Zn (Gloyn, 2004).

The Yellowstone mine workings consisted of a 200-ft-deep, 80° inclined shaft with levels at 50, 100, and 170 ft (Butler and others, 1920), now mostly caved, and a small 15- to 20-ft-deep incline to the west of the main shaft. The ore consists of small veinlets, replacements, and disseminations of galena in light-tan to orange-tan, Fe-stained Howell Limestone. Ore remaining on the dump consisted of Fe-stained limestone having stringers and veinlets of fine-grained galena, disseminated blebs of galena, and thin, coarse-grained, white calcite veinlets with minor galena at the vein margins. Select samples contain as much as 10% to 15% galena (Gloyn, 2004). Butler and others (1920) reported that small bodies of ore were stoped at the 50 ft level along a north-striking structure particularly where shattering occurred at the intersection with an east-trending fracture, and that some ore was mined on the 170 ft level from a zone containing veinlets of calcite and dolomite containing 3% to 4% Pb. Butler and others (1920) report that the mine was worked intermittently and produced a few carloads of hand-sorted ore with values of 30% to 65% Pb and up to 205 ppm Ag.

Butler, B.S., Loughlin, G.F., Heikes, V.C., and others, 1920, The ore deposits of Utah: U.S. Geological Survey Professional Paper 111, 672 p.

Gloyn, R.W., 2004, Millard County mineral resources: unpublished report prepared for the Utah Geological Survey on metallic mineral resources, incomplete and unpaginated.

LEHI DISTRICT

The Lehi (Long Ridge) mining district is in extreme northwestern Utah County, about 27 mi south-southwest of Salt Lake City. The district was organized in 1894 and became an insignificant Pb-Ag producer. The Old Mayflower underground mine is the only known metal producer.

The Lehi district is situated on the east flank of the Oquirrh Mountains in the easternmost Basin and Range Province. The district is aligned along the north-northwest-trending Long Ridge anticline. The Long Ridge anticline is the next major anticline east of, and parallel to, the Ophir anticline. The Long Ridge anticline, like the Ophir thrust-cored anticline, is a closed, asymmetrical fold with a steep northeast limb (30°–70°) and a gentle limb on the southwest (20°–40°). The anticline has a gentle to moderate plunge to the north-northwest (Gilluly, 1932; Laes and others, 1997). Quartz monzonite porphyry dikes occur intermittently near the axis of the anticline from the Old Mayflower mine south to Iron Canyon.

The main mineralized area is in West Canyon and includes the Old Mayflower Pb-Zn-Ag mine in its upper reaches (USGS Model 19a). The Old Mayflower mine occurs in bleached hornfels associated with quartz monzonite porphyry dikes in the Upper Mississippian Manning Canyon Shale, just above the top of the Great Blue Limestone. Minor pyrite, galena, sphalerite, and boulangerite are disseminated along narrow veinlets (Gilluly, 1932).

To the south of the Old Mayflower, sedimentary rock-hosted precious metal mineralization occurs near the crest of the Long Ridge anticline in the Mississippian Great Blue Limestone (USGS Model 19c). The strongest known outcrop of Au mineralization occurs just southeast of Oak Grove in the Left Hand Fork of West Canyon. Alteration includes strong silicification (jasperoid), decalcification, Liesegang banding, and locally argillized/sericitized siltstone. Strong clay alteration and a completely argillized feldspar porphyry dike are noted in the upper Great Blue Limestone near the crest of the anticline in Iron Canyon. The southern zone of alteration and mineralization (south of the Left Hand Fork of West Canyon) lies in the Mercur member just below the Long Trail Shale Member. Gold Fields drilled 14 holes totaling about 7484 ft on the south side of the Left Hand Fork of West Canyon in 1990. Geochemical Au was present in the silty limestones of the Mercur member of the Great Blue Limestone with the best intercept being 15 ft of 0.3 ppm Au (James Lunbeck, 2008, written communication).

Gilluly, James, 1932, Geology and ore deposits of the Stockton and Fairfield quadrangles, Utah: U.S. Geological Survey Professional Paper 173, 171 p., plate 1, scale 1:62,500.

Laes, D.Y.M., Krahulec, K., and Ballantyne, G.H., 1997, Geologic map of the Oquirrh Mountains, Utah, in *John, D.A., and Ballantyne, G.H., editors, Geology and ore deposits of the Oquirrh and central Wasatch Mountains, Utah: Society of Economic Geologists Guidebook, v. 29, scale 1:62,500.*

LINCOLN DISTRICT

The Lincoln mining district is in south-central Beaver County, about 13 mi west of Beaver and just north of Minersville. The district is known as one of the oldest mining areas in Utah and was originally organized as the Pioneer district in 1864, although initial production reportedly began well before this in 1854 (Perry and McCarthy, 1977). The district was later reorganized as the Lincoln district in 1871 and it was a modest Pb-Cu-Au-Ag producer. Total district metal production at modern metal prices is estimated at $3.5 million. The Creole Cu-Au-Ag ±W underground mine was probably the largest producer.

The Lincoln district is situated on the Wah Wah–Tushar mineral belt in the Basin and Range Province in southwestern Utah. The district is on the west flank of the Mineral Mountains on the very south end of the range. The Mineral Mountains expose a large, Oligocene-Miocene (25 to 17 Ma) batholith (78 sq mi). The range has been strongly rotated to the east (40°–85°) (Rowley and others, 2005). The extent of this rotation in the Lincoln district is uncertain, but the stratigraphy in the district youngs eastward from Mississippian- through Jurassic-age rocks and moderately east-dipping Oligocene-Miocene-age volcanic rocks are on the east flank of the range.

Despite its long history, the Lincoln district has had only minor production (about 10,000 tons) of Pb-Zn-Cu-Au-Ag ±W ±Bi ores (Perry and McCarthy, 1977). The mineralization occurs as small Cu skarns (USGS Model 18b) and Pb-Zn-Ag replacement deposits (USGS Model 22c) developed in the Pennsylvanian-Permian carbonate rocks peripherally to the Oligocene (~25 Ma) Lincoln monzonite-granodiorite stock (0.9 sq mi) (Rowley and others, 2005). The strongest mineralization is in the Creole-Lincoln-Rattler group of mines on the east flank (paleo-top?) of the Lincoln stock.

The Lower Permian Kaibab Formation is the primary ore host in the district. Alteration of the carbonate host rocks includes bleaching, recrystallization-marblization, and the formation of the skarn minerals garnet, epidote, vesuvianite (idocrase), tremolite, and wollastonite. The primary ore/sulfide minerals include chalcopyrite, bornite, galena, sphalerite, argentite, scheelite, pyrite, and bismuthinite in a gangue of magnetite, fluorite, calcite, quartz, tourmaline, and amethyst (Perry and McCarthy, 1977).

Perry, L.I., and McCarthy, B.M., 1977, Lead and zinc in Utah, 1976: Utah Geological and Mineral Survey Open-File Report 22, 525 p.

Rowley, P.D., Vice, G.S., McDonald, R.E., Anderson, J.J., Machette, M.N., Maxwell, D.J., Ekren, E.B., Cunningham, C.G., Steven, T.A., and Wardlaw, B.R., 2005, Interim geologic map of the Beaver 30' x 60' quadrangle, Beaver, Piute, Iron, and Garfield Counties, Utah: Utah Geological Survey Open-File Report 454, scale 1:100,000, 27 p.

LISBON VALLEY DISTRICT

The Lisbon Valley mining district is located about 34 mi southeast of Moab in northeastern San Juan County. The district had a desultory history following its organization in 1892 as an intermittent Cu producer prior to the discovery of the Mi Vida U mine by Charlie Steen in 1953, which began over three decades of uninterrupted U production. Important open pit, SX-EW Cu production began in 2006. The district is roughly the eighth most productive district in Utah. The Lisbon Valley district is the largest U and third largest Cu producer in the state. Total district metal production at modern metal prices is estimated at $2.7 billion. The most productive U properties are the Lisbon mine, Hecla Shaft, Mi Vida mine, and Velvet shaft. The most productive Cu mines are the Centennial, GTO, and Sentinel open pits. These major Cu mines are still in production.

Geologically, the Lisbon Valley district is in the Paradox Basin on the Colorado Plateau. The Paradox Basin is underlain by about 7000 ft of Pennsylvanian-age restricted marine evaporites, black shale, and carbonate rocks. The Pennsylvanian strata are overlain by 1900 ft of Permian- and Triassic-age shale and fluvial sandstone followed by another 4200 ft of Jurassic- and Cretaceous-age eolian sandstone and shale. Within this section, the primary host rocks are the Permian Cutler Group sandstone (U-V, Cu), the Triassic Moss Back Member of the Chinle Formation (U), and the Cretaceous Burro Canyon Formation and Dakota Sandstone (Cu). The district is centered on the northwest-trending Lisbon Valley anticline, a large (11-mi-long), upright, open, doubly plunging fold. The anticline has a sub-parallel, large displacement (about 5000 ft), northeast-dipping, normal fault just northeast of its crest. The Lisbon Valley anticline began to form in the Early Triassic followed by movement on the Lisbon Valley fault in the Late Triassic (Chenoweth, 2006). Most of the known U mineralization is on the up-thrown side of the Lisbon Valley fault and follows the erosional contact between a 50-ft-thick white sandstone (“sugar sand”) in the upper part of the Cutler Group and the overlying Moss Back Member of the Chinle Formation (USGS Model 30c). Mineralization precipitated at the interface probably between U-rich oxidizing groundwater in the Moss Back and reducing hydrocarbon and hydrogen sulfide (H_2S)-bearing fluid in the underlying Cutler.

The Lisbon Valley Cu deposits are much younger and are formed by brines expelled along the Lisbon Valley fault. The Cu-bearing fluid may have been a deeply circulating meteoric water that leached Cu from the thick sequence of underlying Cutler red beds in the hanging wall of the Lisbon Valley fault prior to precipitation in the bleached and reduced sandstones (USGS Model 30b). All major Cu orebodies are in the hanging wall of the main fault and are often associated with subsidiary faults (Hahn and Thorson, 2006).

Chenoweth, W.L., 2006, Lisbon Valley, Utah's largest uranium district, in *Bon, R.L., Gloyn, R.W., and Park, G.M., editors, Mining districts of Utah: Utah Geological Association Publication 32, p. 534–550.*

Hahn, G.A., and Thorson, J.P., 2006, Geology of the Lisbon Valley Sandstone-Hosted Disseminated Copper Deposits, San Juan County, Utah, in Bon, R.L., Gloyn, R.W., and Park, G.M., editors, Mining districts of Utah: Utah Geological Association Publication 32, p. 511–533.

LITTLE GRAND DISTRICT

The heart of the Little Grand mining district is located about 15 mi southeast of Green River on the border of Emery and Grand Counties. The initial interest in the district was driven by manganese demands of the two World Wars with most of the production from 1915 to 1918. Despite the district's modest production, it is still ranked as the second largest manganese producer in Utah. Total district metal production at modern metal prices is estimated at $5.4 million. The largest producers in the district are the C.F.&I. and nearby mines (Baker and others, 1952).

The Little Grand district is geologically situated in the Paradox Basin section of the Colorado Plateau. Geology in the Little Grand district consists of a very gently (2° to 4°) northeast-dipping section of Jurassic- and Cretaceous-age strata. The manganese deposits are synsedimentary (USGS Model 34b), primarily hosted in the Upper Jurassic Summerville and Morrison Formations, and the best deposits are in the upper part of the Summerville Formation. The orebodies consist of manganese oxide in thin blankets and nodules in limestone and as cementing material in sandstone. The ore minerals are dominantly pyrolusite, with subordinate psilomelane and manganite having Mn grades from 4% to 40%. Minor amounts of manganocalcite and rhodochrosite are also reported and accessory minerals include iron oxides, barite, and local veinlets of celestite gypsum (Baker and others, 1952).

The Little Grand Mn district also encompasses the Ten Mile Canyon U district. There is no reported U production from this area, and as a result, there is virtually no literature on the mineralization. Weak U-V mineralization is reportedly hosted in the Jurassic Salt Wash Member of the Morrison Formation.

Baker, A.A., Duncan, D.C., and Hunt, C.B., 1952, Manganese deposits of southeastern Utah: U.S. Geological Survey Bulletin 979-B, p. 63–157.

LOCKHART CANYON DISTRICT

The Lockhart Canyon (Hatch Point) district is in the Moab U mining area of northernmost San Juan County, just east of the Colorado River and about 14 mi southwest of Moab. The initial discoveries were made in the 1950s and the district became a minor U producer. Total district metal production at modern metal prices is estimated at $47,000. The Colorado underground mine was the largest producer, but it was a small operation. There is little published literature on the district.

The Lockhart Canyon district is situated in the Paradox Basin on the Colorado Plateau. The mines are geologically positioned on an unnamed east-northeast-trending syncline between Shafer dome to the north and Lockhart anticline to the south.

Lockhart Canyon U mineralization is primarily hosted in the Upper Triassic Moss Back Member of the Chinle Formation with some U occurrences in the Lower Permian Bogus Tongue Member of the Cutler Formation (USGS Model 30c). The mineralization in the Chinle is localized in Moss Back channel sandstones cut into the underlying Moenkopi Formation. Mineralization is associated with carbonaceous debris in the channels having average grades of 0.25% U_3O_8 and just 0.04% V_2O_5. The primary ores are typically uraninite, pyrite, chalcopyrite, and bornite with rare galena and sphalerite. The ore is reportedly anomalous in Ag, Ba, Co, and Cu (Doelling, 1969, 1974).

Doelling, H.H., 1969, Mineral resources, San Juan County, Utah and adjacent areas, Part II—Uranium and other metals in sedimentary host rocks: Utah Geological and Mineralogical Survey Special Study 24, 64 p.

Doelling, H.H., 1974, Uranium-vanadium occurrences of Utah: Utah Geological and Mineral Survey Open-File Report 18, unpaginated.

LONG RIDGE DISTRICT

The Long Ridge (Mona, Trotter) mining district is in southwestern Utah County, 23 mi southwest of Spanish Fork. The district has been a small Mn producer, primarily from the Trotter mine. Total district metal production at modern metal prices is estimated at $180,000.

The Long Ridge district lies on the Deep Creek–Tintic mineral belt in the Basin and Range Province. Geologically, Long Ridge is underlain by complexly faulted, moderately east-dipping, Cambrian-age strata unconformably overlain by Eocene-Oligocene-age volcanic rocks to the south and east and Quaternary-age alluvium to the north. The Mn ore is hosted in strongly sheared and sanded Middle Cambrian carbonate rocks (Cole Canyon Dolomite?) associated with pebble dikes and jasperoids (USGS Model 19b). The principal ore mineral is pyrolusite. The average grade of ore shipped from the Trotter mine was roughly 12.1% Mn; the Silver Hill mine shipped ore at an average grade of 17% Mn; and a U.S. Bureau of Mines sample from the Spaulding mine tested 15.4% Mn (Crittenden, 1951). Some limited sampling suggests elevated Pb-Zn-Ag with the Mn.

Crittenden, M.D., Jr., 1951, Manganese deposits of western Utah: U.S. Geological Survey Bulletin 979-A, 62 p.

LOOKOUT PASS DISTRICT

The Lookout Pass area is in the northern Sheeprock Mountains of southeastern Tooele County. The Lookout Pass Tl-Sb-Au mineralization was discovered by Robert and Terry Steele. The Steeles staked the main mineralized area (southeastern T. 8 S., R. 7 W.) in 1987 and Freeport-McMoRan Gold Company drilled five holes on the property in 1987–88, but the claims lapsed in 1991. The area was then restaked by the Phelps Dodge Mining Company and a few more holes may have been drilled in 1991–92. A separate Au area to the southeast (northwestern T. 9 S., R. 6 W.) was staked by Sherman Jensen in 1991 and held until 1993. The original Steele property was later restaked by Miranda USA, Inc. in 2006 and they held the property through 2009, but no additional drilling was done (Krahulec, 2011). The area has no mines or past production.

The Lookout Pass area lies north of the main Eocene-age Deep Creek–Tintic mineral belt of the Basin and Range Province. The northern Sheeprock Mountains are generally a northeasterly dipping homoclinal sequence of Cambrian- to Mississippian-age sedimentary rocks. These strata are cut by two sets of faults, a northwest-trending set and a (younger?) north-trending, high-angle fault set. Extensive silicification of the section occurs from the Lower Cambrian Ophir Formation up through the Ordovician Eureka Quartzite. The jasperoids are both fault-controlled and stratabound. Alteration or mineralization outside of the jasperoids is limited. Silicification also occurs farther north in sections 14 and 15, T. 8 S., R. 7 W. in Mississippian-age carbonate rocks that are important sediment-hosted Au hosts elsewhere in the eastern Basin and Range. Clark and others (2012) mapped a detachment fault in this section.

Locally abundant, coarse stibnite-stibiconite along with very rare, fine grains of parapierrotite occur in generally northerly-trending, fault-controlled, jasperoid pods hosted by Upper Cambrian to Ordovician carbonate rocks and some shale (Clark and others, 2012). The parapierrotite occurs at a small prospect pit (NE¼SW¼ section 35, T. 8 S., R. 7 W.) and the abundant radiating coarse stibnite (turkey tracks) mostly occurs to the north (section 26, T. 8 S., R. 7 W.). Minor Au was found on a hill (SW¼SW¼ section 35, T. 8 S., R. 7 W.) about 2000 ft southwest of the Little Valley Tl prospect pit. Freeport-McMoRan drilled a hole on the top of this hill and intersected modest Au values (Robert Steele, personal communication, May 2018). This Au anomaly and the parapierrotite prospect are hosted in the Ophir Formation. In addition to silicification, the carbonate rocks have been locally weakly argillized and decalcified. The jasperoids are generally strongly anomalous in As, Hg, Sb, and Tl, but only weakly anomalous in Au (Krahulec, 2011). Mineralization to the southeast at the old Jensen claims on Little Red Pine Creek has anomalous Au, As, Sb, and Ag in Upper Cambrian carbonate rocks.

Clark, D.L., Kirby, S.M., and Oviatt, C.G., 2012, Interim geologic map of Rush Valley 30' x 60' quadrangle, Tooele County, Utah, Salt Lake, and Juab Counties, Utah: Utah Geological Survey Open-File Report 593, 65 p., 2 plates, scale 1:62,500.

Krahulec, K., 2011, Sedimentary rock-hosted gold and silver deposits of the northeastern Basin and Range, Utah, in *Steininger, R., and Pennell, B, editors, Great Basin evolution and metallogeny: Geological Society of Nevada 2010 Symposium Proceedings, v. 1, p. 31–62.*

LOWER KANE CREEK DISTRICT

The Lower Kane Creek district is located on the Grand–San Juan County line about 7 mi southwest of Moab. Lower Kane Creek is part of the greater Moab U mining area. The district is a modest U ±V ±Cu producer, primarily from deposits along the cliffs in lower Kane Springs Canyon. Total district metal production at modern metal prices is estimated at $1.3 million. The largest deposits in the district are the Atomic King Group, including the Honeybee and Canary, on the south end of the district.

The Lower Kane Creek district is in the Paradox Basin on the Colorado Plateau. The district is localized on the crest of the Kane Creek anticline in the Lower Permian Cutler Formation and the Upper Triassic Chinle Formation. The Cutler-hosted mineralization is primarily fracture-controlled and the overlying Chinle deposits are in paleochannels in the Moss Back Member. The ore-controlling faults in the Cutler trend about N. 40° W. and have variable dip to the northeast and southwest. The recognized ore minerals are reportedly uraninite, uranophane, carnotite, chalcopyrite, chalcocite, andersonite, and liebigite with a gangue of calcite, ankerite, barite, pyrite, and galena. Mineralization is associated with bleaching of the normally red sandstone (Butler and Fisher, 1978; Campbell and others, 1982).

The Atomic King Group on the south end of the district is localized in the top of the Cutler sandstone near the overlying Moenkopi Formation contact and the mineralization is primarily U-V. These deposits are categorized as sandstone U deposits (USGS Model 30c).

Butler, A.P., Jr., and Fisher, R.P., 1978, Uranium and vanadium resources in the Moab 1° x 2° quadrangle, Utah and Colorado: U.S. Professional Paper 988-B, 22 p.

Campbell, J.A., Franczyk, K.J., Luft, S.J., Lupe, R.D., Peterson, F., and Robinson, K., 1982, National uranium resource evaluation, Price quadrangle, Utah: U.S. Department of Energy Preliminary Folio PGJ/F-055(82), 49 p., 13 plates.

LUCIN DISTRICT

The Lucin (Buell) mining district lies in the northern Pilot Mountains in southwestern Box Elder County. Mineralization was initially discovered in the district in 1868. Lucin production was fairly continuous from the completion of the transcontinental railroad (1869) until the 1920s, and then intermittent until 1963. Lucin is the oldest and second most productive district in Box Elder County and the county's largest producer of Cu, Pb, and Fe. Lucin's total production is about 171,000 tons of predominantly Cu, Pb, and/or Ag ore with subordinate Fe, Zn, Au, and possibly Mo (Doelling, 2006). Total district metal production at modern metal prices is estimated at $58 million. The Copper Mountain Group and Tecoma mine are the district's largest producers.

The Pilot Mountains are a prominent range in the northeastern Basin and Range Province. The geologically complex Lucin district is underlain by a large slide block of generally north-striking, moderately east-dipping Paleozoic sedimentary rocks sitting on the west-dipping faulted top of the Eocene (39 Ma) McGinty monzogranite (about 27 sq mi). The top of the monzogranite reaches its highest elevation under the Copper Mountain–Tecoma Hill corridor. The rocks of the district have been cut by numerous low-angle, generally bedding-parallel, detachment and attenuation faults and generally younger east- and north-striking, high-angle faults. Some of the low-angle normal faults have resulted in considerable brecciation, particularly at the top of the cliff-forming Devonian Guilmette Formation. There are also at least two periods of dikes, an early (Eocene?) set which primarily cut the monzogranite stock and a later Miocene diabase set which cut stock, Paleozoic strata, and Tertiary sedimentary rocks (Miller and Schneyer, 1985).

The majority of the Lucin district's production was from the Copper Mountain and Tecoma Hill mines in the Regulator Canyon area near the center of the district. The mineralization in the Lucin district is zoned from a central Cu-Fe sector near Copper Mountain to Pb-Zn-Ag-Au ±Cu ±Mo mineralization along the slopes near Tecoma Hill (USGS Model 19a). The ores are mostly oxidized with remnant grains of galena, sphalerite, chalcopyrite, and pyrite, along with minor bismutite and wulfenite. Farther outward from these mineral zones, the district hosts extensive jasperoid breccias and some subeconomic distal-disseminated Au-Ag shows (USGS model 19c).

Doelling, H.H., 2006, Geology of the Lucin and Promontory districts, Box Elder County, Utah, in Bon, R.L., Gloyn, R.W., and Park, G.M., editors, Mining districts of Utah: Utah Geological Association Publication 32, p. 151–166.

Miller, D.M., and Schneyer, J.D., 1985, Geologic map of the Tecoma quadrangle, Box Elder County, Utah and Elko County, Nevada: Utah Geological Survey Map 77, scale 1:24,000, 8 p.

MAIN TINTIC DISTRICT

The combined production from the greater Tintic district constitutes the second largest metal district in Utah. The Main Tintic district, encompassing the town of Eureka, is the largest of the four Tintic subdistricts and is the third largest district in the state. Historical production from the Main Tintic district totaled 13.8 million tons of ore with a recovered grade of 488 ppm Ag, 5.38 ppm Au, 4.63% Pb, and local contributions of Cu and Zn. The Main Tintic district is the second largest Cu and third largest Pb, Au, and Ag producing district in Utah. Total district metal production at modern metal prices is estimated at $7.3 billion. The largest mines in the Main Tintic district are the Chief Consolidated and Mammoth underground mines (Morris, 1990; Krahulec and Briggs, 2006).

The Main Tintic district forms a lynchpin in the Deep Creek–Tintic mineral belt of the Basin and Range Province in central Utah. Geologically, the Main Tintic district is underlain by a thick section of Paleozoic strata, which have been strongly folded into large, north-south trending, asymmetrical anticlines and synclines cut by northeast-trending, right-lateral strike-slip faults. These sedimentary rocks were uplifted, eroded, and covered by early Oligocene calc-alkaline volcanic rocks emanating from a large caldera just to the south of the district. Continuing magmatism resulted in the intrusion of monzonite stocks, plugs, dikes, and sills with associated hydrothermal alteration and mineralization. The area was uplifted on the west during Basin and Range extension, resulting in a slight, post-mineral, eastward rotation of the range and continued erosion of the East Tintic Mountains (Krahulec and Briggs, 2006).

Most of the production from the Main Tintic district has been derived from sub-vertical Cu-Au-Ag chimneys and sub-horizontal, carbonate-hosted, Pb-Zn-Ag replacement deposits (USGS Model 19a). Spatial relationships of metals in the Main Tintic district exhibit an overall zonation from higher temperature Cu-Au-Ag ores in the south adjacent to the contact of the Silver City stock, through a Pb-Zn zone, to a distal, cooler Zn-Pb-Ag zone at the northern periphery of the district (Krahulec and Briggs, 2006).

The Mammoth mine in the southwest part of the district is a large, subvertical, Cu-Au-Ag chimney that essentially marks the southern beginning of the Mammoth-Chief ore run. The Mammoth mine produced 1,280,000 tons of ore averaging 370 ppm Ag, 11.3 ppm Au, 1.4% Cu, and 1.6% Pb. The Chief orebody marks the distal northern manto. The Chief Consolidated is the largest of the replacement deposits in the Main Tintic district and produced nearly 3.5 million tons averaging roughly 515 ppm Ag, 2 ppm Au, 5.9% Pb, and 2.4% Zn (Morris, 1990).

Krahulec, K., and Briggs, D.F., 2006, History, geology, and production of the Tintic mining district, Juab, Utah, and Tooele Counties, Utah, in *Bon, R.L., Gloyn, R.W., and Park, G.M., editors, Mining districts of Utah: Utah Geological Association Publication 32, p. 121–150.*

Morris, H. T., 1990, Gold in the Tintic mining district, in *Shawe, D.R., and Ashley, R.P., Gold-Bearing polymetallic veins and replacement deposits—Part II: U.S. Geological Survey Bulletin 1857-F, p. 1–11.*

MARYSVALE DISTRICT

The Marysvale mining district is about 28 mi northeast of Beaver along the Piute–Sevier County line. The district is a modest U producer and was not discover until 1947. The bulk of the production (1,330,797 lbs U_3O_8) came from underground mines (Chenoweth, 2007). Total district metal production at modern metal prices is estimated at $40 million. The largest operations in the district are the Freedom, Prospector, and Farmer John (Chenoweth, 2007).

The Marysvale district lies on the east flank of the Marysvale Oligocene-Miocene volcanic field in the transition zone between the Basin and Range Province to the west and the Colorado Plateau on the east. The most important production came from the Central Mining Area (CMA), all in an area of less than 0.5 sq mi. The CMA is underlain by a series of subvolcanic plugs ranging in age from about 23 to 18 Ma (Cunningham and others, 1998). Mineralization (19–18 Ma) at Marysvale consists of an anastomosing set of steeply dipping, northeast-trending, quartz-fluorite-pyrite veins (each vein up to 20 inches wide) and subsidiary sub-horizontal, open-space breccia veins generally cutting the monzonitic Central Intrusion (23 Ma). The primary U ore occurs as pitchblende and jordisite containing geochemically anomalous As, Mo, Sb, Tl, and W in steeply pitching shoots within the veins and as breccia pipes and stockworks (USGS Model 25f). At depth, the vein quartz, pyrite, and jordisite content increases and the veins have 2-inch-wide sericitic selvages. Mineralization appears to be related to glassy rhyolite dikes containing trace molybdenite (Cunningham and others, 1998).

Cunningham and others (1998) postulate the CMA mineralization is related to an unexposed 18 Ma rhyolite plug at depth, coeval with the rhyolite porphyry dikes, and the hypothetical plug may host porphyry Mo mineralization.

Chenoweth, W.L., 2007, History of uranium production, Marysvale district, Piute County, Utah, in *Willis, G.C., Hylland, M.D., Clark, D.L., and Chidsey, T.C., Jr., editors, Central Utah—Diverse geology of a dynamic landscape: Utah Geological Association Publication 36, p. 323–329.*

Cunningham, C.G., Rasmussen, J.D., Steven, T.A., Rye, R.O., Rowley, P.D., Romberger, S.B., and Selverstone, J., 1998, Hydrothermal uranium deposits containing molybdenum and fluorite in the Marysvale volcanic field, west-central Utah: Mineralium Deposita, v. 33, p. 477–494.

MERCUR DISTRICT

The Mercur (Lewiston, Camp Floyd) mining district lies in the southwestern Oquirrh Mountains about 35 mi southwest of Salt Lake City. The district was initially organized in 1870, was intermittently productive from 1871 to 1998, and the largest production was from 1890 to 1913 and 1983 to 1998. Mercur is the largest primary Au producer in Utah at 2,605,037 ounces Au along with 1,183,724 ounces of Ag and 3469 flasks of Hg, recovered. Mercur is the sixth most productive district in Utah in terms of total metal value and the largest Hg producer. Total district metal production at modern metal prices is estimated at $2.9 billion. The Mercur Hill, Marion Hill, and Sacramento are the largest open pit mines in the district (Mako, 1999).

The Oquirrh Mountains are among the easternmost in the Basin and Range Province. Most of the mineralization in the Mercur district is concentrated between the crest of the Ophir thrust-cored anticline and its hinge line to the east. The Mercur Au deposits are localized near an east-northeast-trending set of normal faults including the Lulu graben, Eagle Hill tear fault, and Carrie Steele fault. Portions of the district also show a pronounced east-northeast-trending, subvertical joint set. The ores are largely confined to the Mercur member in the lower limestone section of the Mississippian Great Blue Limestone. The Mercur member is a slope-forming, heterogeneous sequence of black, thin- to medium-bedded, carbonaceous, fossiliferous, and Fe-rich (over 1% Fe) limestone, calcareous sandstone, calcareous siltstone, and shale. The best ore host is the thin-bedded, calcareous, sandstone and siltstone of the Mercur beds (Mako, 1999).

The most readily recognized hydrothermal alteration in the Mercur district is the extensive silicification at the contact between the Magazine sandstone and underlying Topliff member limestone. Later argillic alteration and decalcification are more immediately associated with Au ores than this earlier silicification event. In argillic alteration and decalcification, carbonate is removed and detrital phyllosilicate minerals are altered to kaolinite and sericite. Mineralization is localized primarily by the intersection of east-northeast-trending faults and favorable Mercur member host horizons, principally the Magazine sandstone and Mercur beds. Gold mineralization is spatially associated with argillic alteration and decalcification (Mako, 1999). Gold occurs with late arsenian pyrite overgrowths, orpiment, and thallium minerals (USGS Model 26a). Geochemically, the Au ores typically are enriched in As, Ba, Hg, Sb, Si, and Tl and depleted in Ca, Mg, and Sr.

There are two primary Eocene-Oligocene intrusive phases in the district: Porphyry Hill biotite monzonite porphyry and Eagle Hill Rhyolite. The likely age for the Mercur mineralization is between 39 and 31.6 Ma; a late Eocene age is preferred based on the preponderance of mineralization of this age in the Oquirrh Mountains (Krahulec, 2011).

Krahulec, K., 2011, Sedimentary rock-hosted gold and silver deposits of the northeastern Basin and Range, Utah, in *Steininger, R., and Pennell, B, editors, Great Basin evolution and metallogeny: Geological Society of Nevada 2010 Symposium Volume I, p. 31–62.*

Mako, D.A., 1999, A post-mining view of the Mercur gold district, Tooele County, Utah: Geological Society of Nevada Special Publication 30, 44 p.

MINERAL CANYON DISTRICT

The Mineral Canyon district is part of the Green River U mining area in southwestern Grand County. Mineral Canyon is a modest U-V producer having mineral discoveries and production beginning in the early to mid-1950s. Total district metal production at modern metal prices is estimated at $2.4 million. The most productive properties in the district are the A Group and Cottonwood mines.

The Mineral Canyon district is in the northwestern part of the Paradox Basin on the Colorado Plateau. The geology of the district is poorly documented. The primary U-V ±Cu host rock is northwest-trending channels in the Upper Triassic Moss Back Member of the Chinle Formation (USGS Model 30c). Deposits are typically in the lower Moss Back Member conglomeratic sandstones and range up to about 5000 tons. The deposits are tabular and occur in paleochannels associated with bleaching of the host sandstone. The primary recognized ore/sulfide minerals are uraninite, chalcopyrite, and possibly chalcocite (Doelling, 1974).

Doelling, H.H., 1974, Uranium-vanadium occurrences of Utah: Utah Geological and Mineral Survey Open-File Report 18, unpaginated.

MINERAL MOUNTAIN DISTRICT

The Mineral Mountain district is in remote northwestern Washington County about 32 mi northwest of St. George. The area has no reported production.

The Mineral Mountain district is in the Basin and Range Province. The district is considered to be the southwesternmost intrusion of the Miocene-age Iron Axis; however, its stock is 8 to 10 million years younger and much more felsic than the other intrusions on this belt to the northeast.

The alteration/mineralization in the district is centered on the Mineral Mountain stock. The stock (about 12.1 Ma) is a high-silica granite porphyry made up of mostly fine-grained orthoclase and contains abundant, large beta quartz phenocrysts. The stock is cut in half by a west-northwest-trending, right-lateral strike-slip fault and the north half is displaced approximately 7800 ft to the east. A small (600-ft-diameter) alaskite plug intrudes the northern Mineral Mountain stock on the southwest flank of Mineral Mountain, and lamprophyre (kersantite) dikes are noted near some of the mineralization (Morris, 1980).

The Mineral Mountain stock domes and intrudes Pennsylvanian Callville Limestone and overlying Miocene volcanic rocks. Small magnetite-Cu ±Au ±Ag ±Mo vein/replacement deposits are present adjacent to the stock. Anomalous Mo (310 ppm) and weakly anomalous W (25 ppm) are present in a dump sample at the Humbug (Pickadilly) mine on the west side of the stock (Morris, 1980). In addition to narrow brucite-serpentine skarns and more widespread marblization of the carbonate rocks adjoining the stock, the overlying volcanic rocks are locally argillized, silicified, and/or pyritized (Morris, 1980; Eppinger and others, 1990). Morris (1980) also notes that narrow quartz veins with silicified selvages cut the north margin of the granite on Marble Mountain. The 25-foot-wide Beauty Knoll alunite vein cuts andesitic volcanic rocks along a northwest trend for 1500 ft about a mile northeast of the stock.

Minor Zn-Pb mineralization is located 0.6 to 1.5 mi to the southeast of the Mineral Mountain granite. About 2 mi due south of the stock, the Treasure Chest sedimentary rock-hosted Au-Ag prospect (USGS Model 19c) occurs along the unconformity between the Callville Limestone and the overlying Paleocene to Eocene lower Claron Formation. The lower Claron Formation is a light-yellow-gray to red conglomerate. This contact is the same as the mineralized contact in the Goldstrike district about 3 mi to the southeast.

Eppinger, R.G., Winkler, G.R., Cookro, T.M., Shubat, M.A., Blank, H.R., Jr., Crowley, J.K., Kucks, R.P., and Jones, J.L., 1990, Preliminary assessment of the mineral resources of the Cedar City 1° x 2° quadrangle, Utah: U.S. Geological Survey Open-File Report 90-34, 142 p.

Morris, S.K., 1980, Geology and ore deposits of Mineral Mountain, Washington County, Utah: Brigham Young University Geology Studies, v. 27, pt. 2, p. 85–102.

MODENA DISTRICT

The Modena district is in westernmost Iron County about 48 mi west-northwest of Cedar City and immediately northwest of the historical railroad station of Modena. Butler and others (1920) reported the occurrence of some Au-Ag quartz-carbonate veins having minor Fe and Mn oxides cutting rhyolite near Modena. However, the Modena area has not had any recorded metal production. The Red Ant Au-Ag occurrence is the most prominent prospect.

Modena is located near the junction of the Paradise Mountains to the north and the Indian Peak Range to the northeast in the eastern Basin and Range Province. The district is located near the southern margin of the large Oligocene Indian Peak caldera. Eppinger and others (1990) report four prospects near the mouth of Modena Draw in altered Miocene Steamboat Mountain Formation rhyolite. The mineralization consists of north-south-trending, crustiform banded quartz-carbonate veins up to 10 ft thick. The veins locally develop into a stockwork, and rhyolite wall rocks are silicified, argillized, or propylitized (Eppinger and others, 1990). Alunite veins are also reported. The Red Ant mine veins have low values of Au-Ag (USGS Model 25c). The southernmost unnamed prospect has minor epithermal Mn-Fe (USGS Model 25g) in the footwall of a dike, possibly with geochemical Ag, Au, and Pb (Crittenden, 1951).

While the Modena area has had no production, it is periodically held by unpatented mining claims and the prospect area has had sporadic mineral exploration primarily for Au-Ag.

Butler, B.S., Loughlin, G.F., Heikes, V.C., and others, 1920, The ore deposits of Utah: U.S. Geological Survey Professional Paper 111, 672 p.

Crittenden, M.D., Jr., 1951, Manganese deposits of western Utah: U.S. Geological Survey Bulletin 979-A, 62 p.

Eppinger, R.G., Winkler, G.R., Cookro, T.M., Shubat, M.A., Blank, H.R., Jr., Crowley, J.K., Kucks, R.P., and Jones, J.L., 1990, Preliminary assessment of the mineral resources of the Cedar City 1° x 2° quadrangle, Utah: U.S. Geological Survey Open-File Report 90-34, 142 p.

MONROE DISTRICT

The Monroe district is in southern Sevier County, about 12 mi south of Richfield. The district is a minor Mn producer. Total district metal production at modern metal prices is estimated at $264,000. The Georgia mine is probably the most productive operation.

The Monroe district is situated on the northern margin of the Marysvale volcanic field on the Sevier Plateau of the transition zone from the Basin and Range Province to the west and the Colorado Plateau to the east. The district is just outside the Monroe Peak Caldera. The host rocks in the district are predominantly Oligocene-Miocene Bullion Canyon calc-alkaline andesitic volcanics.

Crittenden (1951) gives brief reports of the manganese production from the volcanic rocks in the Monroe district. The Georgia mine targeted a series of Mn-oxide veinlets in weathered igneous rocks over a broad area (USGS Model 19b). Average shipped grades are approximately 43% Mn.

Staatz (1974) reports a Th-bearing vein in Monroe Canyon approximately 2 mi southeast of Monroe, Sevier County (USGS Model 11d). The steeply dipping vein occurs in an area of Bullion Canyon andesitic volcanic rocks which are intruded by Miocene-age quartz monzonite porphyry plugs (22–21 Ma) (Hintze and others, 2003). The quartz-microcline vein contains minor muscovite, goethite, jarosite, lepidocrocite, and brockite (Staatz, 1974). U.S. Geological Survey National Geochemical Database samples in the Monroe Canyon area, collected by Staatz (1974), are anomalous in Th (1500 ppm) and the light rare earth elements (REE) Ce (1000 ppm), Nd (700 ppm), Pr (150 ppm), and Sm (100 ppm). However, the exact location of the Th-REE-bearing vein is uncertain.

Crittenden, M.D., Jr., 1951, Manganese deposits of western Utah: U.S. Geological Survey Bulletin 979-A, 62 p.

Staatz, M.H., 1974, Thorium veins in the United States: Economic Geology, v. 69, p. 494–507.

MONTEZUMA CANYON DISTRICT

The Montezuma Canyon mining district is a part of the Monticello U mining area in east-central San Juan County. Mineralization was initially discovered in the district during the radium prospecting period of 1910 to 1924 and the vanadium exploration phase from 1935 to 1944. Montezuma Canyon has been a modest U-V producing district. Total district metal production at modern metal prices is estimated at $7.3 million. The most productive area is the Middle Montezuma Canyon group, including the Cottonwood, Lucky Boy, Strawberry, and Verdure underground mines.

The Montezuma Canyon district occurs in the Paradox Basin on the Colorado Plateau. Montezuma Canyon is deeply dissected into flat-lying Jurassic- to Cretaceous-age strata. The U-V ores are hosted in the Upper Jurassic Salt Wash Member of the Morrison Formation. The Salt Wash Member is a light-colored, massive, cross-bedded sandstone with siltstone and mudstone lenses. The Salt Wash thickens to the north and pinches out toward the south end of the district. The best U-V deposits (USGS Model 30c) are in the central part of the district in the thickest sandstone lenses with the most abundant carbonaceous trash.

Huff and Lesure (1962) describe the orebodies as zoned lenses: “The concentric zones consist of a brown nonmineralized core, an olive-gray mineralized shell, and a gray nonmineralized outer zone. The brown core is an Fe-stained, porous sandstone commonly containing abundant carbonaceous material. The curved mineralized layer completely encloses the brown core and is composed of oxidized U-V minerals that impregnate the host sandstone. The outer gray zone is light-gray sandstone tightly cemented with calcite and commonly freckled with limonitic specks.”

The U-V ore deposits probably resulted from diffusion of metals in slowly circulating connate water around a brown reduced core formed by abundant organic material. The surrounding olive-gray ore zone is the boundary between the reducing core and the surrounding oxidizing fluid with U and V in solution. The ore zone averages about 0.19% U_3O_8 and 3.46% V_2O_5 and samples show a geochemical association with Fe, Ti, Ag, Co, Mo, Ni, Zr, and Y (Huff and Lesure, 1965).

Huff, L.C., and Lesure, F.G., 1962, Diffusion features of uranium-vanadium deposits in Montezuma Canyon, Utah: Economic Geology, v. 57, p. 226–237.

Huff, L.C., and Lesure, F.G., 1965, Geology and uranium deposits of the Montezuma Canyon area, San Juan County, Utah: U.S. Geological Survey Bulletin 1190, 102 p., 8 plates, various scales.

MONUMENT VALLEY DISTRICT

The Monument Valley (Oljeto Mesa) district is in southwestern San Juan County, Utah, and adjacent Navajo and Apache Counties, Arizona. The Utah portion of the Monument Valley district produced 322,802 pounds U_3O_8 and 532,739 pounds V_2O_5 from 54,033 short tons of ore at an average grade of 0.29% U_3O_8 and 0.48% V_2O_5. Total district metal production at modern metal prices is estimated at $13 million. The most important producer in the district is the Whirlwind mine, which is the northernmost mine in the district on the northeast face of Monitor Butte and adjacent to Lake Powell (Chenoweth, 2006).

Monument Valley lies in the Monument Upwarp on the Colorado Plateau. The ore deposits consist of multiple, closely spaced, lenticular pods, generally concordant to bedding, in paleochannels of the Shinarump Conglomerate Member of the Upper Triassic Chinle Formation. Host units are carbonaceous sandstone and conglomerate in paleochannels cut into the underlying Moenkopi Formation (USGS Model 30c). The paleochannels are 20 to 2000 ft wide and 40 to 200 ft deep. Near the Utah-Arizona line, the channels trend west to northwest, but in the northern part of the district, major identified channels trend northerly. The ore pods are 1 to 8 ft thick, up to several hundred feet long, and typically have width-to-length ratios of 1:5 to 1:10. Primary ore consists of uraninite, coffinite, corvusite, montroseite, chalcocite, and chalcopyrite. Major secondary minerals include tyuyamunite, uranophane, autunite, tobernite, malachite, and azurite. Uranium grades range from 0.10% to over 1.0% U_3O_8 and average 0.30% U_3O_8; copper grades range from 0.29% to 2.5% Cu and average 0.71% Cu; and vanadium grades range from 0.05% to 1.85% V_2O_5 and average 0.60% V_2O_5. The deposits are confined to carbonaceous sandstone and conglomerate in the lower part of the Shinarump Member. The deposits also appear to be restricted to areas where the overlying Monitor Butte Member was deposited in a sub-aqueous, reduced setting containing black, organic-rich mudstone and green, carbonaceous sandstone and siltstone having abundant plant fragments. There is some suggestion that the richer and large deposits occur in the deeper scours and near channel intersections (Young and Malan, 1964; Chenoweth, 2006).

The Monument Valley U district is entirely on Navajo Tribal Lands.

Chenoweth, W.L., 2006, The uranium-vanadium deposits of the Utah portion of the Monument Valley district, in *Bon, R.L., Gloyn, R.W., and Park, G.M., editors, Mining Districts of Utah: Utah Geological Association Publication 32, p. 551–564.*

Young, R.G., and Malan, R.C., 1964, Geologic map showing uranium deposits and Shinarump channels in the Monument Valley district, San Juan County, Utah, Navajo and Apache Counties, Arizona: U.S. Department of Energy Preliminary Map no. 34, scale 1:95,000.

MORGAN DISTRICT

The Morgan mining district is about 5 mi east of Morgan, Morgan County, in the eastern Wasatch Range. The district is a minor Cu-Ag producer that had most of its production from 1916 to 1920. Total recorded district production at modern metal prices is estimated at $12,000. The district has five recognized mines and prospects, and the Chicago-Utah mine is the only producer (Gloyn and others, 1995).

The Wasatch Range is geologically situated in the Middle Rocky Mountain province. The Morgan district lies on the east flank of the Wasatch anticlinorium. The Pennsylvanian to Cretaceous strata of the district are moderately east-dipping (Coogan and others, 2018). The district hosts a series of small, sediment-hosted Cu-Ag (USGS Model 30B) prospects primarily in the Lower Triassic Mahogany Member of the Ankareh Formation. The reported average grade of historical production was 6% Cu and 137 ppm Ag (Gloyn and others, 1995). Most of the mineralization is confined to a roughly 5-ft-thick reduced zone. Mineralization occurs as disseminated grains and small, compact "dark-gray to blue copper sulfide (chalcocite?)" replacements of carbonaceous material in greenish gray, micaceous, fine-grained silty sandstone (Gloyn and others, 1995). The carbonaceous trash consists of small twigs, leaves, and dark, fine-grained, wispy partings. Supergene oxidation of the sulfide ore results in secondary malachite and azurite (Gloyn and others, 1995).

Coogan, J.C., King, J.K., and McDonald, G.N., 2018, Interim geologic map of the Devils Slide quadrangle, Morgan and Summit County, Utah: Utah Geological Survey Open-File Report 691, 50 p., scale 1:24,000.

Gloyn, R.W., Shubat, M.A., and Mayes, B., 1995, Mines and prospects in and around the Farmington Complex, northern Utah: Utah Geological Survey Open-File Report 325, 36 p.

MOUNT BALDY-OHIO DISTRICT

The Mount Baldy–Ohio mining district is located on the east flank of the Tushar Mountains of Piute County about 5 mi southwest of Marysvale. The district is a large Au-Ag producer having significant Zn-Pb. The district ranks as roughly the sixth largest Au producer in Utah. Total district metal production at modern metal prices is estimated at $333 million. The Deer Trail underground mine on the eastern base of Deer Trail Mountain is by far the most important producer.

The Mount Baldy–Ohio district covers part of the Marysvale volcanic field in the transition zone from the Basin and Range Province to the west and the Colorado Plateau to the east. Upper Paleozoic and Mesozoic sedimentary strata occur along the eastern base of the range and are unconformably overlain by rocks of the Marysvale volcanic field. The volcanic rocks are apparently domed by an unexposed Miocene Mount Belknap alkali rhyolite plug (14 Ma) under Deer Trail Mountain (Beaty and others, 1986). The mineral deposits of the district show a crude, overlapping, but consistent vertical zonation from alunite deposits at the top of the mountain above 10,800 ft elevation, to small, epithermal Au-Ag veins containing minor base metals above 9200 ft, to polymetallic veins and replacement deposits below 9200 ft. Most of the production in the district (about 80%) comes from the precious-metal-rich, polymetallic replacement ores in the Permian Toroweap Formation at the Deer Trail mine on the east face of Deer Trail Mountain (USGS Model 22c). The Deer Trail ore averaged approximately 12% Zn, 5% Pb, 514 ppm Ag, and 3.43 ppm Au. The common ore minerals are sphalerite, galena, tennantite, tetrahedrite, chalcopyrite, and rare native gold. Trace elements in Deer Trail massive sulfide ores average roughly 1.5% F, 1000 ppm As, 1000 ppm Sb, 100 ppm Te, 100 ppm Se, 50 ppm Mo, 10 ppm Bi, and 3 ppm Hg. Four U.S. Geological Survey National Geochemical Database rock samples in Bullion Canyon report over 100 ppm Mo (150, 300, 300, and 500 ppm) with one sample also having strongly anomalous Sn, 150 ppm. Wulfenite is reported from several of the mines in the district (Bullock, 1981). Beaty and others (1986) envision a pair of porphyry cupolas west of the Deer Trail manto and under the alunite veins and structural dome near the top of Deer Trail Mountain.

The Mo and fluorite associated with the Deer Trail manto, the high Mo and Sn in Bullion Canyon, and the rhyolite dikes associated with the alunite mines all indicate a possible porphyry Mo signature. The porphyry system is likely under the alunitic alteration zones at Deer Trail Mountain and/or Mt. Brigham (Beaty and others, 1986). Because of the large amount of relief in the district, a deposit 3000 ft deep would still be accessible via a horizontal tunnel from near the Deer Trail mine.

Beaty, D.W., Cunningham, C.G., Rye, R.O., Steven, T.A., and Gonzalez-Urien, E., 1986, Geology and geochemistry of the Deer Trail Pb-Zn-Ag-Cu manto deposits, Marysvale district, west-central Utah: Economic Geology, v. 81, p. 1932–1952.

Bullock, K.C., 1981, Mineral and mineral localities of Utah: Utah Geological and Mineral Survey Bulletin 117, 177 p.

MOUNT NEBO DISTRICT

The Mount Nebo mining district is in easternmost Juab County on the northwest flank of the mountain with the same name. The district was organized in 1870 and became a modest Pb-Zn-Ag producer. Total district metal production at modern metal prices is estimated at $3.3 million. The Privateer (Eva) Pb-Zn-Ag underground mine, discovered in 1911, is the largest producer in the district (Bullock, 1962).

The Mount Nebo district is in the southern Wasatch Range of the Middle Rocky Mountain province. The district is underlain by Proterozoic and Paleozoic rocks that dip moderately east in the northern part of the district and steeply east in the south. Mineralization in the Mount Nebo district is associated with zones of structural weakness created by folding and faulting. The resulting shatter zones acted as channelways for mineralizing hydrothermal fluids and orebodies formed where these channels intersect favorable host strata. Ore deposits consist primarily of fissure veins, pipes, and bedded replacement bodies in Paleozoic carbonate rocks. The Middle Mississippian Deseret Limestone has been the principal ore host. The primary ore/sulfide minerals include galena, sphalerite, chalcopyrite, argentite, pyrite, and barite (Bullock, 1962). The Privateer mine produced about 2000 tons of high-grade ore from a single stope in a crinoidal limestone in the top of the Deseret Limestone. This ore assayed about 30% Pb and 340 ppb Ag. The orebody was truncated by the Eva fault, which trends north-northeast and dips steeply west (Bullock, 1962).

The bulk of this district is currently part of the Mount Nebo Wilderness Area.

Bullock, K.C., 1962, Economic geology of north-central Utah: Brigham Young University Geology Studies, v. 9, pt. 1, p. 85–94.

NEWFOUNDLAND DISTRICT

The Newfoundland mining district occupies the north end of the desolate Newfoundland Mountains about 48 mi northeast of Wendover in south-central Box Elder County. The Newfoundland range is one of the most isolated in Utah, only accessible by a gravel road from the Southern Pacific Railroad service road at Groome station (31 mi east of Lucin). The district was organized in 1872 and had minor, early production from Ag-Cu-Pb veins followed by renewed activity in the 1950s when small shipments of W and Cu were produced (Doelling, 1980). The Newfoundland district is small and had only limited production of W (~85% of production value) and subordinate Ag-Cu ±Pb ores. Total district metal production at modern metal prices is estimated at $81,000. The Desert Flower W mine is probably the largest producer.

The Newfoundland Mountains are a 19-mi-long, northerly trending range in the West Desert of the eastern Basin and Range Province. The range consists of generally west-dipping Paleozoic rocks that were intruded by one large (~10 sq mi), Late Jurassic (~150 Ma), quartz-monzonite stock, three associated smaller plugs, and numerous dikes farther south (Allmendinger and Jordan, 1984). Regional aeromagnetic surveys suggest that these small plugs connect to the main stock at depth, and the main stock also underlies the pediment west of Miners Basin. The stocks are generally light-colored, porphyritic, biotite-hornblende quartz monzonite. The largest stock ranges in texture and composition from dark, coarse-grained, porphyritic granodiorite along the margins to a light-colored, fine-grained, more equigranular, quartz monzonite core. The core of the larger stock and the entire smaller, south-central stock are both weakly, but pervasively, altered to clay-chlorite (Allmendinger and Jordan, 1984). The dikes are generally biotite-feldspar latite porphyries, trend either northeast or northwest, and are locally altered and associated with mineralization.

Mineralization in the Newfoundland district can be divided into two broad types: W skarns and base metal-bearing quartz veins. Tungsten mineralization occurs within the contact metamorphic aureole of the plugs, mostly marble and hornfels, and is generally hosted in the Ordovician Garden City Limestone. Small scheelite lenses occur in garnet skarn (USGS Model 14a) immediately adjoining the south-central stock. Tungsten, in the form of wolframite, is also reported from the Copper Flat area to the northeast of the large stock (Doelling, 1980). Tungsten grades at the Desert Flower mine ran about 1.25% WO_3.

The Ag-Cu-Pb ores occur in narrow, northwest-trending quartz veins typically about a mile from the stocks. In addition to chalcopyrite and galena, bismuthinite is reported from the Stone House Cu-Ag veins in Miners Basin on the west-side of the range. A few scattered base metal prospects also occur a few miles south of the main district.

Allmendinger, R.W., and Jordan, T.E., 1984, Mesozoic structure of the Newfoundland Mountains, Utah—horizontal shortening and subsequent extension in the hinterland of the Sevier belt: Geological Society of America Bulletin, v. 95, p. 1280–1292.

Doelling, H.H., 1980, Geology and mineral resource of Box Elder County, Utah: Utah Geological and Mineral Survey Bulletin 115, 251 p.

NEWTON DISTRICT

The Newton mining district is located northeast of Beaver on the west flank of the Tushar Mountains. The district produced some Au-Ag beginning in 1893, U was discovered in the district in about 1950, and the district became a modest U producer primarily in the 1950s. Total district metal production at modern metal prices is estimated at $8.2 million. The Mystery Sniffer is believed to be the largest producer.

The Tushar Mountains are within the Marysvale volcanic field and lie in the transition zone between the Basin and Range Province to the west and the Colorado Plateau on the east. The host rocks in the Newton district are predominantly Oligocene-Miocene Bullion Canyon calc-alkaline andesitic volcanic rocks intruded by Miocene-age monzonite, quartz latite, and rhyolite porphyries. Mineralization in the district is primarily small, low-sulfidation, epithermal, quartz-carbonate veins having some Au-Ag-Mo ±W ±U (USGS Model 25b). This lithophile mineralization appears to be associated with Miocene Mount Belknap (20-18 Ma) rhyolite porphyries (Cunningham and others, 1984a).

The primary U producer in the Newton district is the Mystery-Sniffer mine on Indian Creek. Mineralization is contained in a complex east-west-trending, moderately north-dipping, argillized normal fault zone cutting Bullion Canyon Volcanics. Mineralization consists of pockets of disseminated, crystalline torbernite, autunite, and some fluorite, marcasite/pyrite, and quartz stringers in a gray clay zone (USGS Model 25f).

Precious metal production from the Newton district comes primarily from the Sheep Rock and Rob Roy mines near the western range front fault. The Sheep Rock mine developed a 5- to 25-ft thick, white cockscomb quartz-carbonate ±fluorite vein trending N. 20° E. dipping 70° SE and cutting sericitized and pyritized andesitic Bullion Canyon Volcanics. Ore minerals are argentite and native gold. The wall rocks of the vein contain sericite, pyrite, and are locally strongly silicified (Cunningham and others, 1984b).

Huebnerite is reported from the Louise group of claims on Pole Creek, about 10 mi northeast of Beaver in the Newton district. Everett (1961) reported that huebnerite occurs in quartz stringers in rhyolite porphyry. Workings on this prospect include a 40 ft adit and several prospect pits. Similarly, wolframite is reported from the head of nearby North Creek. And finally, Cunningham and others (1984b) noted the presence of Tungsten Hollow as a tributary to the South Fork of North Creek. The huebnerite-wolframite and the geochemical Mo in the rhyolite porphyry could indicate a porphyry Mo system at depth.

Cunningham, C.G., Steven, T.A., Campbell, D.L., Naeser, C.W., Pitkin, J.A., and Duval, J.S., 1984, Multiple episodes of igneous activity, mineralization, and alteration in the Western Tushar Mountains, Utah: U.S. Geological Survey Professional Paper 1299-A, 21 p.

Everett, F.D., 1961, Tungsten deposits in Utah: U.S. Bureau of Mines Information Circular 8014, 44 p.

NORTH TINTIC DISTRICT

The North Tintic district lies north of the much larger Main and East Tintic districts of the greater Tintic district in the East Tintic Mountains of southeastern Tooele County. The North Tintic district is a geographically large, but modest Zn-Pb producer. Total district metal production at modern metal prices is estimated at $34 million. The Scranton underground mine is the only notable producer (Disbrow and Morris, 1957).

The East Tintic Mountains are one of the easternmost ranges in the Basin and Range Province in central Utah. The late Proterozoic- and Paleozoic-age strata of the North Tintic district have been broadly folded about the north-plunging, North Tintic anticline and Tintic syncline, which have been disrupted by numerous northeast-striking, right-lateral, strike-slip faults (Clark and others, 2012). While mineralization in the Main Tintic district to the south appears to be related to Eocene intrusives, Clark and others (2012) report Oligocene ages (29 to 25 Ma) on mafic intrusions and volcanics in the North Tintic district.

North Tintic has the smallest historical production of the four Tintic subdistricts, but, on average has the highest Zn ore grades (Krahulec and Briggs, 2006). The North Tintic district also has several Mn deposits. The Scranton mine, by far the largest operation in the North Tintic district, developed Zn-Pb mantos hosted in the Mississippian-age carbonate section. Average grades at the Scranton are 16.7% Zn, 9.5% Pb, 23.7 ppm Ag, and some minor Cu and Au which may not have been recovered (Disbrow and Morris, 1957). Nearly all historical production was derived from oxidized ores.

Clark, D.L., Kirby, S.M., and Oviatt, C.G., 2012, Interim geologic map of Rush Valley 30' x 60'quadrangle, Tooele, Utah, Salt Lake, and Juab Counties, Utah: Utah Geological Survey Open-File Report 593, 65 p., 2 plates, scale 1:62,500.

Disbrow, A.E. and Morris, H.T., 1957, Ore deposits of the North Tintic district, in *Cook, D.R., editor, Geology of the East Tintic Mountains and ore deposits of the Tintic mining districts: Utah Geological Society Guidebook to the Geology of Utah, no. 12, p. 140–154.*

Krahulec, K., and Briggs, D.F., 2006, History, geology, and production of the Tintic mining district, Juab, Utah, and Tooele Counties, Utah, in *Bon, R.L., Gloyn, R.W., and Park, G.M., editors, Mining districts of Utah: Utah Geological Association Publication 32, p. 121–150.*

NOTCH PEAK DISTRICT

The Notch Peak mining district lies in the House Range of central Millard County about 45 mi west of Delta. Placer gold was the initial mineral discovery in the Notch Peak district in the early 1930s and W skarns were located in the 1940s. The district is a small Au-W producer. Total district metal production at modern metal prices is estimated at $1.3 million. The Amasa Valley placer and the Klondike and Scheelite Queen W mines were the largest producers and the gold placer operation is still intermittently productive.

The House Range is a large north-trending range in the eastern Basin and Range Province. The Notch Peak district is centered on the large (7.4 sq mi) Jurassic (~163 Ma) Notch Peak quartz monzonite stock/laccolith. The stock is light gray, coarsely crystalline, porphyritic, and ranges from diopside monzonite to biotite granite. Late, small aplitic and fine-grained granophyric dikes and sills intrude the stock and adjacent Middle and Upper Cambrian carbonate strata. The stock is surrounded by a broad contact metamorphic halo. The thermal metamorphic halo is roughly a mile wide and generally follows the intrusive contact except for a distinct projection to the north encompassing the Brown Queen W mine (USGS Model 14a). It has been suggested that a dike or sill may underlie this prong of alteration at moderate depth. This idea is supported by an aeromagnetic anomaly which broadly mimics the extension of the alteration to the north (Stoeser and others, 1990).

The Notch Peak district is the fourth largest W producer in Utah at just over 100,000 pounds of WO_3 and still hosts a number of small, subeconomic, inferred W ±Mo skarn resources near the intrusive contact totaling several hundred thousand tons at 0.02% WO_3. Most of these resources are clustered around the New Klondike mine (Everett, 1961). The W deposits are typically banded, prograde garnet-diopside skarns containing scheelite, molybdenite, and wolframite. Rock samples run as high as >1% W, 5000 ppm Cu, 2000 ppm Mo, and 700 ppm Sn (Stoeser and others, 1990).

The district has also produced several hundred ounces of Au, predominantly from a small placer operation in Amasa Valley (USGS Model 39a). The Au is derived from a series of wide-spaced, narrow, low-grade quartz veins that cut the east-central part of the stock. These veins have thin silicic and broader argillic alteration selvages.

Much of the southern, western, and northern portions of the district, including the northern prong of alteration, are covered by the Notch Peak Wilderness Study Area.

Everett, F.D., 1961, Tungsten deposits in Utah: U.S. Bureau of Mines Information Circular IC-8014, 43 p.

Stoeser, D.B., Campbell, D.L., Labson, Victor, Zimbelman, D.R., Podwysocki, M.H., Brickey, D.W., Duval, J.S., Cook, K.L., and Lundby, W., 1990, Mineral resources of the Notch Peak Wilderness Study Area, Millard County, Utah: U.S. Geological Survey Bulletin 1749-C, 28 p.

OPHIR DISTRICT

The Ophir mining district is in the southwestern Oquirrh Mountains about 33 mi south-southwest of Salt Lake City. The Ophir district was organized in the 1860s as a bonanza Ag camp and mining continued sporadically into the early 1970s. The Ophir district is about the tenth most productive in Utah. Ophir is credited with production of about 2.8 million tons of ore averaging 6.2% Pb, 1.5% Zn, 0.8% Cu, 237 ppm Ag, and 0.21 ppm Au, recovered. Total district metal production at modern metal prices is estimated at $877 million. The Ophir Hill mine in Ophir Canyon is the largest producer in the district with about 1.5 million tons of production followed by the Hidden Treasure mine at 300,000 tons (Rubright, 1978).

The Ophir district lies on the Bingham–Park City mineral belt of the Basin and Range Province. The southwestern Oquirrh Mountains are geologically dominated by the asymmetrical Ophir thrust-cored anticline. This fold is part of a north-northwest-trending, Mesozoic fold belt characterized by thrust-cored, asymmetrical, closed anticlines and synclines with a wavelength of about 35,000 ft and amplitude of 15,000 ft (Gilluly, 1932).

Mineralization in the Ophir district is largely confined to a northwest-trending belt less than 1 mi wide and over 3 mi long, approximately coincident with the crest of the Ophir anticline. The ore deposits of the Ophir district are dominantly distal skarns, carbonate replacement deposits, and veins. The dominant ore controls are the intersections of northerly trending fissures and favorable host horizons, principally the Cambrian Ophir Formation, Mississippian Gardison Limestone, and Mississippian lower Great Blue Limestone. A series of poorly exposed Eocene-age monzonite and rhyolite plugs, dikes, and sills intrude near the anticlinal crest and may be related to ore (Gilluly, 1932).

The Ophir district is unusual because it is, in part, a vertically zoned mining district. Past production ranges from distal, sediment-hosted Ag-Au-Pb ±Ba deposits high on Lion Hill to the south, through medial, Pb-Zn-Ag carbonate replacement deposits in Dry Canyon to the north, to Ag-Pb-Cu distal skarns in the bottom of Ophir Canyon and continuing north under Dry Canyon. The Ophir Hill Ag-Pb-Cu distal skarn is the most important mine in the district (Gilluly, 1932; Rubright, 1978). The primary ore/sulfide minerals are galena, sphalerite, argentite, chalcopyrite, acanthite, tetrahedrite, pyrite, pyrrhotite, arsenopyrite, wolframite, and fluorite. The bulk of the remaining district production has come from numerous Ag-Pb-Zn vein and replacement deposits (USGS Model 22c). Several companies have explored the Ophir district for a porphyry system like those found in the adjoining Bingham and Stockton districts, but no significant results have been released.

Gilluly, J., 1932, Geology and ore deposits of the Stockton and Fairfield quadrangles, Utah: U.S. Geological Survey Professional Paper 173, 171 p., 1 plate, scale 1:62,500.

Rubright, R.D., 1978, Geology of the Ophir district, Utah, in *Shawe, D.R., and Rowley, P.D., editors, Guidebook to mineral deposits of southwestern Utah: Utah Geological Association Publication 7, p. 35–40.*

ORANGE CLIFFS DISTRICT

The Orange Cliffs (Poison Spring) district is a part of the Green River U mining area in easternmost Garfield County about 26 mi southeast of Hanksville. The district is rugged and moderately inaccessible but still managed to become a small U producer. Total district metal production at modern metal prices is estimated at $84,000. The Cedar Point Group, along the Dirty Devil River in the southwest part of the district, is the district's most productive mine.

The Orange Cliffs district is on the eastern limb of the Henry Basin on the Colorado Plateau. The sedimentary strata in the area dip very gently (1° to 3°) to the west. Mineralization is hosted in the Monitor Butte and Moss Back Members of the Upper Triassic Chinle Formation. These basal Chinle units consist of sandstone, mudstone, and conglomerate-filled channels cut into the underlying Moenkopi Formation (Doelling, 1975).

The Orange Cliffs district's weak U-Cu mineralization occurs in these paleochannels in association with logs, asphaltite, and coaly material. Ore minerals commonly include uraninite, torbernite, and uranophane along with malachite, azurite, and chalcocite (Doelling, 1974, 1975). Ore grades average about 0.2% U_3O_8 and 0.02% V_2O_5 with high Cu (USGS Model 30c).

Doelling, H.H., 1974, Uranium-vanadium occurrences of Utah: Utah Geological and Mineral Survey Open-File Report 18, unpaginated.

Doelling, H.H., 1975, Geology and mineral resources of Garfield County, Utah: Utah Geological and Mineral Survey Bulletin 107, 172 p.

ORDERVILLE GULCH DISTRICT

The Orderville Gulch mining district is in extreme western Kane County. The district is a minor U-V producer. The district shipped a few hundred tons of low-grade U-V ore to the Marysvale purchasing depot of the Atomic Energy Commission in the 1950s. Total district metal production at modern metal prices is estimated at $28,000. This production seems to have come primarily from the Lynn mine (Beroni and others, 1953).

The Orderville Gulch district is geologically situated on the Markagunt Plateau in the transition zone from the Basin and Range Province on the west to the Colorado Plateau on the east. The rocks of the district are nearly flat-lying Jurassic- and Cretaceous-age strata, dipping just 5° to the northeast. The mineralization is near the contact of the cliff-forming Dakota Formation and the very top of the Winsor Member of the Carmel Formation–Entrada Sandstone (USGS Model 30c). Mineralization is associated with carbonaceous clay, carbonized wood fragments, petrified logs, and Fe oxide concretions. The recognized ore minerals include carnotite, tyuyamunite, torbernite, and autunite-bearing clay. In addition to U and V, geochemical work suggests the mineralization may be enriched in As and Mo (Beroni and others, 1953; Doelling and others, 1989).

Beroni, E.P., McKeown, F.A., Stugard, F. Jr., and Gott, G.B., 1953, Uranium deposits of the Bulloch group of claims, Kane County, Utah: U.S. Geological Survey Circular 239, 9 p.

Doelling, H.H., Davis, F.D., and Brandt, C.J., 1989, The geology of Kane County, Utah—geology, mineral resources, geologic hazards: Utah Geological and Mineral Survey Bulletin 124, 192 p., 10 plates, scale 1:100,000.

PARADISE DISTRICT

The Paradise (La Plata, Hyrum) mining district covers a geographically large area centered about 12 mi south-southeast of Logan in south-central Cache County. The district was discovered in the 1890s and became a minor Fe-Cu-Zn-Pb producer. Total district metal production at modern metal prices is estimated at $27,000. None of the mines are noteworthy producers.

The Paradise district covers a large section of the Bear River Range of the Middle Rocky Mountain province. Geologically, the Bear River Range contains the Sevier-age, north-trending Logan Peak syncline which exposes Cambrian strata on the flanks of the range and Pennsylvanian strata on the crest of the range in the core of the large, open syncline. The mineral deposits in the Paradise district consist of a series of small, isolated, structurally controlled Cu-Zn-Pb, Pb-Zn-Ag, Cu-Fe, and Fe replacement deposits, primarily hosted in Cambrian sedimentary rocks, principally carbonates. The primary ore minerals are chalcopyrite, bornite, sphalerite, galena, and specularite (Bullock, 1970; Perry and McCarthy, 1977). There are no Mesozoic- or Cenozoic-age intrusive igneous rocks known in the Paradise district and the mineral deposits may have been produced from hydrothermal fluids generated during Sevier folding and thrusting.

Bullock, K.C., 1970, Iron deposits of Utah: Utah Geological and Mineralogical Survey Bulletin 88, 101 p., 1 plate.

Perry, L.I., and McCarthy, B.M., 1977, Lead and zinc in Utah, 1976: Utah Geological and Mineral Survey Open-File Report 22, 525 p.

PARIA EAST DISTRICT

The Paria East mining district lies about 32 mi east of Kanab in south-central Kane County. The district has been an insignificant U producer. The Hattie Green Cu prospect was the first reported mineral occurrence in the area in 1899. The Radiance Group is the only known mine to ship ore, but with just trivial U production.

The Paria East district is aligned along the moderately east-dipping East Kaibab monocline (The Cockscomb) on the Colorado Plateau. The stratigraphic section along the monocline is attenuated by bedding-parallel faulting which has removed most of the Upper Triassic Chinle Formation, leaving the Triassic Moenkopi Formation in fault contact with the overlying Jurassic Moenave Formation. The weak Radiance U ±Cu mineralization is associated with this attenuation fault (Buranek, 1942; Doelling and others, 1989). The Radiance Group has a total recorded production of just 172 lbs U_3O_8. In addition to the sandstone U mines (USGS Model 30c), scattered sediment-hosted Cu (USGS model 18b) shows are also in the district, but it has no recorded Cu production. The Hattie Green Cu mine has the most extensive workings and may have shipped a few small test lots. A high-grade sample of the ore yielded 7.05% Cu, 19 ppm Ag, 0.28% Pb, and 260 ppm Zn (Doelling and others, 1989).

The Paria East district was also the site of a brief Au excitement from about 1910 to 1913. This fever was set off by Au values being reported from shales in the lower half of the Petrified Forest Member of the Chinle Formation near the now abandoned Paria town site. However, Lawson (1913) reported trench sampling of the shales only ran 33 to 83 ppb Au and the rush was soon over. Four Chinle samples taken at this prospect by the U.S. Bureau of Mines all returned less than 7 ppb Au (Brown and Hannigan, 1986).

Brown, S.E., and Hannigan, B.J., 1986, Mineral investigations of a part of the Paria-Hackberry Wilderness Study Area (UT-040-247), Kane County, Utah: U.S. Bureau of Mines Open-File Report MLA 34-86, 25 p.

Buranek, A.M., 1942, Report on the uranium deposits near Paria, Kane County, Utah (includes uranium deposits covered by the Radient claims): Utah Department of Publicity and Industrial Development Circular 17, 8 p.

Doelling, H.H., Davis, F.D., and Brandt, C.J., 1989, The geology of Kane County, Utah—geology, mineral resources, geologic hazards: Utah Geological and Mineral Survey Bulletin 124, 192 p.

Lawson, A.C., 1913, The gold of the Shinarump at Paria: Economic Geology, v. 8, p. 434–448.

PARIA WEST DISTRICT

The Paria West mining district lies about 25 mi east of Kanab in south-central Kane County. Manganese mineralization was initially discovered in 1908, but production did not begin until World War II when the district became a small Mn producer (Buranek, 1945). Total district metal production at modern metal prices is estimated at $115,000. The Manganese King mine is the only producer in the district.

The Paria West district is situated in the Grand Staircase on the Colorado Plateau. The district contains both Mn and U prospects, but only the Mn made it to production. Both the Mn and U ores are hosted in the Upper Triassic Chinle Formation. The Manganese King ores occur in the Petrified Forest Member of the Chinle. The section consists of a lower bentonitic mudstone that grades upward into a dark manganiferous shaly mudstone, which is in turn overlain by a calcareous, rhyolitic (?) tuff and sandy limestone.

The ore at the Manganese King occurs primarily as botryoidal nodules up to several inches in diameter in the top few feet of the dark mudstone (USGS Model 34b). The main ore minerals are psilomelane, pyrolusite, and earthy black Mn wad. Barite and calcite crystals and veinlets occur within the ore zone clay (Baker and others, 1952). The nodules may contain over 50% Mn (Buranek, 1945), but the in-place grades are only approximately 10% Mn. The Mn ore was extracted by a series of short tunnels and surface cuts. A total of at least 191 tons of Mn nodules were shipped (Havens and Agey, 1949; Doelling and others, 1989).

The small Kitchen Corral U occurrence is hosted in the Shinarump Conglomerate Member of the Chinle Formation and is associated with accumulations of carbon trash in the channel (USGS Model 30c).

Baker, A.A., Duncan, D.C., and Hunt, C.B., 1952, Manganese deposits of southeastern Utah—Part 2, Manganese deposits of Utah: U.S. Geological Survey Bulletin 979-B, 157 p.

Buranek, A.M., 1945, Notes on the Manganese King property near Kanab. Kane County, Utah (includes the Johnson manganese deposit): Utah Department of Publicity and Industrial Development Circular 33, 11 p.

Doelling, H.H., Davis, F.D., Brandt, C.J., 1989, The geology of Kane County, Utah—geology, mineral resources, geologic hazards: Utah Geological and Mineral Survey Bulletin 124, 192 p.

Havens, R. and Agey, W.W., 1949, Concentration of manganese ores from Piute and Kane Counties, southern Utah: U.S. Bureau of Mines Report Investigation 4551, 9 p.

PARK CITY DISTRICT

The Park City (Uintah, Snake Creek) mining district lies in the Wasatch Range of Summit and Wasatch Counties about 22 mi east of Salt Lake City. The district is essentially tied with the greater Tintic district for the second largest mining district in the state in terms of total metal production value. The principal metals produced are Ag, Pb, Au, and Zn, in decreasing order of importance. Park City is the second largest Pb, Zn, and Ag producer in the state. Total district metal production at modern metal prices is estimated at $10 billion. The largest producers in the district are the Daly West, Mayflower, Ontario, Park Utah, and Silver King Coalition underground mines (John, 2006).

The Park City district is part of the Bingham–Park City mineral belt in the Middle Rocky Mountain province. The district is underlain by a sequence of Mississippian- to Triassic-age interbedded carbonate rocks, sandstone, and shale folded along the gentle, north-plunging, open, upright, asymmetrical, Park City anticline and cut by gently west-dipping thrust faults. These older structures are cut by a series of east-northeast-trending, steeply dipping, normal faults which extend eastward from the Clayton Peak stock across the Park City anticline. A number of diorite to granodiorite porphyry stocks (34–33 Ma) intrude the south end of the anticline (John, 2006).

The vast majority of the Park City district's production is from sedimentary rock-hosted vein and replacement ores. These ores primarily occur along the east-northeast-trending faults producing veins in the relatively non-reactive Pennsylvanian-Permian Weber Sandstone in the core of the anticline and mantos in the adjoining favorable limestones. The most important ore host is the Jenny horizon, about 100 ft above the base of the Permian Park City Group and just above the Weber Sandstone. Only the Mayflower veins in the southeastern end of the district are important intrusive-hosted (granodiorite) ores. The Mayflower veins were productive over a vertical distance of nearly 3300 ft and had the highest Cu and Au grades in the district. Bromfield (1989) maps a central zone of hydrothermal biotite surrounded by quartz-sericite-pyrite at the surface near the Mayflower mine. Pebble dikes and a breccia pipe were also reported from the Ontario and Mayflower mines in the southern section of the district.

The Park City district appears to be zoned from intrusive-hosted, enargite-bearing Cu-Au-rich ores near the Mayflower in the southeast, through Ag-Pb-Zn replacement ores in the central and western parts of the district (USGS Model 19A), to distal Ag-dominant ores at the Park City Consolidated mine in the northeast near Deer Valley (John, 2006).

Bromfield, C.S., 1989, Gold deposits in the Park City mining district, Utah: U.S. Geological Survey Bulletin 1857-C, p. C14–C26.

John, D.A., 2006, Geology and mining history of the Park City mining district, central Wasatch Mountains, Utah, in *Bon, R.L., Gloyn, R.W., and Park, G.M., editors, Mining districts of Utah: Utah Geological Association Publication 32, p. 67–93.*

PARK VALLEY DISTRICT

The Park Valley (Golden, Century Hollow) mining district lies on the south flank of the Raft River Mountains about 70 mi west-northwest of Tremonton in north-central Box Elder County. Park Valley is a modest Au district. The district began production in the late 1890s and continued to be a small but steady Au producer well into the 1910s (Butler and others, 1920). There was a revival of activity in the district with the devaluation of the U.S. dollar during the depths of the Great Depression in 1934 and the consequent escalation of the Au price from $20.67 to $35 per oz. Some of the more refractory and lower grade (?) sulfide ores may have been processed at this time. Total district metal production at modern metal prices is estimated at $18 million. The last recorded production from Park Valley was in 1946 and the estimated total production is 16,409 ounces of Au along with minor Ag, Pb, and Cu.

The Park Valley area is geologically complex, being on the south flank of the Albion–Raft River–Grouse Creek metamorphic core complex. The mines developed narrow, high-grade Au quartz veins primarily hosted in Neoarchean Green Creek Complex quartz monzonite gneiss (the oldest intrusive rock in Utah) and lesser schist. The Green Creek Complex is unconformably overlain by the Neoproterozoic Elba Quartzite which dips moderately, about 10° to 35°, to the south. The age of mineralization has not been documented, but ore does not seem to extend up into the Elba Quartzite.

The known Au mineralization in the district is focused in the Corner Creek–Suzanna Canyon–Century Hollow area but extends eastward into Twin Canyon (Great Buffalo mine), Big Hollow, and possibly even Pine Creek canyons. The Century underground mine is the largest producer and the Suzannah underground mine, the second largest producer, potentially lies on the southwestern extension of the same vein set. These veins extend for a distance of at least a couple of thousand feet trending about N. 20° E. and have a moderate to steep southeast dip. Some of the ore shoots plunge southeasterly within the plane of the vein. Two types of veins are recognized: (1) barren, coarse quartz ±orthoclase veins and (2) mineralized, green-gray, fine-grained, quartz-sulfide veins. The ore zone ranges from several inches to a few feet thick and the primary ore/sulfide minerals include galena, sphalerite, chalcopyrite, arsenopyrite, and pyrite (Butler and others, 1920). Panning of the ore zone yields visible native gold. The historical ore grades run from about 5 to 15 ppm Au and 50 to 200 ppm Ag. Gold grades reportedly increase with the Pb (1% to 10% Pb) content. The deposits have been mostly worked out to the water table (Perry and McCarthy, 1977).

All known mineralization in the Park Valley district is on private land.

Butler, B.S., Loughlin, G.F., Heikes, V.C., and others, 1920, The ore deposits of Utah: U.S. Geological Survey Professional Paper 111, 672 p.

Perry, L.I., and McCarthy, B.M., 1977, Lead and zinc in Utah, 1976: Utah Geological and Mineral Survey Open-File Report 22, 525 p.

PINE GROVE DISTRICT

The Pine Grove mining district lies in the Wah Wah Mountains of western Beaver County about 32 mi west of Milford. The mining district was historically a minor Zn-Pb-Ag producer (about $871,000 at modern metal prices), but substantial Mo exploration began in 1975 when Phelps Dodge Corporation drilled the first deep hole into porphyry Mo mineralization at a depth of 3300 ft. The Tasso (Wah Wah) underground mine is the largest producer.

Pine Grove lies in the Wah Wah Mountains of the eastern Basin and Range Province. The district hosts a giant, Climax-type porphyry Mo deposit related to a sub-volcanic, silicic-alkalic, high-silica rhyolite porphyry plug that intrudes a thick sequence (over 6000 ft) of Upper Proterozoic and Lower Cambrian quartzose clastic sedimentary rocks. The Pine Grove rhyolite porphyry (~24 Ma) is a steep-walled, oval-shaped plug covering about 0.4 sq mi at the surface. Molybdenum mineralization occurs mostly along the margins of the Pine Grove porphyry beginning at a depth of about 3000 ft (Staff, 1984; Keith and others, 1986; Stegen, 2016).

According to Keith and others (1993), the evidence that Pine Grove is a Climax-type porphyry Mo deposit includes: (1) multiple intrusions of high-silica rhyolite, (2) large tonnage of high-grade ore, (3) accessory fluorite, topaz, and huebnerite in the ore zone, (4) lack of appreciable Cu in the system, and (5) accessory monazite, xenotime, and ilmenorutile in the intrusive phases (USGS Model 16). The commonly published reserve figure for Pine Grove is about 125 million tons at 0.17% Mo at a minimum 300-foot width and a 0.12% Mo cutoff grade (Stegen, 2016). This reserve is contained within a much larger estimated geological mineral inventory of over 300 million tons at 0.17% Mo. No important mineral exploration or development has been done on the property since about 1983. Because porphyry Mo deposits tend to occur in clusters, there could be a potential for the discovery of additional Mo resources in the district (Keith and others, 1993).

Keith, J.D., Christiansen, E.H., and Carten, R.B., 1993, The genesis of giant molybdenum deposits, in *Whiting, B.H., Mason, R., and Hodgson, C.J., editors, Giant ore deposits: Society of Economic Geologists Special Publication 2, p. 285–316.*

Keith, J.D., Shanks, W.C. III, Archibald, D.A., and Farrar, E., 1986, Volcanic and intrusive history of the Pine Grove porphyry molybdenum system, southwestern Utah: Economic Geology, v. 81, p. 553–577.

Staff (Pine Grove Joint Venture), 1984, Geologic review of the Pine Grove molybdenum deposit, in *Field trip 7 porphyry molybdenum deposits: Association of Exploration Geochemists annual meeting in Reno, Nevada, p. 5–13.*

Stegen, R.J., 2016, Mineralization and alteration characteristics of the Pine Grove porphyry molybdenum deposit, Beaver County, Utah, in *Comer, J.B., Inkenbrandt, P.C., Krahulec, K.A., and Pinnell, M.L., editors, Resources and Geology of Utah's West Desert: Utah Geological Association Publication 45, p. 59–72.*

PINK KNOLLS DISTRICT

Pink Knolls district lies in the southern Wah Wah Mountains on the Beaver–Iron County line. The area has had only a tiny amount of U production from the Desert View mine, probably in the late 1940s, and little other recorded development. Much of the more recent activity has focused on the Cina Hg-S mine area. Several unpublished reports suggest the Cina mine was thoroughly investigated as a Hg prospect in the late 1960s and early 1970s, including drilling, trenching, underground development, calculation of mineral resources, metallurgical studies, economic evaluations, market analysis, and possibly some pilot-scale test mining.

The Pink Knolls district lies astride the east-trending, Miocene-age, Blue Ribbon lineament of Rowley and others (1978) in the eastern Basin and Range Province. The Cina mine (Iron County) hosts cinnabar and native sulfur along a northeast-trending, moderately west-dipping, normal fault between strongly altered Miocene Blawn Formation rhyolitic tuffs in the northwest hanging wall and unaltered Middle Cambrian Trippe Limestone in the footwall (Steven and Morris, 1987). Mineralization can be traced along the fault zone for over a mile but is most intense in areas where east-trending cross-faults intersect the main fault zone. The main fault is filled with 1- to 10-ft-wide zones (average ~2.5 ft) of opal and chalcedony and paleo-hot spring fumaroles occur along the zone sporadically (USGS Model 27a). Red cinnabar occurs as thin seams in the chalcedony along with black metacinnabar, sulfur, and white, coarse-grained gypsum. Cinnabar is primarily concentrated in the vein/fault itself under the siliceous sinter capping. The cinnabar occurs as disseminated specks, intergranular fillings, and veinlets. Sulfur occurs as lenses/pods in porous zones in the gypsum-bearing altered tuff hanging wall.

Some mineral exploration in the 1970s (SX East) focused on the broad areas of advanced argillic alteration in Blawn Formation tuffs as a source of alunite. Most of the subsequent mineral exploration in the 1980s and later focused on the potential for Au at depth under the Hg-S paleo-fumaroles. The Seeps low-sulfidation, epithermal quartz veins (USGS Model 25c) were also drilled for Au in the 1980s.

Rowley, P.D., Lipman, P.W., Mehnert, H.H., Lindsey, D.A., and Anderson, J.J., 1978, Blue Ribbon lineament, an east-trending structural zone within the Pioche mineral belt of southwestern Utah and eastern Nevada: Journal of Research of the U.S. Geological Survey, v. 6, no. 2, p. 175–192.

Steven, T.A., and Morris, H.T., 1987, Summary mineral resource appraisal of the Richfield 1° x 2° quadrangle, west-central Utah: U.S. Geological Survey Circular 916, 24 p.

PROMONTORY DISTRICT

The Promontory mining district is located about 25 mi west of Ogden in eastern Box Elder County. The major orebodies of the Promontory district were not discovered until 1914 and its most productive periods were 1915 to 1919 and 1942 to 1947. The district is a moderate Zn-Pb producer with minor Cu and Ag. Total district metal production at modern metal prices is estimated at $8.4 million. The district is unusual for the eastern Basin and Range in that it is Zn dominant over Pb and has only trivial precious metal credits. The Lakeview Zn-Pb underground mine is the largest producer.

The Promontory district lies on the southern end of the Promontory Mountains in the Basin and Range Province. The Promontory Mountains extend southward as a peninsula into Great Salt Lake. The major mines in the Promontory district occur on the west flank of Lead Mountain in a homoclinal, moderately northeast-dipping sequence of interbedded Cambrian-age quartzites, shales, and carbonate rocks (Doelling, 2006).

Mineralization in the Promontory district is localized at the intersection of north-trending, steeply west-dipping fissures and favorable, northeast-dipping Middle Cambrian carbonates (Perry and McCarthy, 1977; Doelling, 2006). The bulk of the mineralization in the district occurs in a north-trending swath parallel to the fissures less than 1 mi wide and over 3 mi long. The district is zoned from Cu-Ag ore on the south, through Pb-Zn ores on Lead Hill, to Zn-dominant ores on the north. The most important class of ores is the Zn-dominant vein/replacement deposits hosted in a section of interbedded carbonate and shale (Middle Cambrian Dome Limestone equivalent). This host carbonate is a 40- to 100-ft-thick, cliff-forming, light-gray, very fine grained, oolitic limestone. The small disseminated Cu deposit in the south is hosted in the Lower Cambrian Geertsen Canyon Quartzite (Tintic Quartzite equivalent). No intrusive igneous rocks are reported in the district (Perry and McCarthy, 1977; Doelling, 2006). Only the Zn-dominant replacement ores have had significant production.

The Promontory district is almost entirely on private land except for some BLM-administered tracts to the northeast of the major mines.

Doelling, H.H., 2006, Geology of the Lucin and Promontory districts, Box Elder County, Utah, in *Bon, R.L., Gloyn, R.W., and Park, G.M., editors, Mining districts of Utah: Utah Geological Association Publication 32, p. 151–166.*

Perry, L.I., and McCarthy, B.M., 1977, Lead and zinc in Utah, 1976: Utah Geological and Mineral Survey Open-File Report 22, 525 p.

PROVO DISTRICT

The Provo mining district is in east-central Utah County due east of Provo. The district was organized in 1871 and was a minor Pb-Zn producer. Total district metal production at modern metal prices is estimated at $42,000. The Monarch (Buckley) underground mine was the only reported producer.

The Provo district lies in the Wasatch Range of the Middle Rocky Mountain province. The rocks in the district include Neoproterozoic-, Cambrian-, Devonian-, and Mississippian-age strata exposed in an anticline overturned to the east. The Monarch mine is developed on a replacement deposit in the Middle Mississippian Deseret Limestone. The primary ore/sulfides are galena, argentite, pyrite, and probably sphalerite (Bullock, 1962).

Bullock, K.C., 1962, Economic geology of north-central Utah: Brigham Young University Geology Studies, v. 9, pt. 1, p. 85–94.

RED BUTTE DISTRICT

The Red Butte mining area is located in the central Grouse Creek Mountains of northwestern Box Elder County. Red Butte is a newly designated district which was previously included in the Rosebud district to the south. The district is separated here in an effort to make the district boundaries more accurately reflect the individual intrusive-centered, paleohydrothermal systems. In the case of Red Butte, the mineralization is probably related to the nearby southern Red Butte stock (0.8 mi) rather than the distant (6.6 mi) Immigrant Pass plutonic complex of the Rosebud district.

The Grouse Creek Mountains are part of the Albion–Raft River–Grouse Creek metamorphic core complex in the Basin and Range Province. The Grouse Creek Mountains are geologically complex, and the Red Butte district includes Precambrian rocks in the footwall of a major low-angle normal fault that has an attenuated sequence of upper Paleozoic sedimentary strata in the hanging wall. Doelling (1980) indicates that the Grouse Creek range has been rotated westward by Neogene Basin and Range extension.

In the Red Butte district, the core of the range is Neoarchean Green Canyon Complex granite gneiss and some thin Neoproterozoic metasedimentary rocks intruded by a pair of small (1 to 2 sq mi), Oligocene (~25 Ma) quartz monzonite stocks (Miller and others, 2012). The stocks are light gray, medium grained, equigranular, biotite quartz monzonite. The stocks are cut by small, leucocratic alaskite and aplite dikes (Todd, 1973) and have modest associated magnetic highs. A west-dipping detachment fault on the crest of the range separates the footwall Precambrian metamorphic rocks and Oligocene quartz monzonite from weakly metamorphosed blocks of Mississippian, Pennsylvanian, and Permian sedimentary rocks in the hanging wall. The top of the southern quartz monzonite stock is cut and mylonitized by the detachment fault (Doelling, 1980).

The main Red Butte underground mine workings are in Ingham Canyon and consist of a series of adits driven from the bottom of the canyon to both the north and south. The workings develop a series of narrow, rusty, clayey, Ag-Au quartz fissures in Mississippian Chainman Shale (Doelling, 1980). The mine has no reported production, but some ore may have been shipped.

Doelling, H.H., 1980, Geology and mineral resource of Box Elder County, Utah: Utah Geological and Mineral Survey Bulletin 115, 251 p.

Miller, D.M., Clark, D.L., Wells, M.L., Oviatt, C.G., Felger, T.J., and Todd, V.R., 2012, Progress report geologic map of the Grouse Creek 30' x 60' quadrangle, Box Elder County, Utah and Cassia County, Idaho: Utah Geological Survey Open-File Report 598, 25 p., scale 1:100,000.

Todd, V.R., 1973, Structure and petrology of metamorphosed rocks in central Grouse Creek Mountains, Box Elder County, Utah: Stanford, California, Stanford University Ph.D. dissertation, 316 p.

RED CANYON DISTRICT

The Red Canyon mining district is part of the greater White Canyon U mining area located in remote southwestern San Juan County. The White Canyon area as a whole is credited as Utah's second largest U producer and the Red Canyon district is one of the largest U producer in its own right. The Red Canyon district is in the southwestern part of the White Canyon area and according to Chenoweth (1993), from 1949 to 1970 the 26 mines of the Red Canyon district produced 520,000 tons of ore averaging 0.26% U_3O_8 for a total of 2,744,000 pounds of U_3O_8. Total district metal production at modern metal prices is estimated at $94 million. The district had extensive U exploration in the 1970s during high U prices, but exploration essentially ceased when the market collapsed in the early 1980s. The largest producers in the Red Canyon district include the Daneros, Maybe, Markey, and Radium King underground mines.

The Red Canyon district is on the western margin of the Paradox Basin on the Colorado Plateau. Red Canyon is part of the deeply incised Red Rock Plateau/White Canyon Slope, sandwiched between the Colorado River on the west and the Monument Uplift on the east. The U ores of the Red Canyon district are hosted in the basal Shinarump Member of the Upper Triassic Chinle Formation. The Shinarump Member is a fluvial sandstone and conglomerate deposited in a complex braided stream system overlying and locally scouring down into the underlying Lower Triassic Moenkopi Formation (Chenoweth, 1993).

Uranium mineralization in the Red Canyon district is associated with channel scours and sandstone pinch-outs against mudstone and the grade is directly proportional to the amount of carbonaceous material present (Doelling, 1969). The generally unoxidized orebodies average 3.5 ft thick and range from 10 to 500 ft wide and 50 to 1000 ft long (Doelling, 1969). Uraninite is the primary ore mineral in the deposits. The low-lime ore has a low V content, but commonly contains over 1% Cu values primarily as chalcopyrite (Doelling, 1969). Some mineralization has cobalt-oxides locally associated with the Cu-rich zones. The Daneros U ±Cu property is the only property in the Red Canyon district that has been in production this century. Between 2009 and 2013, approximately 121,000 tons of 0.26% U_3O_8 were mined at the Daneros. The remaining indicated resource is 20,000 tons at 0.36% U_3O_8 (Energy Fuels, 2018).

Chenoweth, W.L., 1993, The geology and production history of the uranium-vanadium deposits in the White Canyon district, San Juan County, Utah: Utah Geological Survey Miscellaneous Publication 93-3, 24 p.

Doelling, H.H., 1969, Mineral resources, San Juan County, Utah and adjacent areas, Part II—Uranium and other metals in sedimentary host rocks: Utah Geological and Mineralogical Survey Special Study 24, 64 p.

Energy Fuels, 2018, Energy Fuels Inc. United States Security and Exchange Commission Form 10-K for the year 2017: Online, http://www.energyfuels.com/wp-content/uploads/2018/03/EFR-2017.12.31-10K-FINAL-filed-3.9.2018-2.pdf, accessed April 2018.

REDMOND DISTRICT

The Redmond mining district is in north-central Sevier County 5 mi northeast of Salina. The Redmond district had a sporadic record of minor Zn-Pb production from the World War I era until 1950. Total district metal production at modern metal prices is estimated at $85,000. The only productive operation was the Redmond Silver (Salina Zinc) mine.

The Redmond district is within the Sanpete–Sevier Valleys section of the transition zone between the Basin and Range Province to the west and the Colorado Plateau to the east. Mineralization in the district is associated with a north-northeast-trending, high-angle normal fault that has Jurassic Arapien Shale in the eastern footwall and Eocene Green River Formation limestone in the western hanging wall. The Redmond Silver Zn-Pb ±Ag orebody occurs in the fault zone, replacing the hanging wall Green River limestone. The orebody was completely oxidized to hydrozincite, smithsonite, cerussite, and limonite (Heyl, 1963; Perry and McCarthy, 1977). There are no intrusive rocks in the district and the metalliferous fluids are likely the result of expulsion of connate fluids associated with the halotectonics of the Arapien Shale.

Heyl, A.V., 1963, Oxidized zinc deposits of the United States, pt. 2, Utah: U.S. Geological Survey Bulletin 1135-B, 104 p.

Perry, L.I., and McCarthy, B.M., 1977, Lead and zinc in Utah, 1976: Utah Geological and Mineral Survey Open-File Report 22, 525 p.

RICHMOND DISTRICT

The Richmond mining district is about 12 mi north-northeast of Logan in the Bear River Range, Cache County. The district was organized in 1896 and most of the prospects were for Pb-Ag. There is no clear record of mineral production, but a couple of the workings are extensive enough to suggest that at least some test lots of ore may have been shipped. The district only has five or six recorded mines or prospects and the Fitzgerald and Eagan mines have the largest workings (Bigsby, 1982; Dover and Bigsby, 1983).

The Bear River Range is geologically situated in the Middle Rocky Mountain province. The Richmond district is on the west limb of the regionally important, northerly trending, upright, open Logan Peak syncline in the upper plate of a thrust of the Sevier orogeny. In the district this structure is overprinted by younger, generally west-dipping Basin and Range normal faults. The mineralization is hosted in the Middle Cambrian Langston Formation carbonate rocks and the overlying Ute Formation limestone (Dover and Bigsby, 1983; Dover, 2007). Unoxidized mineralization generally consists of disseminated galena cubes or pods of galena, sphalerite, and barite along bedding or in cross-cutting veinlets. Reported grades are modest with values ranging up to 3% Pb, 1% Zn, and 6.9 ppm Ag. Barite-rich samples run up to 41% Ba (Bigsby, 1982). Copper is reported from the minor Smithfield Canyon claim on the south end of the district.

The Richmond district is largely within the U.S. Forest Service Mount Naomi Wilderness Area.

Bigsby, P.R., 1982, Mineral investigation of the Mount Naomi Rare II further planning area, Cache County, Utah, and Franklin County, Idaho: U.S. Bureau of Mines Mineral Lands Assessment Open-File Report 126-82, 17 p.

Dover, J.H., 2007, Geologic map of the Logan 30' by 60' quadrangle, Cache and Rich Counties Utah and Lincoln and Uinta Counties, Wyoming: Utah Geological Survey Miscellaneous Publication MP06-8 DM, scale 1:100,000.

Dover, J.H., and Bigsby, P.R., 1983, Mineral resource potential map of the Mount Naomi Roadless Area, Cache County, Utah, and Franklin County, Idaho: U.S. Geological Survey, Miscellaneous Field Studies Map MF-1566-A, 7 p., scale 1:100,000.

ROCKY DISTRICT

The Rocky mining district lies in the Rocky Range immediately south of the Beaver Lake district in central Beaver County 6 mi northwest of Milford. The Rocky district was organized in 1872 and has a long history of sporadic Cu, Fe, and W production up to the present day. The history of the district changed with the discovery of the Bawana, Hidden Treasure, and Maria Cu skarns by Cerro Verde Mining Company in 1956–58. This was followed by small-scale open pit mining and the discovery of several other small Cu skarn deposits and the larger Valley deposit at depth in the pediment on the southwest flank of the range by Anaconda in 1961 (Wray, 2006). These discoveries resulted in several generally unsuccessful attempts at Cu production from the small, open pit skarns. Most of the mining problems with the Rocky Cu skarn deposits were their relatively small size and partial oxidation resulting in small pits with steep walls, high stripping ratios, and poor metallurgical recoveries due to the mixed oxide-sulfide nature of the ores. District Cu production restarted in 1962 and continued until 1974. A new mill was completed in 2008 and intermittent production continued through 2018. The total historical district production is estimated at about 3,400,000 tons averaging nearly 2% Cu with minor Ag, Au, and locally W and/or Mo (Wray, 2006). Approximately another 2,600,000 tons of somewhat lower grade Cu ore has been mined in the last decade. Total district metal production at modern metal prices is estimated at $138 million. The Bawana, Maria, and Hidden Treasure mines are the largest producers. The Cu skarns remain in sporadic production and the Copper Ranch Cu deposit is currently in production (April 2018).

The Rocky Range is a small range situated on the Wah Wah–Tushar mineral belt in the eastern Basin and Range Province. Geologically the district is composed of a series of Cu skarns adjacent to a quartz monzonite stock (~30 Ma) (Best and others, 1989). The stock also intrudes and possibly domes the east-dipping Horn Silver Andesite on the east flank of the range. These mineralized Permian-Triassic limestone xenoliths or roof pendants lie in a large (6-sq-mi) quartz monzonite composite stock. This stock, or possibly a series of thick dikes and sills, appears to have been passively injected, stoping its way upward. The skarn deposits are typically metamorphosed to anhydrous, prograde, garnet-diopside-epidote skarns containing magnetite-chalcopyrite-bornite ±scheelite mineralization having a low pyrite content (USGS model 18b). The grades range from just under 1% to just over 2% Cu and probably average about 1.4% Cu. The largest remaining resource is the covered Valley Cu skarn deposit with a subeconomic inferred resource of about 26 million tons at 1.4% Cu. The Valley Cu skarn deposit lies beneath 230 to 1300 ft of alluvium in the pediment west of the smaller, open pit skarn deposits in the range.

Best, M.G., Lemmon, D.M., and Morris, H.T., 1989, Geologic map of the Milford quadrangle and east half of the Frisco quadrangle, Beaver County, Utah: U.S. Geological Survey, Miscellaneous Investigations Series Map I-1904, scale 1:50,000.

Wray, W.B., 2006, Mines and geology of the Rocky and Beaver Lake districts, Beaver County, Utah, in *Bon, R.L., Gloyn, R.W., and Park, G.M., editors, Mining districts of Utah: Utah Geological Association Publication 32, p. 183–285.*

ROOSEVELT HOT SPRINGS DISTRICT

The Roosevelt Hot Springs mining district is located on the western range front of the Mineral Mountains in northeastern Beaver County about 11 mi northeast of Milford. Roosevelt Hot Springs is an active geothermal field with a small 33-megawatt power plant on site. The hot springs were discovered in the early 1900s, geothermal exploration began in the 1960s, the first production well was completed in 1975, and a single-stage flash steam plant was commissioned in 1984 (Allis and Larson, 2012). The district has a few mineral prospects, but no metal production.

The Mineral Mountains are a major range in the eastern Basin and Range Province. The range exposes a large Oligocene-Miocene (25 to 17 Ma) batholith (about 94 sq mi) that has been strongly rotated to the east (40°–85°) (Rowley and others, 2005). Both the mineralization and geothermal system in the district are associated with the Opal Mound range front fault and Quaternary (0.8 to 0.5 Ma) high-silica topaz rhyolites. The rhyolites occur as early flows followed by pyroclastics and finally porphyritic flow domes. The domes range from 74.5% to 76.5% SiO_2 and 4.6% to 5.2% K_2O (Nash, 1976).

Opaline and chalcedonic sinters are scattered along the N. 10° E. to N. 20° E. trend of the Opal Mound fault for a distance of approximately 3 mi in the area of Negro Mag Wash. The largest sinter is near the south end of this trend at Opal Mound. Three small metal prospects are located north of Opal Mound along this fault. These prospects are hosted in Precambrian metamorphic rocks and Tertiary coarse-grained granite. One of these prospects is in Negro Mag Wash and has cinnabar and native sulfur (USGS Model 27a). A sample here had 5.7 ppm Hg. Alteration is kaolinite, alunite, and montmorillonite. Farther north along this trend is a small Cu prospect that has malachite staining and a small reported Au occurrence. A rock sample from the Cu prospect had 4% Cu with moderately anomalous Zn, Pb, Mo, and Mn. None of these prospects have any production.

Allis, R., and Larsen, G., 2012, Roosevelt Hot Springs geothermal field, Utah—reservoir response after more than 25 years of power production: Thirty-Seventh Workshop on Geothermal Reservoir Engineering Stanford University, 8 p.

Bamford, R.W., Christensen, O.D., and Capuano, R.M., 1980, Multielement geochemistry of solid materials in geothermal systems and its applications—Part 1, the hot-water system at the Roosevelt Hot Springs KGRA, Utah: University of Utah Research Institute, Earth Science Laboratory No DE-Ac03-79ET-27002, 168 p.

Nash, W.P., 1976, Petrology of the Quaternary volcanics of the Roosevelt KGRA, and adjoining area, Utah: National Science Foundation Contract GI-43741, 99 p.

Rowley, P.D., Vice, G.S., McDonald, R.E., Anderson, J.J., Machette, M.N., Maxwell, D.J., Ekren, E.B., Cunningham, C.G., Steven, T.A., and Wardlaw, B.R., 2005, Interim geologic map of the Beaver 30' x 60' quadrangle, Beaver, Piute, Iron, and Garfield Counties, Utah: Utah Geological Survey Open-File Report 454, scale 1:100,000, 27 p.

ROSEBUD DISTRICT

The Rosebud mining district covers a large area in the southern Grouse Creek Mountains of west-central Box Elder County. Rosebud is a small W district in terms of production but is nonetheless the third largest WO_3 producer in Utah. The peak production occurred during high W prices in 1940–44 and 1954–56. Rosebud also may have produced a minor, unrecorded amount of Ag-Pb-Zn replacement ore (Doelling, 1980). Total district metal production at modern metal prices is estimated at $840,000. The Lone Pine W mine is the largest producer.

The Rosebud district is structurally complex and lies on the southwest side of the Albion–Raft River–Grouse Creek metamorphic core complex of the Basin and Range Province. Rosebud is underlain by upper Paleozoic sedimentary strata intruded and domed by three large (total about 11 sq mi) Eocene-age quartz diorite to quartz monzonite plutons collectively known as the Immigrant Pass plutonic complex. These stocks become increasingly felsic and larger over time so that the smaller, older southwestern phase is granodiorite and the larger, younger eastern phase is principally coarse-grained biotite granite. Doelling (1980) suggests that the Grouse Creek Mountains have been rotated westward by Basin and Range extension.

The Immigrant Pass plugs are locally surrounded by narrow garnet skarns, followed by tremolite-wollastonite, and finally broader zones of marblization and bleaching up to 1000 ft wide. Both the alteration and mineralization associated with the southwestern granodiorite stock is the strongest. The granodiorite adjoining the W orebodies is commonly propylitically altered to chlorite and epidote near the carbonate contact. The W mineralization typically occurs as 2- to 6-ft-thick, dark green, garnet-epidote-quartz skarns (USGS Model 14a) developed in the host carbonates. In addition to scheelite, the other primary minerals reported with the W ore include actinolite, barite, chlorite, diopside, galena, powellite, stolzite, vanadinite, and wulfenite (Meyer, 1981). The Lone Pine W underground mine is developed in a Devonian Guilmette Formation xenolith near the west side of the western intrusive and is the largest producer in the district, accounting for approximately 75% of the district's total W production. Vanadium and Mo are also reported from this skarn. The A&W W skarn is another known producer. In addition to the W skarn deposits, Meyer (1981) reported scheelite and powellite disseminated over a wide area within the stock and quartzite near the Rocky Pass W underground mine.

Scattered, small shows of Pb-Zn-Ag mineralization lie outboard of the bleached and marbleized carbonate rocks. These prospects lie at a distance ranging from several hundred feet to a couple of miles from the Immigrant Pass plutons. These prospects include the Silver Riddle (Ag-Cu-Pb) and Mogul (Pb-Ag-Au) mines north of the Immigrant Pass plutonic complex (Doelling, 1980). The Silver Riddle mine reportedly has exceptionally high Ag values.

Doelling, H.H., 1980, Geology and mineral resource of Box Elder County, Utah: Utah Geological and Mineral Survey Bulletin 115, 251 p.

Meyer, C.R., 1981, Tungsten mineralization in the southern Grouse Creek Mountains, Utah: Lubbock, Texas Tech University, M.S. thesis, 43 p.

RYAN CREEK DISTRICT

The Ryan Creek mining district is located about 32 mi northeast of Moab along Ryan Creek in Grand County near the Colorado border. Fluorite mineralization was discovered in the district in the late 1930s and development was sporadically attempted into the 1960s. Some small test lots of fluorite were shipped in 1948 and again in 1966–67, but it proved to be uneconomic (Bullock, 1976). The Blue Spar fluorite mine has the most extensive workings.

The Ryan Creek district lies along the southern boundary of the Uncompahgre Uplift of the Colorado Plateau. Fluorite mineralization is associated with west-northwest-trending normal faults with Mesoproterozoic-age granite to the north and Triassic- and Jurassic-age sedimentary strata to the south. The normal faults create a very narrow graben south of the granite and are displaced several hundred feet. Fluorite veins fill the faults in both the granite to the north and the Triassic Chinle Formation and the overlying Jurassic Wingate Sandstone to the south (USGS Model 26b). Minor disseminated fluorite also occurs in the sedimentary strata near the veins (Bullock, 1976). The fluorite veins range from a few inches to 4 ft wide. The veins have crystalline, pale yellow and green fluorite, quartz, calcite, barite rosettes, and minor base metal sulfides including primary galena, sphalerite, and chalcopyrite (Bullock, 1976).

Bullock, K.C., 1976, Fluorite occurrences in Utah: Utah Geological and Mineral Survey Bulletin 110, 89 p.

SALINA CANYON DISTRICT

The Salina Canyon mining district is located about 4 mi east of Salina in north-central Sevier County. Initial reports of production in the district suggest that minor quantities of Pb ores were produced between 1908 and 1912 and again in 1944 (Perry and McCarthy, 1977). Total district metal production at modern metal prices is estimated at $21,000. The Lead Hill mine is the only known producer.

Salina Canyon is situated in the High Plateaus of the transition zone from the Basin and Range Province to the Colorado Plateau. Mineralization in the district is localized near the unconformity between the near-vertical beds of Jurassic Arapien Shale and Twist Gulch Formation and flat-lying Paleocene Flagstaff Formation. Willis (1986) reports that the Lead Hill mine ores are gently northwest-dipping channel sandstones of the Flagstaff Formation. The mineralized bed ranges from a few inches to 6 ft thick (Perry and McCarthy, 1977). The Pb-Zn-Ag ores occur as an intergranular sulfide replacement in the sandstone with average grades of about 3% Pb, 0.75% Zn, and 3 ppm Ag (Willis, 1986). The primary sulfide minerals are galena, sphalerite, pyrite, and chalcopyrite. No intrusive rocks are recognized in the district and the metalliferous fluids may have resulted from the expulsion of connate fluids associated with the halotectonics of the Arapien Shale.

Perry, L.I., and McCarthy, B.M., 1977, Lead and zinc in Utah, 1976: Utah Geological and Mineral Survey Open-File Report 22, 525 p.

Willis, G.C., 1986, Geologic map of the Salina quadrangle, Sevier County, Utah: Utah Geological and Mineral Survey Map 83, scale 1:24,000.

SAN FRANCISCO DISTRICT

The San Francisco (Preuss, Newhouse, Frisco) mining district is in the southern San Francisco Mountains about 16 mi west-northwest of Milford in north-central Beaver County. The district was organized in 1871 and was a sporadic metal producer into the early 1950s. The San Francisco district is about the ninth most productive metal mining district in Utah. Total district metal production at modern metal prices is estimated at $907 million. The history of the district is dominated by the Horn Silver Pb-Ag underground mine and Cactus Cu-Au-Ag open pit/underground mine (Wray, 2006).

The district lies on the Wah Wah–Tushar mineral belt in the eastern Basin and Range Province. The district is centered on the 9-sq-mi, Oligocene (~31 Ma) Cactus granodiorite stock which intrudes a section of Neoproterozoic clastic sedimentary rocks that have been thrust over lower Paleozoic sedimentary rocks. The stock is medium- to coarse-grained, dark-gray, mafic-rich, and strongly magnetic. The San Francisco district is zoned from Cu ±Au ±Mo at the Cactus and Imperial mines outward to Pb-Zn-Ag zones as at the Horn Silver mine (Wray, 2006).

The Cactus Cu mine is a magmatic-hydrothermal tourmaline breccia pipe hosted on the north flank of the Cactus granodiorite stock. The Cactus pipe is about 820 ft by 200 ft in plan view, elongated to the northwest, and plunges steeply to the north to a depth of at least 900 ft. Past production from the Cactus mine is estimated at about 1.4 million tons averaging recovered grades of 1.23% Cu, 0.34 ppm Au, and 6.8 ppm Ag and reportedly still contains a similar subeconomic inferred resource (Wray, 2006). A zone of weak porphyry Cu-Mo stockwork mineralization has been intersected by a few scattered, moderately deep drill holes as a series of chalcopyrite-bearing veins adjacent to and beneath the Cactus breccia pipe. The Imperial Cu skarn adjoins the south flank of the Cactus stock.

Much of the rest of the metal production from the San Francisco district is attributable to the 1.1 million tons of high-grade, supergene-enriched Horn Silver replacement ore running over 18% Pb and 592 ppm Ag, recovered (Perry and McCarthy, 1977). Mineralization at the Horn Silver mine is developed in a very steeply east-dipping normal fault, that juxtaposes moderately northwest-dipping Cambrian-Ordovician carbonate rocks on the west and gently east-dipping, altered Oligocene Horn Silver andesitic volcanic rocks on the east. Throw on the fault is over 4600 ft. Mineralization occurs in a crudely arrowhead-shaped orebody over 700 ft long at the surface, 100 ft thick, and reaching a point at a depth of about 1030 ft. The deposit resulted from a combination of breccia filling and replacement, mostly of the hanging wall volcanic rocks, although mineralization is also known in the footwall carbonates. The Beaver Carbonate mine lies about 3 mi northeast of the Horn Silver and has been a modestly productive Pb-Ag mine (Wray, 2006).

Perry, L.I., and McCarthy, B.M., 1977, Lead and zinc in Utah, 1976: Utah Geological and Mineral Survey Open-File Report 22, 525 p.

Wray, W.B., 2006, Mines and geology of the San Francisco district, Beaver County, Utah, in *Bon, R.L., Gloyn, R.W., and Park, G.M., editors, Mining districts of Utah: Utah Geological Association Publication 32, p. 286–457.*

SAN RAFAEL RIVER DISTRICT

The San Rafael River (Tidwell Bottoms) district of the Green River mining area is in eastern Emery County approximately 13 mi west of Green River. The district was a large historical U-V producer from roughly 1948 to the mid-1980s and ranks as one of the largest U producers in the state. Total district metal production at modern metal prices is estimated at $136 million. The largest mines were the Incline Group, Snow Mine, and the Newell Shaft.

The San Rafael River district lies in the northern Paradox Basin on the Colorado Plateau. The district is divided into a northern Tidwell belt and a southern Acerson belt. The Tidwell belt is further subdivided into northern and southern areas and most of the larger and better grade mines are in the northern area. Most of the San Rafael River district's U-V deposits are in the upper part of the Salt Wash Member of the Upper Jurassic Morrison Formation, but minor deposits also occur in the overlying Brushy Basin Member (USGS Model 30c). The Salt Wash-hosted deposits are confined to thick, massive to cross-bedded, channel sandstone in the upper third of the member. Individual channel sandstones range from 5 to 35 ft thick and may coalesce vertically to form thick aggregate units 80 to 90 ft thick. These sandstone channels typically trend north-northeast.

The San Rafael River U-V orebodies are tabular, amoeboid to elongate bodies ranging in size up to 10 ft thick and 200 ft long. Individual orebodies can occur in clusters aligned parallel to channel trends as much as 1200 ft long and 300 ft wide. Deposits range from 2000 to 20,000 tons of ore with clusters to over 100,000 tons (Gloyn and others, 2003). The ore is generally concentrated at the base or edges of individual channels, particularly in heterogeneous zones containing abundant carbonaceous material, clay galls, pebble beds, and shale partings (Gloyn and others, 2003). According to Trimble and Doelling (1978), the deposits typically show a zonation from a higher grade core surrounded by lower grade material. The ore zone consists of an upper, low-grade zone 2 to 4 ft thick containing 0.01% to 0.20% U_3O_8, a central, higher grade zone up to 1.5 ft thick containing 0.25% to 2.5% U_3O_8, and a lower, low-grade zone 1 to 4 ft thick containing 0.01% to 0.20% U_3O_8. The ore minerals fill pore spaces, voids, and replace interstitial clay, cementing material, organic debris, and fossil logs. Unoxidized ore consists of coffinite with subordinate uraninite and the vanadium minerals montroseite and paramontroseite. Associated sulfides are mostly pyrite and marcasite and only minor base metal sulfides/minerals (sphalerite, chalcopyrite, and clausthalite) are present. The Co mineral bieberite is reported from the Lucky Strike #2 mine.

Gloyn, R.W., Tabet, D.E., Tripp, B.T., Bishop, C.E., Morgan, C.E., Gwynn, J.W., and Blackett, R.E., 2003, Energy, mineral, and ground-water resources of Carbon and Emery Counties, Utah: Utah Geological Survey Bulletin 132, 161 p., 14 plates, scale 1:855,000.

Trimble, L.M., and Doelling, H.H., 1978, Geology and uranium-vanadium deposits of the San Rafael River mining area, Emery County, Utah: Utah Geological and Mineral Survey Bulletin 113, 122 p., 4 plates, various scales.

SAN RAFAEL SWELL DISTRICT

The San Rafael Swell mining district is located along the southern and southwestern margins of the San Rafael Swell about 40 mi southwest of Green River in southern Emery County. The district includes the Sinbad, Tomsich Butte, and Delta subdistricts, from northwest to southeast, but not the Calf Mesa, Greasewood Draw, or Temple Mountain districts to the north and east. Uranium was discovered in the San Rafael Swell district in the late 1940s at the Lucky Strike, and the district became a significant U-V producer. Total district metal production at modern metal prices is estimated at $63 million. The most important production was derived from the Delta and Sinbad underground mines.

The San Rafael Swell is a major structural feature of the Colorado Plateau. The Swell is a north-northeast-trending, asymmetric, doubly plunging anticline that has a more steeply dipping east limb. Mineralization in the San Rafael Swell district is predominantly hosted in the Upper Triassic Chinle Formation. The Chinle consists of three fining-upward, fluvial-lacustrine sandstone sequences. Sedimentological work on the Chinle suggests northwest-trending transport from a braided-stream environment in the southeast to floodplain and lacustrine environments progressively to the northwest (Lupe, 1977).

The major producers in the San Rafael Swell district are hosted in a north-northwest-trending sandstone channel in the Monitor Butte Member of the Chinle Formation, but the overlying Moss Back Sandstone Member may host some lower grade ore. Mineralization in the district is principally interstitial to sand grains and may be associated with Cu, V, Zn, Pb, and Mo (Gloyn and others, 2003). Orebodies occur both as tabular deposits and crescent-shaped rolls typically in the 1000- to 5000-ton range (USGS Model 30c). Ore and associated sulfide minerals include uraninite, asphaltite, pyrite, galena, sphalerite, chalcopyrite, and chalcocite.

A significant portion of the San Rafael Swell U-V district is in a series of BLM designated Wilderness Study Areas.

Gloyn, R.W., Tabet, D.E., Tripp, B.T., Bishop, C.E., Morgan, C.E., Gwynn, J.W., and Blackett, R.E., 2003, Energy, mineral, and ground-water resources of Carbon and Emery Counties, Utah: Utah Geological Survey Bulletin 132, 161 p., 14 plates, scale 1:855,000 approximately.

Lupe, R.D., 1977, Depositional environment as a guide to uranium mineralization in the Chinle Formation, San Rafael Swell, Utah: Journal of Research of the U.S. Geological Survey, v. 5, no. 3, p. 365–371.

SAND PASS DISTRICT

The Sand Pass district lies on the Juab–Millard County line about 45 mi west-northwest of Delta. Sand Pass has no production, and mineralization was not recognized until the mid-1950s, so there are no appreciable old workings. Between 1978 and 1988, several major mining companies evaluated and drilled the Sand Pass area initially as a porphyry Mo prospect and then as a sedimentary rock-hosted Au-Ag prospect.

The Sand Pass district is in the northernmost House Range in the eastern Basin and Range Province, although some mineralization lies about 6 mi to the west, across Tule Valley, in the Chalk Hills. The House Range is characterized by a section of sedimentary strata from the Lower Cambrian Prospect Mountain Quartzite to the west, to the Upper Cambrian Lamb Dolomite to the northeast. The section has been thinned by a series of Sevier-age attenuation faults, particularly in the Tatow and Chisholm Formations (Chidsey, 1978a). In the House Range, bedding generally has gentle to moderate dips, mostly to the north or east.

The best Au-Ag prospects occur in a 3-mi-long, 1-mi-wide, north-south-trending band of steeply west-dipping reverse faults, quartz latite porphyry dikes, and hydrothermal alteration (Chidsey, 1978b). The northern portion of this zone was tested for deep porphyry Mo mineralization near a couple of very small (<0.01 sq mi) quartz latite porphyry plugs (~40 Ma) in the 1970s. Some of the intrusions contain quartzite and intrusive rock xenoliths, and there are several breccia pipes/diatremes recognized mainly in the southeastern part of the area (Chidsey, 1978b). The best Au-Ag mineralization at Sand Pass commonly occurs near the Middle Cambrian Howell Limestone–Chisholm Formation contact, which is often a fault rather than a depositional contact. The Au-Ag mineralization is associated with brown or red-brown jasperoids. The jasperoids may be dike-like or stratiform and are typically brecciated, fractured, and vuggy (Chidsey, 1978b). Gold may be anomalous in some jasperoids; however, the best Au mineralization occurs in the adjoining altered limestone, silty limestone, or limey siltstone. These Au zones are commonly limonite-stained and contain very fine grained disseminated or rarely veinlet pyrite. Some drill holes report visual estimates of up to 15% pyrite. Several of the higher grade surface samples are in bleached and partly decalcified limestone, but the higher grade drill intercepts still effervesced strongly with acid. The best reported mineralized drill intersection is from a shallow hole in the Roadside deposit, which cut 20 ft of basal Chisholm Formation (?) averaging 2.6 ppm Au with anomalous Te, Sb, Bi, Hg, and Mo (USGS Model 19c). Some weak Ag-Au mineralization also occurs on the Juab–Millard County line in the Chalk Hills about 6.5 mi to the west.

Chidsey, T.C., Jr, 1978a, Stratigraphy and attenuation faulting in the northern House Range, Utah: Utah Geology, v. 5, no. 2, p. 143–155.

Chidsey, T.C., Jr., 1978b, Intrusions, alteration, and economic implications in the northern House Range, Utah: Brigham Young University Geology Studies, v. 25, pt. 3, p. 47–65.

SANTAQUIN DISTRICT

The Santaquin mining district is in south-central Utah County. The Santaquin district covers Dry Mountain, 2 mi due east of the town of Santaquin. The district was organized in 1871 and has been a small Pb-Ag producer, totaling about 700 tons primarily of high-grade Pb-Ag ore. Total district metal production at modern metal prices is estimated at $260,000. The Union Chief Pb-Ag underground mine is the district's only significantly productive operation.

The Santaquin district is situated in the southern Wasatch Range of the Middle Rocky Mountain province. The district covers Proterozoic- and Paleozoic-age strata dipping moderately eastward. Mineralization in the district is associated with zones of structural weakness created by folding and faulting; resultant shatter zones acted as pathways for mineralizing hydrothermal fluids. Ore deposits consist primarily of veins, pipes, and bedded replacement bodies in favorable Paleozoic carbonate rocks (Butler and others, 1920). The less reactive Proterozoic rocks to the west host structurally controlled Cu prospects, and the more reactive Paleozoic carbonates to the east host small Pb-Ag veins and replacement deposits at structural intersections (USGS Model 19a). The most important ore host is the Middle Cambrian Teutonic Limestone. The Union Chief mine is developed by a series of adits, drifts, and stopes in the Teutonic Limestone over a vertical distance of about 150 ft. The orebody consists of small replacement bodies in coarse-grained limestone and fissure fillings along structural intersections. The mine produced about 470 tons of ore running over 20% Pb and 250 ppm Ag. The primary ore/sulfide minerals in the district are argentiferous galena, chalcopyrite, pyrite, barite, fluorite, and probably sphalerite (Bullock, 1962).

Bullock, K.C., 1962, Economic geology of north-central Utah: Brigham Young University Geology Studies, v. 9, pt. 1, p. 85–94.

Butler, B.S., Loughlin, G.F., Heikes, V.C., and others, 1920, The ore deposits of Utah: U.S. Geological Survey Professional Paper 111, 672 p.

SANTOBAR DISTRICT

The Santobar mining district is in west-central Sanpete County about 6 mi west-northwest of Ephraim. There is little published information on the district and it is a minor Zn-Pb producer. Total district metal production at modern metal prices is estimated at $47,000. The only productive operation was the Santobar mine.

The Santobar district is within the Sanpete–Sevier Valleys section of the transition zone from the Basin and Range Province on the west to the Colorado Plateau on the east. Mineralization is associated with a N. 15° E.-trending, 70° SE.-dipping fault that places Cretaceous-Paleocene North Horn Formation against Paleocene Flagstaff Limestone. The ore occurs in a fault zone and in the Flagstaff Limestone. The primary ore/sulfide minerals are galena, pyrite, and presumably sphalerite (Pratt and Callaghan, 1970; Perry and McCarthy, 1977). There are no intrusive rocks in the district and the metalliferous fluids are likely the result of expulsion of connate fluids associated with the halotectonics of the Arapien Shale.

Perry, L.I., and McCarthy, B.M., 1977, Lead and zinc in Utah, 1976: Utah Geological and Mineral Survey Open-File Report 22, 525 p.

Pratt, A.R., and Callaghan, E., 1970, Land and mineral resources of Sanpete County, Utah: Utah Geological and Mineralogical Survey Bulletin 106, 69 p.

SETTLEMENT CANYON DISTRICT

The Settlement Canyon mining district is located 5 mi southeast of Tooele and just west of the Bingham Canyon district in easternmost Tooele County. Mineralization in Settlement Canyon was discovered in 1878 and the district became a small Pb-Ag producer. Total district metal production at modern metal prices is estimated at $144,000. The Kelsey Canyon underground mine is the only producer and has hand-sorted grades running about 73% Pb and 3200 ppm Ag (Dunham, 1943).

Settlement Canyon is in the west-central Oquirrh Mountains of the easternmost Basin and Range Province. A few abandoned mines and prospect pits occur in the North Fork of Kelsey Canyon. The abandoned Pb-Ag mine workings are along the steep, south-facing slope, which exposes fresh monzonite, pyritic latite porphyry, and altered limestone. Mineralization on the Kelsey Canyon mine dump is primarily gossan, and cerussite is the presumed primary ore mineral (USGS Model 19a). The small monzonite stock is dark, magnetic, fine-grained, and resembles the Last Chance stock at Bingham Canyon and the Soldier Canyon and Spring Gulch stocks in the Stockton district. The west-dipping limestone and orthoquartzite host sequence lies on the southwest flank of the Long Ridge anticline and belongs to the Lower Butterfield Peaks Formation, below the Alphabet Series limestone beds (Krahulec, 1999).

The limestone is altered near the monzonite contacts. The fresh limestone outcrops become striped with alternating dark gray fresh and light gray bleached limestone. As the monzonite is approached, the limestone becomes pervasively bleached and recrystallized, as it is at the old mine workings. Locally, marble, mottled wollastonite marble, and weak epidote-garnet skarns are cut by pyritic latite porphyry dikes. No sulfide-rich alteration is apparent outside of the dikes themselves (Dunham, 1943; Krahulec, 1999). The property has been periodically evaluated and occasionally drilled by exploration groups, but no development has ensued.

Dunham, W.C., 1943, Kelsey mine, Tooele County, Utah: U.S. Bureau of Mines War Minerals Memorandum, 3 p.

Krahulec, K., 1999, Road log from Salt Lake City to the Mercur gold mine, Tooele County, Utah: Reno, Geological Society of Nevada Special Publication no. 30, 17 p.

SEVEN MILE CANYON DISTRICT

The Seven Mile Canyon district of the Green River mining area is located approximately 10 mi northwest of Moab in Grand County. Uranium was discovered in Seven Mile Canyon in 1948 and major mines were operated from the early 1950s to 1988. The district is a significant U ±V ±Cu producer. Total district metal production at modern metal prices is estimated at $47 million. The largest mines are the Bicentennial, Thornburg-Memorial, and Shinarump.

Seven Mile Canyon is situated in the Paradox Basin on the Colorado Plateau. The main U host is the Upper Triassic Chinle Formation. The mineralized zones are quasi-horizontal, but the zones cross lithologic boundaries and have little recognizable relationships to permeability. In fact, most of the ore in the Thornburg-Memorial and Bicentennial mines was in silty to clayey, fine-grained sandstone. Ore zones can be up to 18 ft thick, but most are much thinner. Ore zones are generally bleached. The ore occurs as discontinuous, single or multiple, tabular lenses or saucer-shaped zones of disseminated U mineralization in the lower 25 to 30 ft of the Chinle Formation (USGS Model 30c). Three mineralized horizons are present in the Shinarump No. 1 mine: (1) a basal siltstone with interbedded shale, sandstone, and conglomerate, 1 to 10 ft thick; (2) the upper part of an overlying gray-brown, 2- to 10-ft-thick limestone pebble conglomerate; and (3) within a carbonaceous siltstone 5 to 10 ft stratigraphically above the pebble conglomerate (Finch, 1954). Droullard and Jones (1955) reported that the basal ore zone was deposited in channels scoured into the underlying Moenkopi Formation and pebble conglomerate ore zones were moderately high-grade (>1.0% U_3O_8) and characterized by massive uraninite and its oxidation products. Most of the production from the Shinarump No. 1 was from the basal siltstone zone whereas most of the production from the Shinarump No. 3 was from the upper siltstone unit. Little has been written about the Thornburg-Memorial and Bicentennial mines, but most of the ore at these mines appears to have been in the same horizon as the Shinarump No. 3.

Ore minerals consist mostly of uraninite, chalcocite, and pyrite with subordinate chalcopyrite and bornite (Finch, 1954). The ore minerals occur as impregnations, replacements of carbonaceous material and as coatings on limestone clasts. The ore is reportedly high in carbonate and low in vanadium. The ratios of U_3O_8 to V_2O_5 range from 1:3 to 500:1. Few vanadium-bearing minerals are recognized and most of the vanadium is probably associated with clays (Droullard and Jones, 1955). Reported grades ranged from 0.18% to over 0.40% U_3O_8 and up to 0.13% V_2O_5.

Droullard, R.F., and Jones, E.E., 1955, Geology of the Seven Mile Canyon uranium deposits: U.S. Atomic Energy Commission Rare Metals Evaluation RME-4066, 14 p.

Finch, W.I., 1954, Geology of the Shinarump No. 1 uranium mine, Seven Mile Canyon area, Grand County, Utah: U.S. Geological Survey Circular 336, 14 p.

SIERRA MADRE DISTRICT

The Sierra Madre mining district is a minor district in the Wasatch Range about 3 mi southeast of Willard and lying mostly in Box Elder County. The district stretches along the Wasatch Front for over 5 mi, including a few prospects in adjoining Weber County on the southwest face of Ben Lomond Peak. The district was developed in very steep terrain and some of the workings were connected by two long, aerial tramways in the early 1900s. However, despite splashy reports in the *Salt Lake Mining Review*, the district had very limited production of Cu-Au-Ag (205 tons of ore) and only a couple of car loads (less than 100 tons of ore) of Pb-Zn-Ag (Butler and others, 1920; Doelling, 1980). Total district metal production at modern metal prices is estimated at $16,000. None of the mines had any appreciable production.

The Wasatch Range is a part of the Middle Rocky Mountain province. The lower section of the Sierra Madre district is Paleoproterozoic (~1.8 Ga) Farmington Canyon Complex orthogneiss. The gneiss is a light-gray, medium-grained, massive to weakly foliated, biotite-hornblende quartz monzonite cut by narrow, ptygmatic pegmatite dikes and quartz veins. The gneiss is unconformably overlain by Lower and Middle Cambrian Tintic Quartzite, Ophir Formation shales and silty limestone, and Maxfield Limestone.

Mineralization occurs mostly as veins in Paleoproterozoic rocks and to a lesser extent as replacement deposits in the Middle Cambrian Ophir Formation and Maxfield Limestone. Narrow Cu-Ag fissures in the gneiss contain minor pyrite, chalcopyrite, and bornite with minor sericite replacing the original hornblende and biotite. Replacement mineralization is reported in a lower, white, coarse-grained dolomite in the Ophir Formation or basal Maxfield Limestone. Fine-grained galena, sphalerite, and pyrite occur with a gangue of quartz and sericite in small, irregular lenses (Butler and others, 1920; Doelling, 1980). Assays of ore from the upper El Dorado mine average about 5% Pb, 6% Zn, and 10 ppm Ag.

Butler, B.S., Loughlin, G.F., Heikes, V.C., and others, 1920, The ore deposits of Utah: U.S. Geological Survey Professional Paper 111, 672 p.

Doelling, H.H., 1980, Geology and mineral resource of Box Elder County, Utah: Utah Geological and Mineral Survey Bulletin 115, 251 p.

SILVER ISLAND DISTRICT

The Silver Island (Silver Islet) mining district lies about 15 mi northeast of Wendover in northwestern Tooele County. The Silver Island district is a small Ag-Pb vein and replacement district covering the Silver Island Mountains. The district was organized in 1872 and its most productive period was between 1908 and 1913 (Tripp and others, 1989). Total district metal production at modern metal prices is estimated at $2.5 million. The southwest end of the district, near the Jensen prospect had a series of short, unsuccessful exploration programs in the 1980s, 1990s, and 2010s for Au. The Lomato Ag-Pb mine and the Haphazard Group Ag-Cu-Zn-Pb mine were the two largest producers.

The Silver Island Mountains are part of the Basin and Range Province. The northeast-trending mountains are geologically complex but show an overall pattern of gently to moderately northwest-dipping Paleozoic sedimentary rocks, so that the oldest sedimentary strata lie on the southeast flank of the range and the youngest rocks, including Tertiary volcanic rocks, lie on the northwest (Schaeffer, 1960).

Lower Paleozoic limestone and dolomites host mineralization and the mountain range is folded into a number of north-trending and plunging anticlines and synclines. Most of the mine workings are associated with the Campbell Peak and Tetzlaff Peak anticlines. Igneous rocks in the area include a Jurassic granodiorite (~160 Ma) stock, and Eocene andesitic and Miocene rhyolitic volcanic rocks. The Jurassic granodiorite plug is surrounded by a large area of recrystallization and bleaching. Diorite dikes of uncertain age are associated with the lenticular polymetallic quartz vein deposits (Schaeffer, 1960). The most important Ag-Pb-Cu-Zn ±Au ±Sb mine workings are clustered south and west of Lamus Peak in Cambrian carbonate rocks. A small body of massive barite ±As ±Sb occurs at one prospect (Bryan Group) on eastern Silver Island Mountain at the Devonian carbonate-Mississippian shale contact (USGS Model 27e).

As in the Crater Island district to the north, very weak sedimentary rock-hosted precious metal-style mineralization is associated with stratiform jasperoids at the base of the Mississippian Pilot Shale, Joana Limestone, and Chainman Shale, mostly south of Silver Island Pass (USGS Model 19c). Weakly anomalous Au-As-Sb-Hg-Ba is associated with small northerly and northeasterly trending jasperoids, structures, and faults in the Mississippian and Pennsylvanian strata.

Schaeffer, F.E., 1960, Geology of the Silver Island Mountains, Box Elder and Tooele Counties, Utah and Elko County, Nevada: Utah Geological and Mineralogical Survey, Guidebook to the geology of Utah, no. 15, 192 p.

Tripp, B.T., Bishop, C.E., Shubat, M.A., Bishop, C.E., Blackett, R.E., and Gloyn, R.W., 1989, Mineral occurrences of the Tooele 1° x 2° quadrangle, west-central Utah: Utah Geological and Mineral Survey Open-File Report 153, 85 p.

SILVER REEF DISTRICT

The Silver Reef (Harrisburg, Leeds) mining district is in Washington County, about 15 mi northeast of St. George. Silver Reef was a large Ag-Cu producer from about 1875 until the collapse of the Ag price in 1893 and had continuing intermittent production until about 1980. In the 1950s, the district also produced a minor amount of U-V ore. Total district metal production at modern metal prices is estimated at $141 million. The largest Ag-Cu mines were the Leed-AS&R, Tecumseh-Harman, and California-Savage.

The district lies within the transition zone from the Basin and Range Province on the west to the Colorado Plateau on the east. Silver Reef is localized on the northeast-plunging nose of the large, Sevier-age, Virgin anticline. The Virgin anticline is an open, upright, symmetrical fold having a gentle plunge of about 10°–15° NE. The ore is primarily hosted in the Lower Jurassic Springdale Sandstone Member of the Moenave Formation. This sandstone is a thick-bedded, fine-grained, fluvial sandstone containing thin lenses of intraformational conglomerate with mudstone and siltstone rip-up clasts and poorly preserved carbonized plant remains (Biek and Rohrer, 2006).

The district has four major "reefs" or sandstone hogbacks; from west to east these are White, Buckeye, Butte, and East Reef. Buckeye Reef has been the most important, having yielded about 70% of the Ag produced. The average recovered grades from the district are approximately 577 ppm Ag and 1.3% Cu, but typical head grades are over 685 ppm Ag. The principal ore minerals are argentite, chalcocite, chlorargyrite, bornite, and native silver. The district is unique for the Ag-dominant character of its redbed-hosted Cu deposits (USGS Model 30b) with Ag accounting for very roughly 75% of the district's production value. The district also has subordinate sandstone U-V production (USGS Model 30c). The best Cu-Ag mineralization is associated with the structurally complex, northwestern corner of the plunging anticlinal nose where the best host Springdale Sandstone is repeated three times by thrust faults. Individual orebodies are tabular, stratiform, stratabound, and average about 300 ft long, 100 ft wide, and less than 8 ft thick. The Ag-Cu ores are typically associated with carbon trash zones or thin, soft, shaly conglomerate interbeds (James and Newman, 1986). The most recognizable alteration is the bleaching of the host Springdale Sandstone resulting from the passage of reducing fluids, as evidenced by the gray-green rinds on the pink clay galls in the bleached sandstone. In addition to Ag-Cu, the ore is reportedly anomalous in As, Cl, Mo, Se, U, V, and Zn.

Biek, R.F., and Rohrer, J.C., 2006, Geology, mining history, and reclamation of the Silver Reef mining district, Washington County, Utah, in *Bon, R.L., Gloyn, R.W., and Park, G.M., editors, Mining districts of Utah: Utah Geological Association Publication 32, p. 477–510.*

James, L.P., and Newman, E.W., 1986, Subsurface character of mineralization at Silver Reef, Utah, and a possible model for ore genesis, in *Griffen, D.T., and Phillips, W.R., editors, Thrusting and extensional structures and mineralization in the Beaver Dam Mountains, southwestern Utah: Utah Geological Association Publication 15, p. 149–158.*

SOUTH HENRY MOUNTAIN DISTRICT

The South Henry Mountain (Little Rockies, Shootaring, Delmonte) mining district lies in eastern Garfield County about 40 mi south of Hanksville. Beginning in the 1950s and operating into the early 1980s, the district became a significant U-V producer. The numerous historical U-V mines were mostly small, but had moderate grade, averaging about 0.3% U_3O_8. Total district metal production at modern metal prices is estimated at $24 million. Although none of the individual historical operations had important production, significant U reserves were discovered at the Tony M, Copper Bench, and Frank M mines in the late 1970s and largely remain undeveloped.

The South Henry Mountain district occurs in the southern Henry Mountains of the Colorado Plateau. The U-V deposits in the Henry Mountains occur in the Upper Jurassic Salt Wash Member of the Morrison Formation. Nearly all deposits occur along a northerly trending exposure of the Morrison Formation on the east flank of the Henry structural basin. Mineralization is peneconcordant and associated with carbonaceous trash, fossil wood, and mudstone lenses in the fluvio-lacustrine sandstone host rocks (USGS Model 30c). The mined uranium deposits of the Henry Mountains are typically small oxide bodies, and the mean size of the deposits is about 80 tons of ore. Coffinite and tyuyamunite are the principal ore minerals with subordinate autunite (Chenoweth, 1980; Northrop and others, 1986a).

The large South Henry Mountain district mineral resources are typical tabular, uranium-vanadium deposits hosted in fluvial sandstone of the Salt Wash Member. The host sandstone ranges from 30 to 40 ft thick and occurs 10 to 100 ft above the base of the Morrison Formation (Chenoweth, 1980). The mineralized zones are characteristically argillaceous and carbonaceous sandstone. These zones occur as multiple uraniferous horizons associated with and enclosed within a broader vanadium-rich interval and haloed by dolomite-cemented sandstone (Northrop and others, 1986a; Northrop and others, 1986b). These larger U-V resources consist of closely spaced clusters of smaller deposits.

Chenoweth, W.L., 1980, Uranium-vanadium deposits of the Henry Mountains, Utah, in *Picard, M.D., editor, Henry Mountains symposium: Utah Geological Association Publication 8, p. 299–304.*

Northrop, H.R., Goldhaber, M.B., Whitney, C.G., Peterson, F., Reynolds, R.L., and Campbell, J.A., 1986a, Diagenesis and the sources of the ore-forming fluids, Tony M vanadium-uranium deposit, Henry structural basin, in *Mumpton, F.A., editor, Studies in diagenesis: U.S. Geological Survey Bulletin 1578, p. 281–290.*

Northrop, H.R., Peterson, F., Whitney, C.G., and Goldhaber, M.B., 1986b, An exploration model based on genetic model for the tabular-type uranium-vanadium deposits in the Henry Basin Utah, in *USGS research on energy resources, 1986, program and abstracts: U.S. Geological Survey Circular 0974, p. 44–45.*

SOUTH UINTA DISTRICT

The South Uinta mining district stretches for over 70 mi along the south flank of the Uinta Mountains through portions of Wasatch, Duchesne, and Uintah Counties. The South Uinta district was a minor Fe producer, shipping about 500 tons of ore in 1879–80 to Park City smelters to be used as flux (Bullock, 1970). Total district metal production at modern metal prices is estimated at $30,000. Most of the district's production came from the Ferry Iron mine in Wasatch County with inconsequential production from the Paint mine in Duchesne County.

The South Uinta district encompasses a series of small Fe and some Mn occurrences along the South Flank fault zone in the Middle Rocky Mountain province. The N. 80 E.-trending, steeply south-dipping fault zone imperfectly marks the boundary between the Proterozoic quartzite of the high Uinta Mountains and the Paleozoic sedimentary strata to the south. The South Flank fault zone has a long, complex history involving both reverse and normal movements. Mineralization in the district is likely related to the expulsion of overpressured, reducing hydrothermal brines from the Uinta Basin to the south (Conn, 2005; Nelson and others, 2005).

The Ferry (Rhodes Plateau) Fe mine lies on the west end of the South Flank fault zone, just east of Soapstone Basin. Mineralization occurs along a wide brecciated fault zone cutting Lower Mississippian Madison Limestone. The ore is gray, fine-grained, massive specularite and red hematitic ocher that occurs as a 15-ft-thick lens of breccia filling. Six ore samples from the mine averaged 57.2% Fe and 20.1% SiO_2 (Bullock, 1970). The Paint Fe mine lies on a splay of the South Flank fault zone west of Moon Lake. The ore occurs as small pods of reddish, ocherous hematitic breccia hosted in Madison Limestone that has been used as pigment (Bullock, 1970). The Fe ores of the South Flank fault zone may show some Cu carbonates and can be anomalous in Ag, As, Co, Cu, Mo, Mn, Pb, V, and Zn (Conn, 2005). Several other generally similar, but smaller Fe prospects occur along the length of the South Flank fault zone. The district also includes some scattered, small, poorly described Au-Ag prospects (Conn, 2005). In addition, a few small emeralds have been found near the fault zone along the South Fork of Rock Creek, hosted by sulfidic Red Pine Shale (Nelson and others, 2005).

Bullock, K.C., 1970, Iron deposits of Utah: Utah Geological and Mineralogical Survey Bulletin 88, 101 p., l plate.

Conn, G.R., 2005, Potential economic mineralization in the Uinta Mountains, northeastern Utah, in *Dehler, C.M., Pederson, J.L., Sprinkel, D.A., and Kowallis, B.J., editors, Uinta Mountain geology: Utah Geological Association Publication 33, p. 369–384.*

Nelson, S.T., Keith, J.D., Constenius, K.N., Olcott, J., Duerichen, E., and Tingey, D.G., 2005, Emerald and fibrous calcite mineralization in the southwestern Uinta Mountains, in *Dehler, C.M., Pederson, J.L., Sprinkel, D.A., and Kowallis, B.J., editors, Uinta Mountain geology: Utah Geological Association Publication 33, p. 385–393.*

SOUTHWEST TINTIC DISTRICT

The Southwest Tintic district is in the East Tintic Mountains of Juab County, about 45 mi due south of Bingham in the igneous-dominated terrane lying immediately south of the Main Tintic district. The greater Tintic district is the second most productive in Utah. The Southwest Tintic district is credited with approximately 122,000 tons of ore at an average recovered grade of about 410 ppm Ag, 3.4 ppm Au, and 3.4% Pb, along with subordinate amounts of Cu. Total district metal production at modern metal prices is estimated at $46 million. The Swansea Ag-Au-Pb underground mine is the largest producer in the Southwest Tintic district.

The Southwest Tintic district lies on the Deep Creek–Tintic mineral belt of the Basin and Range Province. The East Tintic Mountains have been rotated eastward 10° to 20° by post-mineral listric faulting. The early Oligocene East Tintic volcanic field host rocks are predominantly intermediate, calc-alkaline, potassic volcanics and lesser shoshonite and rhyolite. The district's production is derived from a series of intermediate- to high-sulfidation epithermal, enargite-rich veins generally north of the SWT porphyry Cu deposit (Krahulec and Briggs, 2006).

The Southwest Tintic district is centered on the shallowly eroded SWT porphyry Cu-Mo system. The mineralization is probably slightly younger than the Silver City stock (33.6 Ma) which hosts some of the veins. The SWT porphyry Cu-Mo deposit lies wholly within the Copperopolis Latite caldera (USGS Model 17). SWT's present surface expression is characterized by roughly 3 sq mi of poorly exposed, barren, quartz-sericite-pyrite alteration. The primary porphyry Cu-Mo mineralization at SWT is about 1000 ft deep and centered southwest of Horseshoe Hill. This porphyry mineralization consists of vein and disseminated chalcopyrite in potassically altered quartz monzonite porphyry and volcanic rocks. The SWT porphyry Cu-Mo deposit contains about 1.5 billion tons of 0.21% Cu and 0.01% Mo as a subeconomic inferred resource and is still open in every direction but up (Krahulec and Briggs, 2006).

In addition to the low-grade porphyry resource at depth, a small, shallow, supergene enrichment blanket is developed in Diamond Gulch on the southern extension of the high-sulfidation veins where they overprint the pyrite halo (Krahulec, 1996). The poorly defined Diamond Gulch chalcocite blanket contains a subeconomic inferred resource of about 88 million tons at 0.15% Cu. The subdistrict's mineral production has come from small, north-northeast-trending, intermediate to high-sulfidation Ag-Au-Pb and Au-Au-Cu veins (USGS Model 25e). The primary ore/sulfide minerals are enargite, pyrite, galena, sphalerite, and barite.

Krahulec, K., 1996, Geology and geochemistry of the Southwest Tintic porphyry copper system, Tintic mining district, Juab County, Utah, in *Green S.M., and Struhsacker, E., editors, Geology and ore deposits of the American Cordillera: Reno, Geological Society of Nevada Field Trip Guidebook Compendium, p. 62–78.*

Krahulec, K., and Briggs, D.F., 2006, History, geology, and production of the Tintic mining district, Juab, Utah, and Tooele Counties, Utah, in *Bon, R.L., Gloyn, R.W., and Park, G.M., editors, Mining districts of Utah: Utah Geological Association Publication 32, p. 121–150.*

SPOR MOUNTAIN DISTRICT

The Spor Mountain mining district is 43 mi northwest of Delta in Juab County. The district is the world's premier beryllium (Be) producer and the seventh largest district in Utah as valued by total metal production value. The district is also Utah's largest fluorite producer and has produced a minor amount of U. The district's total Be production is estimated at over 3 million tons of ore averaging over 0.2% Be, derived from seven small open pits since production began in 1969. Total district metal production at modern metal prices is estimated at $2.8 billion. The Roadside Be open pit mine is probably the most productive mine in the district. The Spor Mountain Be operation is still in production.

The district is part of the Deep Creek–Tintic mineral belt in the eastern Basin and Range Province. Spor Mountain proper consists of a southwest-tilted block of Ordovician to Devonian carbonate rocks and some interbedded shale and orthoquartzite on the northwest flank of the late Eocene Thomas caldera. These sedimentary strata are unconformably overlain by Eocene to Miocene volcanic and volcaniclastic rocks. All of the Be deposits in the district are associated with the 21 Ma, high-silica, topaz rhyolites of the Spor Mountain Formation. The Spor Mountain Formation is in turn overlain by the post-mineral, 6 Ma Topaz Mountain Rhyolite (Lindsey, 2001).

The Be deposits are mostly west of Spor Mountain itself and are typically associated with northeast-trending, down-to-the-southeast normal faults/feeders creating half grabens. Beryllium mineralization occurs as epithermal, stratiform, disseminated replacement deposits in a porous volcanic tuff at the base of the half graben. The bertrandite mineralization primarily replaces carbonate clasts in the basal tuff. Beryllium mineralization is associated with Mn and is enriched in other lithophile elements such as F, U, Li, and the rare earth elements (REE) Ce, Dy, Er, Gd, Ho, Nd, Sm, Y, and Yb. The fluorite production in the district comes from a series of small pipes and veins exposed in the Paleozoic carbonate rocks on Spor Mountain proper. The fluorite pipes are generally small-diameter (<50 m) breccia pipes related to faults and small rhyolitic intrusive bodies. On average, the pipes plunge about 70° E, probably in part due to about 20° of westward, post-mineral rotation. The pipes are generally carrot-shaped and narrow at depth. The breccia clasts are primarily carbonate, which have largely been replaced by fluorite (Lindsey, 1982). The Be deposits and fluorite pipes are believed to result from ascending hydrothermal fluids derived from a granitic pluton at depth. Lindsey (1982) postulated a hypothetical rhyolite pluton near Eagle Rock Ridge may be the source of the Be, F, and U mineralization at Spor Mountain.

Lindsey, D.A., 1982, Tertiary volcanic rocks and uranium in the Thomas Range and northern Drum Mountains, Juab County, Utah: U.S. Geological Survey Professional Paper 1221, 71 p.

Lindsey, D.A., 2001, Beryllium deposits at Spor Mountain, Utah, in *Bon, R.L., Riordan, R.F., Tripp, B.T., and Krukowski, S.T., editors, Proceedings of the 35th forum on the geology of industrial mineral—the International West Forum 1999: Utah Geological Survey Miscellaneous Publication 01-2, p. 73–77.*

SPRING CREEK DISTRICT

The Spring Creek district lies on the west flank of the Deep Creek Range about 65 mi south of Wendover along the Utah-Nevada border in extreme western Juab County. The district was organized in 1891 and has been a modest Au producer. Total district metal production at modern metal prices is estimated at $6 million. The principal mine in the district, the Queen of Sheba underground mine, is credited with the production of 4980 ounces of Au and 8820 ounces of Ag from about 9500 tons of high-grade ore (Hannigan, 1990).

The Deep Creek Range is a prominent mountain range in the Basin and Range Province. The Deep Creek Range lies just northeast of the Snake Range metamorphic core complex in Nevada. The Deep Creek Range is believed to be rotated westward by Miocene Basin and Range listric faulting. The Spring Creek district is located southwest of the Ibapah batholith. A small alaskite body identified underground in the Queen of Sheba mine, but not exposed at the surface, grades upward into pegmatite dikes and quartz veins generally trending N. 85° E., dipping 40° to 65° SE., and cutting moderately east-dipping Neoproterozic McCoy Group quartzite. The quartz veins carry significant Au values (Nutt and others, 1990). Mineralization/sulfides recognized in the quartz veins include galena, chalcopyrite, and pyrite. In addition to Au, the ore is anomalous in Ag, Cu, Pb, Zn, and weakly anomalous in As, Bi, and W (Hannigan, 1990). Hannigan (1990) lists a subeconomic inferred resource of 75,000 tons averaging about 7 ppm Au and containing a total of about 15,000 ounces of Au. Small bodies of greisen-like alteration are associated with the margins of the alaskite dikes. The greisens consist of fluorite, muscovite, quartz, and lesser beryl, topaz, garnet, and cassiterite.

The remaining mines and prospects in the district were primarily developed to exploit small Pb-Cu-Zn-Ag replacement deposits (USGS Model 19a). These replacement deposits are mostly on the east side of the district hosted in Ordovician carbonates; however, production has been minimal.

Much of the Spring Creek district lies within the Goshute Indian Reservation.

Hannigan, B.J., 1990, Mineral resources of a part of the Deep Creek Mountains Study Area: U.S. Bureau of Mines Open-File Report MLA 1-90, 186 p.

Nutt, C.J., Zimbelman, D.R., Campbell, D.L., Duval, J.S., and Hannigan, B.J., 1990, Mineral resources of the Deep Creek Mountains Wilderness Study Area, Juab and Tooele Counties, Utah: U.S. Geological Survey Bulletin 1745, p. C1–C36.

SPRY DISTRICT

The Spry mining district lies about 17 mi north of Panguitch on the Markagunt Plateau in northwesternmost Garfield County. The district covers a small, poorly documented, but diverse array of unimportant Hg, Mn, Ag, F, U, and clay prospects that have no recorded production. The Veater Hg prospect may be the oldest, discovered in 1915, and most interesting occurrence in the district (Doelling, 1975).

The Spry district lies on the Markagunt Plateau in the transition zone from the Basin and Range Province on the west to the Colorado Plateau on the east. The Spry district is associated with the Oligocene Spry intrusive (about 25 Ma). This concordant, subvolcanic intrusive has two separate intrusions, a larger southeastern body of 9 sq mi and a smaller northwestern body of 3 sq mi. The intrusive is a light-gray, fine-grained, porphyritic, calc-alkaline monzonite. Phenocrysts are plagioclase, orthoclase, and subequal biotite and hornblende. The Spry intrusive domed the Paleocene-Eocene Claron Formation and erupted to form the Buckskin Breccia and volcanic rocks of Bull Rush Creek. The Spry monzonite porphyry is cut by prominent N. 80 E.-trending vertical joints. The Spry intrusives have been described as two stocks but are currently believed to be two laccoliths (Doelling, 1975; Rowley and others, 2005).

Mineralization in the Spry district is primarily associated with the northwestern sides of the two bodies of the Spry monzonite porphyry. The Veater Hg prospect is on the northern margin of the northwestern laccolith. Mercury mineralization occurs along a northeast-trending normal fault with an unknown limestone in the footwall and andesite in the hanging wall. The recognized Hg minerals are cinnabar and metacinnabar in a 15- to 50-ft-wide zone of argillization and opalization with Fe-oxide staining, suggestive of a hot-springs Hg environment (USGS Model 27a). Five samples yielded 400 to 3000 ppm Hg with an average of 1340 ppm (Doelling, 1975). Half a mile to the southwest along this contact is a small Ag quartz vein with a sample reporting 69 ppm Ag. Farther southwest is a small fluorite vein (USGS Model 26 B) in the monzonite porphyry. Mineralization associated with the southeastern lobe of the Spry monzonite porphyry includes a couple of very small Mn prospects with psilomelane and pyrolusite and a U-clay prospect with uranophane and kaolinite (Doelling, 1975).

Doelling, H.H., 1975, Geology and mineral resources of Garfield County, Utah: Utah Geological and Mineral Survey Bulletin 107, 172 p.

Rowley, P.D., Vice, G.S., McDonald, R.E., Anderson, J.J., Machette, M.N., Maxwell, D.J., Ekren, E.B., Cunningham, C.G., Steven, T.A., and Wardlaw, B.R., 2005, Interim geologic map of the Beaver 30' x 60' quadrangle, Beaver, Piute, Iron, and Garfield Counties, Utah: Utah Geological Survey Open-File Report 454, scale 1:100,000 map, 27 p.

STAR DISTRICT

The Star (North Star) mining district lies in the Star Range about 6 mi west of Milford in Beaver County. The original Star district was organized in 1870 and the adjoining North Star district followed the next year. The combined Star district's historical production is about 208,000 tons at an average recovered grade of about 14% Pb and 340 ppm Ag with byproduct Zn, Cu, Au, and minor W primarily from small skarn and carbonate replacement deposits. Total district metal production at modern metal prices is estimated at $106 million. District production was derived from numerous modest operations including the Harrington-Hickory, Wild Bill, Cedar-Talisman, Red Warrior, and Moscow mines (Heyl, 1963; Perry and McCarthy, 1977).

The Star district is part of the Wah Wah–Tushar mineral belt in the eastern Basin and Range Province. The Star Range is basically an east-dipping homocline of upper Paleozoic strata in the upper plate of the Blue Mountain thrust, which was intruded by a series of Tertiary stocks. The stocks belong to two distinctly different groups, older Oligocene (~30 Ma) quartz monzonite in the northeast, and younger Miocene (~21 Ma) granite in the southwest (Best and others, 1989).

The Oligocene mineralization includes the Harrington section in the northeast, Shenandoah section in the west-center, and Vicksburg section in the southeast. Ore deposits associated with these older intermediate intrusives include W skarn (USGS Model 14a), Cu skarn (USGS Model 18b), and polymetallic vein and replacements (USGS Model 19a) (Perry and McCarthy, 1977). The most significant production was Pb, Ag, Zn, with minor Cu, Au, and W. The largest producers were the Cedar-Talisman, Harrington-Hickory, and Rebel mines. The primary ore/sulfide minerals reported are galena, sphalerite, chalcopyrite, tetrahedrite, rhodochrosite, vanadinite, wulfenite, and scheelite.

The Moscow section is situated adjacent to the Miocene Moscow granite and south of Elephant Canyon. Mineralization occurs predominantly as replacement deposits and small mantos along northeast- and east-trending veins. Deposits are typically hosted near the top of the east-dipping Devonian carbonate section beneath a shale contact (Perry and McCarthy, 1977). The most significant production was Zn, Pb, Ag, Cu, with minor Au. The largest producers were the Moscow, Red Warrior, and Mowitza mines. Primary ore/sulfide minerals reported are sphalerite, galena, fluorite, chalcopyrite, greenockite, and rhodochrosite (USGS Model 22c).

Best, M.G., Lemmon, D.M., and Morris, H.T., 1989, Geologic map of the Milford quadrangle and east half of the Frisco quadrangle, Beaver County, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-1904, scale 1:50,000.

Heyl, A.V., 1963, Oxidized zinc deposits of the United States, pt. 2, Utah: U.S. Geological Survey Bulletin 1135-B, 104 p.

Perry, L.I., and McCarthy, B.M., 1977, Lead and zinc in Utah, 1976: Utah Geological and Mineral Survey Open-File Report 22, 525 p.

STATELINE DISTRICT

The Stateline mining district lies along the Nevada border in extreme northwestern Iron County, 57 mi west-northwest of Cedar City and 7 mi north of the Gold Springs district. The Stateline district veins were discovered in the early 1890s and by 1896 most of the known mines had been discovered. Some on-site mills were erected but were not very profitable. The district was a modest Au-Ag producer (about 2540 ounces Au), nearly all from Utah, with sporadic production between about 1897 and 1948 (Thomson and Perry, 1975). Total district metal production at modern metal prices is estimated at $4.3 million. The principal operations were the Ofer, Johnny, and Gold Dome underground mines.

The Stateline district lies in the Paradise Mountains of the Basin and Range Province. The rocks exposed at Stateline consist of a thick sequence of Miocene volcanic rocks. From older to younger the sequence consists of andesitic flows, ash-flow tuffs, and rhyolitic flows. These volcanic rocks are cut by pale olive rhyolite dikes (~16.5 Ma), which are locally cut by small quartz veins near the Ofer mine. Precious metal production is derived from a series of conjugate, north-northeast-trending (N. 5°–20° E.) and more productive west-northwest-trending (N. 70°–80° W.), epithermal, low-sulfidation, brecciated, quartz-adularia-carbonate-pyrite ±fluorite veins (USGS Model 25c), and host the district's principal mines, the Ofer, Johnny, Gold Dome, and Margarette. The veins are typically about 3 to 20 ft wide and can be traced on the surface for several hundred to a few thousand feet. The north-northeast-trending veins dip to the west at about 60° and the west-northwest striking veins dip an average of 65° north (Smith, 1902). The Au:Ag ratio of the ores increases from west to east across the district (Smith, 1902). The Ofer mine to the west produced high-grade Ag ore (700 ppm Ag) and the Johnny mine to the east averaged just 110 ppm Ag, but had better Au values (Thomson and Perry, 1975).

The ore is in localized shoots within the veins. The ore shoots on the east-west vein set rake about 45° NW approximately paralleling the intersection of the two vein sets. Wall rocks of the veins are generally argillized. The principal Ag mineral in the district is chlorargyrite associated with other unidentified non-sulfide Ag-bearing minerals in the Fe, Mn, and Mo oxides. The Ofer and Johnny mines reached primary argentite, sylvanite, and pyrite ore (Thomson and Perry, 1975). A 0.2-sq-mi area of pervasive phyllic alteration, disseminated pyrite, quartz veining, and anomalous Mo (to 7600 ppm Mo) occurs at and south of the Ofer mine.

Smith, G.H., 1902, Geology of Stateline district: Salt Lake Mining Review, December 30, p. 67–68.

Thomson, K.C., and Perry, L.I., 1975, Reconnaissance study of the Stateline mining district, Iron County, Utah, in *Stewart, R.C., editor, Utah Geology: Utah Geological and Mineral Survey Series v. 2, no. 1, p. 27–47.*

STOCKTON DISTRICT

The Stockton (Rush Valley) mining district is located 11 mi southwest of Bingham on the west slope of the Oquirrh Mountains in easternmost Tooele County. Stockton is one of the oldest districts in Utah, mining having begun in the mid-1860s and lasting nearly continuously until 1958. The total production from Stockton is roughly 2.2 million tons of ore averaging 7.7% Pb, 2.7% Zn, 0.3% Cu, 157 ppm Ag, and 1.27 ppm Au, recovered grades, making it about the eleventh most productive mining district in Utah and the fifth largest Pb and Zn producer. Total district metal production at modern metal prices is estimated at $810 million. The largest producers in the district are the Calumet Pb-Ag-Au and Great Basin Pb-Zn-Ag mines.

Stockton is an intrusive-centered mining district on the Bingham–Park City mineral belt in the Basin and Range Province. The manto-style, base and precious metal replacement mineralization developed by the Stockton underground mines are hosted by a thick sequence of alternating dark-gray limestones and light-gray quartz sandstones of the Pennsylvanian-Permian Oquirrh Group. The strata dip steeply north and are cut by west-dipping faults and mineralized fissures. The intersection of the favorable limestones and mineralizing fissures has produced about 80 small, steeply north-northwest-plunging, ribbon-like, massive sulfide replacement deposits (USGS Model 19a). These mantos are typically about 3 to 10 ft thick, 10 to 80 ft wide along strike, and plunge up to several hundreds of feet down dip. The common primary ore/sulfide minerals are galena, sphalerite, chalcopyrite, tetrahedrite, and pyrite. The total length of the underground mine workings in the district exceeds 35 mi, most of which are interconnected on the Honerine 1200 ft level (Gilluly, 1932; James and Atkinson, 2006).

The Oquirrh Group sedimentary sequence is intruded by the sill-like, melanocratic, fine- to medium-grained, equigranular, strongly magnetic, augite-hornblende-biotite monzonite of the Spring Gulch stock and younger north-trending, fine-grained, biotite-quartz latite Raddatz porphyry dikes, which are characterized by large K-spar phenocrysts that have been dated at 39.4 ± 0.34 Ma (Krahulec, 2014). These igneous rocks are compositionally very similar to the pre-mineral melanocratic Last Chance monzonite and late-mineral quartz latite porphyry phases at Bingham. Over a dozen mineral exploration holes were drilled in the district without success from 1950 to 1995. Porphyry Cu mineralization was discovered in the pediment southwest of the district on the first hole drilled by Kennecott Utah Copper in late 1995. The Stockton porphyry system is a quartz monzonite porphyry Cu-Au system (USGS Model 17), similar to Bingham, but lower grade and at a moderate depth of greater than 1000 ft (James and Atkinson, 2006; Krahulec, 2014).

Gilluly, J., 1932, Geology and ore deposits of the Stockton and Fairfield quadrangles, Utah: U.S. Geological Survey Professional Paper 173, 171 p., plate 1, scale 1:62,500.

James, L.P., and Atkinson, W.W., Jr., 2006, The Rush Valley mining district, Stockton quadrangle, Tooele County, Utah, in *Bon, R.L., Gloyn, R.W., and Park, G.M., editors, Mining districts of Utah: Utah Geological Association Publication 32, p. 94–120.*

Krahulec, K., 2014, Discovery of the Stockton porphyry copper system, Stockton mining district, Tooele County, Utah: Society of Economic Geologists Guidebook 41, p. 37–50.

SULPHURDALE DISTRICT

The Sulphurdale (Gordon, Cove Fort) mining district is located 24 mi north of Beaver on the west side of the southern Pahvant Range and the adjoining northwest flank of the Tushar Mountains on the Millard–Beaver County line. The district was discovered in 1869 and became a small producer of native sulfur and minor fluorite. Grades of production and possible resources range from about 14% to 30% S (Rodriguez, 1960). Total district metal production at modern metal prices is estimated at $953,000. The Sulphurdale open-pit mine in Beaver County is the largest S producer in Utah.

The Pavant Range and Tushar Mountains are part of the transition zone from the Basin and Range Province to the Colorado Plateau. The Sulphurdale district is an active geothermal system probably associated with a cooling Pleistocene intrusive at shallow depth. The deposits are fumarolic sulfur hot spring deposits (USGS Model 25m) developed along northerly trending normal faults primarily in Oligocene-Miocene volcanics and Pliocene-Pleistocene tuffs and sediments (Rowley and others, 2013). The prospects and acid leach zones are near or adjacent to major north- and northeast-trending faults, but, in several of the pits, the strongest alteration and more visually apparent native sulfur mineralization are more closely associated with smaller, generally subparallel, subsidiary faults rather than the major mapped structure. The host rocks are all white, strongly altered rocks consisting of porous aggregates of opaline silica, gypsum, anhydrite, and remnant quartz or cristobalite. Rodriguez (1960) developed a composite vertical mineralogical zoning for the deposits having gypsum at the surface grading down to gypsum-sulfur, sulfur, sulfur-pyrite-marcasite, pyrite-marcasite, to pyrite at depth. No sinters were recognized in any of the sulfur-bearing prospects. The native sulfur occurs as fine-grained disseminations and cavity fillings (Rodriguez, 1960).

Some of the deposits on the north end of the Sulphurdale district in Millard County occur in upper Paleozoic carbonates and have minor associated fluorite. Fluorite is present here, with native sulfur deposits, as open-space fillings and partial replacements of limestone breccia along major range-bounding normal faults (Rodriguez, 1960). The main fluorite occurrence is the Rain Bow (Forminco) mine. The fluorite may or may not be related to the Holocene geothermal activity that formed the native sulfur deposits.

Rodriguez, E.L., 1960, Economic geology of the sulphur deposits at Sulphurdale, Utah: Salt Lake City, University of Utah, M.S. thesis, 74 p.

Rowley, P.D., Rutledge, E.F., Maxwell, D.J., Dixon, G.L., and Wallace, C.A., 2013, Geology of the Sulphurdale geothermal resources area, Beaver and Millard Counties, Utah: Utah Geological Survey Open-File Report 609, 27 p.

SUNSHINE DISTRICT

The Sunshine (South Mercur) mining district is located on the southern slopes of the Oquirrh Mountains, about 18 mi southeast of Tooele and just south of the Mercur district, in Tooele and Utah Counties. Sunshine is a significant district having an estimated 21,000 ounces of Au produced between 1898 and 1910 (Gilluly, 1932). The area also produced a significant amount of refractory clay to the east in the Clay Canyon area, Utah County. Total district metal production at modern metal prices is estimated at $23 million. The Overland and Sunshine underground mines are the largest historical Au producers.

The Oquirrh Mountains are one of the easternmost ranges in the Basin and Range Province. The main Sunshine Au orebodies underlie Sunshine Canyon. The Au deposits occur in the Mercur member clastic carbonate of the Mississippian Great Blue Limestone, just below the carbonaceous Long Trail Shale Member. The deposits are on the east limb of the asymmetrical Ophir thrust-cored anticline stratigraphically analogous to the Au orebodies in the Mercur district to the north. At Sunshine, the host Mercur member bed dips 20° to 25° east and the ore is associated with northwest-trending, high-angle faults. The resulting elongated, tabular Au deposits rake moderately to the southeast. The ores are largely oxidized to a depth of about 150 ft but become more carbonaceous and refractory at depth. Alteration associated with the mineralization is primarily silicification and decalcification. Iron oxides are common and arsenic oxides occur locally, typically with Au values. The Au ores are anomalous in As (500–4000 ppm), Hg (1–10 ppm), Sb (25–100 ppm), and Tl (7–31 ppm) (USGS Model 26a).

The Sunshine district was extensively explored in the 1980s and 1990s, resulting in the delineation of three small Au resources. On the north, the Overland deposit is located at the Overland mine shaft and under the canyon to the west; its footprint is about 900 ft in an east-west direction and 950 ft north-south. The next deposit to the south, and the smallest, is Red Cloud located near the old Sunshine town site; it is about 700 ft north-south by 270 ft east-west. The Sunshine deposit at the old Sunshine mine, the southernmost and largest of the three deposits, is centered just north of the Sunshine shaft, and is about 1300 ft north-south by 700 ft east-west.

Roughly 1 mi east of Sunshine Canyon, Clay Canyon has an unnamed shale in the upper Great Blue Limestone that has been variably altered to clay, including illite, kaolinite, halloysite, smectite, variscite, and crandallite (Shubat, 1988). Clay Canyon trends northwesterly parallel to a series of faults. The clay has been exploited for fire brick, largely by the Interstate Brick Company. Very limited geochemical sampling of the clay mines showed weak Au to 0.09 ppm, As to 74 ppm, Sb to 29 ppm, and Zn to 590 ppm.

Gilluly, J., 1932, Geology and ore deposits of the Stockton and Fairfield quadrangles, Utah: U.S. Geological Survey Professional Paper 173, 171 p., plate 1, scale 1:62,500.

Shubat, M.A., 1988, Scandium-bearing aluminum phosphate deposits of Utah: Utah Geological and Mineral Survey Report of Investigation 209, 26 p.

SWAN PEAK DISTRICT

The Swan Peak mining district is located 25 mi northeast of Logan in the Wasatch Range straddling the Cache–Rich County line. The district was organized in 1900, was most productive from 1900 into the 1920s, and was a minor Ag-Pb producer. Total district metal production at modern metal prices is estimated at $25,000. The district only has six recorded mines or prospects and the Amazon Ag-Pb-Zn mine is the only recognized producer (Perry and McCarthy, 1977).

The Wasatch Range is geologically situated in the Middle Rocky Mountain province. The major feature of the Swan Peak district is the northerly trending, upright, open Swan Peak syncline in the upper plate of the west-dipping Paris thrust (Dover, 2007). The primary strata in the syncline are Cambrian carbonate rocks and shale and Ordovician carbonate rocks and sandstone. The Middle Cambrian Blacksmith Fork Formation and the overlying Bloomington Formation are the primary ore hosts. The Amazon mine in Amazon Hollow lies on the west limb of the Swan Peak syncline near a mapped northwest-trending high-angle fault. Bedding at the mine strikes northwest and dips gently to the northeast. The underground workings intersect a series of west-northwest- and east-northeast-trending fractures and an easterly trending, south-dipping breccia zone (Heyl, 1963). Primary sulfide mineralization observed at the mine includes pockets of galena, sphalerite, pyrite, and trace chalcopyrite in a gangue of dolomite, ankerite, calcite, and barite (Heyl, 1963; Chappelle, 1975). Heyl (1963) reported high-grade ore samples having up to 850 ppm Ag.

Chappelle, J.C., 1976, Mineralization in the Bear River Range, Utah and Idaho: Logan, Utah, Utah State University, M.S. thesis, 63 p.

Dover, J.H., 2007, Geologic map of the Logan 30′ x 60′ quadrangle, Cache and Rich Counties Utah and Lincoln and Uinta Counties, Wyoming: Utah Geological Survey Miscellaneous Publication MP06-8 DM, scale 1:100,000.

Heyl, A.V., 1963, Oxidized zinc deposits of the United States, pt. 2, Utah: U.S. Geological Survey Bulletin 1135-B, 104 p.

Perry, L.I., and McCarthy, B.M., 1977, Lead and zinc in Utah, 1976: Utah Geological and Mineral Survey Open-File Report 22, 525 p.

TECOMA DISTRICT

The Tecoma (Jackson) mining district straddles the Utah-Nevada state line in extreme west-central Box Elder County 100 mi due west of Brigham City. The district has a modest history as a Pb-Ag producer, but all production has come from the Nevada portion of the district (Hill, 1916). Sediment-hosted Au exploration in the late 1970s and early 1980s resulted in the discovery of jasperoid hosting the TUG (Tecoma Utah Gold) Au-Ag deposit in 1980. Delineation drilling of TUG has continued intermittently to the present day.

The Tecoma district lies on the southern termination of the Grouse Creek Mountains of the Basin and Range Province. The unmined TUG distal disseminated Au-Ag deposit (USGS model 19c) is the most important mineralization in the Tecoma district. The TUG mineralization is localized along a detachment fault separating the underlying Devonian Guilmette Formation from the overlying Mississippian Chainman Shale and Diamond Peak Formation. The fault/ore dips about 25° to the northeast. The overlying Mississippian Chainman Shale and Diamond Peak Formation are considerably attenuated by Miocene-Pliocene-age low-angle faulting which cuts out several hundred feet of section including the Devonian-Mississippian Tripon Pass/Pilot Shale (Selway and others, 2012). The ore-bearing fluids at TUG rose along northwest-trending, steeply northeast-dipping normal faults and flooded out at the intersection with the low-angle fault and more permeable section. Quartz monzonite porphyry dikes commonly occupy these northwest-trending faults. Alteration consists of dolomitization of the Guilmette Formation carbonate rocks, silicification ±barite of the Guilmette Formation and Chainman Shale, destruction of carbonaceous material in the Chainman Shale, and argillization of the Miocene (?) quartz monzonite porphyry dikes (Douglas and Oriel, 1984). Mineralization in the jasperoid is associated with barite, pyrite, arsenic-oxides, dussertite, aguilarite, and acanthite.

About 70% of the Au-Ag ore in the TUG deposit is in silicified rock (up to 70 ft thick), which typically shows evidence of multiple episodes of brecciation/silicification. Unsilicified shale ore has thin quartz veinlets, weak silicic zones, and disseminated sulfides. This ore is slightly lower in average Au grade and much lower in Ag. Dolomitic ore is more baritic and gossanous having thin silicified zones and quartz-barite veinlets. Dolomitic ore is about average grade in Ag, but below average grade in Au (Douglas and Oriel, 1984). Drilling programs over the past few decades have delineated a stratiform, subeconomic inferred resource of 8.1 million tons at 1 ppm Au and 31 ppm Ag (Selway and others, 2012).

Douglas, I.H., and Oriel, W.M., 1984, Geology of the Tecoma disseminated gold and silver deposit, in *Kerns, G.K., and Kerns, R.L., Jr., editors, Geology of northwest Utah, southern Idaho, and northeast Nevada: Utah Geological Association Publication 13, p. 185–191.*

Hill, J.M., 1916, Notes on some mining districts in eastern Nevada: U.S. Geological Survey Bulletin 648, 214 p.

Selway, J., Baker, J., Hodder, S., Robinson, J., 2012, Independent technical report and estimated resources for TUG property, Utah, United States: unpublished technical report prepared for West Kirkland Mining Inc., dated July 13, 2012, 140 p.

TEMPLE MOUNTAIN DISTRICT

The Temple Mountain mining district is part of the San Rafael Swell U mining area in southern Emery County about 30 mi southwest of Green River. The district has been a large U-V producer with initial production beginning in the early 1900s. This early development was principally for radium, before U became the primary focus in the late 1940s followed by initial U-V production in 1950. Total district metal production at modern metal prices is estimated at $93 million. The most productive mines were the Vanadium King and North Mesa.

The San Rafael Swell is a significant structure in the Colorado Plateau. The San Rafael Swell is a north-northeast-trending, asymmetric, doubly plunging anticline, and Temple Mountain is on the more steeply dipping east limb. Mineralization in the Temple Mountain district is hosted in the Upper Triassic Moss Back Sandstone Member of the Chinle Formation (USGS Model 30c). The Chinle consists of three fining-upward, fluvial-lacustrine sandstone sequences of which the Mossback Sandstone is the middle member. The Chinle was deposited by a northwest-flowing braided-stream environment in the southeast to floodplain and lacustrine environments progressively farther to the northwest (Gloyn and others, 2003).

The Temple Mountain U-V deposits are unusual due to their association with sedimentary collapse breccia pipes. Sixteen of these collapse structures were recognized by Hawley and others (1968) in the San Rafael Swell, but only the Temple Mountain collapse structures are uraniferous. The breccia pipes consist of a central core of brecciated, contorted, and down-dropped sedimentary rocks surrounded by sagging, inward-dipping, sedimentary strata. The pipes range from 100 to 2500 ft across, and strata in the pipes are down-dropped as much as 400 ft from their original stratigraphic position. The collapse structures apparently bottom out in the underlying Permian White Rim Sandstone and likely formed by dissolution of subsurface Permian and Triassic carbonate units. The collapse structures are thought to have formed after formation of the anticline, possibly in the early Tertiary. The host Moss Back Sandstone is a fine- to medium-grained massive sandstone up to 150 ft thick. Individual ore-bearing sandstone channels are 1 to 50 ft thick and 100 to 3000 ft wide. Uranium occurs as both roll fronts and peneconcordant tabular bodies. Individual ore deposits typically range from 1000 to 20,000 tons. The roll front deposits are typically 100 to 700 ft long, 2 to 15 ft wide, and 40 ft thick. Average grades are 0.25% U_3O_8 and 0.73% V_2O_5. These are some of the highest V grades reported in a Chinle hosted district. The primary ore/sulfide minerals include uraninite, montroseite, native arsenic, pyrite, ferroselite, sphalerite, galena, and chalcopyrite. The deposits are associated with bleached sandstone peripheral to the pipes (Gloyn and others, 2003). The ores seem to have formed by precipitation at the interface between a reducing fluid, possibly emanating from the pipes, and a uraniferous fluid in the Moss Back Sandstone aquifer.

Gloyn, R.W., Tabet, D.E., Tripp, B.T., Bishop, C.E., Morgan, C.E., Gwynn, J.W., and Blackett, R.E., 2003, Energy, mineral, and ground-water resources of Carbon and Emery Counties, Utah: Utah Geological Survey Bulletin 132, 161 p.

Hawley, C.C., Robeck, R.C., and Dyer, H.B., 1968, Geology, altered rocks, and ore deposits of the San Rafael Swell, Emery County, Utah: U.S. Geological Survey Bulletin 1239, 115 p., 7 plates.

THIRD TERM DISTRICT

The Third Term (Grantsville) mining district is in the central Stansbury Mountains 17 mi west of Tooele in east-central Tooele County. The district was organized in 1875 and had small, intermittent Pb-Ag production from 1880 to 1917 and again briefly in 1939. Total production is estimated to be about 400 tons of ore (Sorensen and Kness, 1982). Total district metal production at modern metal prices is estimated at $131,000. The most productive mines were probably the Metal Queen and Third Term in the Willow Canyon section of the district.

The Third Term district is geologically situated on the west end of the Bingham–Park City mineral belt of the Basin and Range Province. The geology of the Stansbury Mountains is dominated by the north-south-trending Deseret anticline which is cored by Tintic Quartzite and the fold axis lies near the crest of the range. Moderately outward-dipping Paleozoic sedimentary rocks flank its quartzite core. Eocene (about 40 Ma) volcanic rocks lie on the east flank of the range near Willow Canyon (Sorensen and Kness, 1982). These volcanic and volcaniclastic rocks dip from 10° to 25° east, suggesting some post-Eocene eastward rotation of the range similar to the Oquirrh Mountains to the east. A pair of long, north-south-trending quartz monzonite dikes intrude the Paleozoic strata between North Willow Canyon and the Mining Fork of South Willow Canyon (Sorensen and Kness, 1982).

The main ore control in the Third Term district is often an unconformable contact between Cambrian and Devonian-Mississippian strata and much of the ore is hosted in the overlying Fitchville Formation and Gardison Limestone. Small replacement orebodies occur in these rocks near this unconformable contact, particularly near the dikes in the Willow Canyon area (Sorensen and Kness, 1982; Tripp and others, 1989; Stein and others, 1989).

Most of the Third Term district is in part of the Wasatch National Forest and the central third, covering the crest of the Stansbury Mountains, is in the Deseret Peak Wilderness Area.

Sorensen, M.L. and Kness, R.F., 1982, Mineral resource potential of the Stansbury roadless areas, Tooele County, Utah: U.S. Geological Survey Map MF-1353-C, 7 p., scale 1:62,500.

Stein, H.J., Bankey, V., Cunningham, C.G., Zimbelman, D.R., Brickey, D.W., Shubat, M., Campbell, D.L., and Podwysocki, M.H., 1989, Tooele 1° x 2° quadrangle, northwest Utah—a CUSMAP preassessment study: U.S. Geological Survey Open-File Report 89-0467, 134 p.

Tripp, B.T., Bishop, C.E., Shubat, M.A., and Blackett, R.E., 1989, Mineral occurrences of the Tooele 1° x 2° quadrangle, west-central Utah: Utah Geological and Mineral Survey Open-File Report 153, 85 p.

THOMPSON DISTRICT

The Thompson (Yellow Cat) mining district is located on the crest and northeast limb of the Salt Valley anticline in central Grand County approximately 24 mi north of Moab. Although U-V are the most important commodities produced, the district also has minor Cu ±Ag and Mn prospects. The Thompson district was mined successively for radium (1911–23), V (1939–44), and U-V (post-1948) (Cannon, 1964). Total district metal production at modern metal prices is estimated at $39 million. The largest producers were the Parco, Blackstone Incline, and Ringtail–Mineral Treasure underground U-V mines.

The Thompson district is geologically situated in the Paradox Basin on the Colorado Plateau. The U-V deposits in the district occur as relatively continuous, tabular and roll-type orebodies and as isolated mineralized logs surrounded by a halo or aureole of lower grade ore. Tabular bodies are the most common, but roll-type deposits have also been exploited (Stokes and Mobley, 1954). Both tabular and roll-type orebodies occur together with roll-type orebodies grading into tabular bodies along bedding or unconformities. The size of individual orebodies ranges from a few to several thousand tons, but multiple bodies often cluster within an area of 400 to 800 ft long by 250 to 300 ft wide.

The major Thompson deposits are confined to the Salt Wash Member of the Upper Jurassic Morrison Formation. Overall the Salt Wash contains almost equal amounts of sandstone and mudstone/siltstone, but many of the uranium deposits are in the lowest sandstone horizon. Most deposits are in coarse- to medium-grained sandstone but are also present in siliceous pebble conglomerate in the uppermost sandstone-conglomerate horizons. Unoxidized deposits contain uraninite, coffinite, and montroseite associated with sulfides and selenides. The ore minerals occur as void fillings, as coatings on detrital grains, and as replacements of clay in thin seams, clay pebble conglomerates or galls, and as replacement of carbonaceous material.

Ore grades average about 0.25% U_3O_8 and 2.0% V_2O_5 (Cannon, 1964). Replacements of carbonaceous material may assay as high as 10% U_3O_8. The deposits contain anomalous amounts of Se, Mo, As, Ni, and Co. The association with anomalous selenium has been used successfully as a prospecting tool, because selenium indicator plants such as *Astragalus* occur over, or adjacent to, concealed deposits (Cannon, 1964). Most of the mines are now flooded.

Cannon, H.L., 1964, Geochemistry of rocks and related soils and vegetation in the Yellow Cat area, Grand County, Utah: U.S. Geological Survey Bulletin 1176, 127 p., 3 plates, various scales.

Stokes, W.L., and Mobley, C.M., 1954, Geology and uranium deposits of the Thompson area, Utah, in *Stokes, W.L., editor, Uranium deposits and general geology of southeastern Utah: Utah Geological Society Guidebook to the Geology of Utah, no. 9, p. 78–94.*

TROUT CREEK DISTRICT

The Trout Creek district lies on the southeast flank of the Deep Creek Range in western Juab County, about 110 mi due west of Nephi. The district is a minor Zn-Ag producer and most of its production occurred during World War II. The district produced 93 tons of Zn-Pb-Ag ore and the total W production was 7980 lbs WO_3 (Hannigan, 1990). Total district metal production at modern metal prices is estimated at $41,000. Three mines have minor reported production from the district: Trout Creek (Zn-Ag-W-Pb), Gold Bond (Au), and Apex (W).

The Deep Creek Range is a major mountain range in the Basin and Range Province. The most important geological feature of the Trout Creek district is that Neoproterozoic metamorphic rocks of the Trout Creek sequence have been thrust over Middle Cambrian strata. These Neoproterozoic rocks have been intruded and domed by a series of alaskite sills (Nutt and others, 1990). The age of the alaskite is uncertain (radiometric ages range from 29.4 to 20.5 Ma), but an Oligocene age (~27 Ma) is inferred. The alaskite primarily occurs as sills and varies from coarse-grained pegmatite to aplite, is commonly foliated along its contacts, and is principally composed of quartz, potassium feldspar, muscovite, garnet, and locally biotite (Nutt and others, 1990).

Mineralization occurs as coarse greisen-like veins and carbonate replacement/skarn deposits surrounding the alaskite intrusive in the Neoproterozoic dolomite (Nutt and others, 1990). Mineralization consists of sphalerite, scheelite, quartz, muscovite, fluorite, pyrrhotite, and beryl. Geochemical sampling shows sporadic ore-grade W, Zn, and Be, and geochemically anomalous Au, Ag, Bi, Cd, Cu, F, Pb, Mo, and Sn (Thomson, 1973; Hannigan, 1990; Nutt and others, 1990).

Hannigan, B.J., 1990, Mineral resources of a part of the Deep Creek Mountains Study Area (UT -O20-60/UT -O50-020), Juab and Tooele Counties, Utah: U.S. Bureau of Mines Open-File Report MLA 1-90, 186 p.

Nutt, C.J., Zimbelman, D.R., Campbell, D.L., Duval, J.S., and Hannigan, B.J., 1990, Mineral resources of the Deep Creek Mountains Wilderness Study Area, Juab and Tooele Counties, Utah: U.S. Geological Survey Bulletin 1745, p. C1–C36.

Thomson, K.C., 1973, Mineral deposits of the Deep Creek Mountains, Tooele and Juab Counties, Utah: Utah Geological and Mineralogical Survey Bulletin 99, 76 p.

TUSCHER CANYON DISTRICT

The Tuscher Canyon mining district is in the Book Cliffs of northwestern Grand County about 17 mi northeast of Green River. The district is a poorly documented series of small U prospects. The first reported discovery was in 1952. Tuscher Canyon is an insignificant U producer having a total of only about 19 tons of ore shipped. The Pine Tree mine is the only reported producer, although the Joker #2 has the most extensive workings.

The Tuscher Canyon district is geologically situated in the Book Cliffs on the Colorado Plateau. The district is unusual in that the ore is hosted in sandstones and mudstones of the Eocene Wasatch Formation (USGS Model 30C) and not the Triassic Chinle or Jurassic Morrison Formations as are most of Utah's U districts. Mineralization consists of carnotite, uraninite, and autunite associated with small lenses of carbonized logs and limbs in paleo-stream channels. No references to these prospects are found outside the Utah Mineral Occurrence System (UMOS).

The Tuscher Canyon district is largely within the U.S. Bureau of Land Management Desolation Canyon and Floy Canyon Wilderness Study Areas.

TUTSAGUBET DISTRICT

The Tutsagubet mining district lies in the central part of the Beaver Dam Mountains in southwestern Washington County. Prospects were initially located in the area in the 1870s, but the district was not organized until 1883. Early hand-sorted ore shipments from the Apex mine to the rail head at distant Milford for transport to Swansea, Wales, ran 54.2% Cu and 140 ppm Ag. The district was worked intermittently from 1884 to 1962. The presence of Ga-Ge was initially detected at the Apex mine in 1958 by Gaylon Hansen, and the mine produced minor Cu-Ga-Ge intermittently from the 1980s to very early 1990s. Total district metal production at modern metal prices is estimated at $45 million. The district is a significant producer and the Apex underground mine is the only important ore deposit.

The Apex mine exploited a Cu-Ga-Ge deposit in a steeply plunging, solution collapse breccia pipe, hosted in the Pennsylvanian Callville Limestone and overlying Permian Pakoon Dolomite. The Apex mine was developed to a depth of approximately 1400 ft where the ore was still thoroughly oxidized, but the breccia pipe probably bottoms in the heavily karstic Mississippian Redwall Limestone hundreds of feet below the deepest workings (Wenrich and Verbeek, 2014). Gallium and Ge are contained in goethite, jarosite, and hematite minerals in gossans that also contain oxidized Cu minerals. A cluster of smaller, but similar occurrences lie in an area of slightly more than 1 sq mi near the Apex mine, but strong Ga-Ge geochemical anomalies are reported along a north-northwesterly trend up to 7 mi to the north-northwest. The Apex deposit's geochemical signature is Ga-Ge-Cu-Ag-As-In-Re-Sb. The Apex mine is a Kipushi Cu-Pb-Zn type deposit (USGS Model 32c). Worldwide, other Kipushi-type deposits include the Kipushi Cu-Zn ±Ga ±Ge deposit, Zaire; Tsumeb Cu-Pb-Zn ±Ga ±Ge deposit, Namibia; and the Ruby Creek and Kennicott Cu-Ag deposits in Alaska. These other deposits are all large, significant, high-grade deposits (Peterson and others, 1988; Wenrich and Verbeek, 2014).

Nearly all of the Apex's early Cu-rich ore production was mined from the upper levels, leaving behind the Fe-rich minerals that contain the majority of the Ga-Ge. Production details are sketchy from the Apex mine but are very crudely estimated at about 30,000 tons prior to 1963. Musto produced another 10,270 tons from the Apex mine in 1986 yielding 1645 pounds of Ga, 5634 pounds of Ge, and 224,800 pounds of Cu. The remaining subeconomic inferred resource at the Apex mine is roughly one million tons averaging 0.033% Ga, 0.087% Ge, 1.8% Cu, and 41 ppm Ag, with about two-thirds of the value in Ge.

Peterson, E.U., Bowling, D.L., Mahin, R.A., and Bowman, J.R., 1988, Geology, mineralogy, and genesis of the Apex Ga-Ge deposit, Tutsagubet district, Utah, in *Torma, A.E., and Gundiler, I.H., editors, Precious and rare metal technologies: Amsterdam, Elsevier Publishing Co., p. 511–530.*

Wenrich, K.J., and Verbeek, E.R., 2014, The Apex mine, Utah—A Colorado Plateau-type solution-collapse breccia pipe and a Tsumeb, Namibia, analogue, in *MacLean, J.S., Biek, R.F., and Huntoon, J.E., editors, Geology of Utah's far south: Utah Geological Association Publication 43, p. 651–688.*

TWIN PEAKS DISTRICT

The Twin Peaks mining district is in southeastern Millard County. The district is an insignificant Fe producer. Bullock (1970) reported approximately 50 tons of ore was shipped to the Ironton Works in Provo in 1940. The Twin Peaks Fe mine is the only operation with recorded production.

The Twin Peaks district is in the southern Sevier Desert section of the Basin and Range Province. Mineralization is associated with the Pleistocene North Twin Peaks rhyolite dome. The dome is part of a bimodal basalt-rhyolite volcanic suite. The North Twin Peaks dome is estimated to be 600 ft high and a basalt flow lies just 1.5 mi to the southeast. The rhyolite is porphyritic and has phenocryts of plagioclase, sanidine, quartz, and biotite (Hintze and Davis, 2003).

Three areas of magnetite veining occur on North Twin Peak and the largest workings are a 200-foot-deep incline shaft and several small prospect pits located just northeast of North Twin Peak proper. The mineralization consists of narrow, open-space veins and veinlet zones of magnetite with subordinate hematite and martite (hematite pseudomorphs after magnetite) cutting the North Twin Peak rhyolite. The veins are narrow, from 0.5 to 3 ft wide, and traceable for less than 100 ft (Bullock, 1970). Zones of anastomosing magnetite veinlets may be up to 6 ft wide (Crawford and Buranek, 1945). The main vein was developed along an east-trending, south-dipping fault, but smaller veins apparently developed along N. 50° E. and N. 70° W. joints in the rhyolite. Seven samples collected by Bullock (1970) contained an average of 60.7% Fe and 3.8% SiO_2.

The prospect has little potential as an iron mine, but it does contain nice crystals of martite, augite, and apatite (Crawford and Buranek, 1945).

Bullock, K.C., 1970, Iron deposits of Utah: Utah Geological and Mineralogical Survey Bulletin 88, 101 p., l plate.

Crawford, A.L., and Buranek, A.M., 1945, The martite iron deposits at Twin Peaks, Millard County: Utah Department of Publicity and Industrial Development Circular 30, 6 p.

Hintze, L.F., and Davis F.D., 2003, Geology of Millard County, Utah: Utah Geological Survey Bulletin 133, 305 p.

UCOLO DISTRICT

The Ucolo district is part of the Slick Rock V-U area in easternmost San Juan County about 16 mi east-northeast of Monticello on the Colorado border. The Utah portion of the Ucolo district is ranked as a large V-U producer, but the Colorado portion of the district has had even more production. The Slick Rock V-U area, as a whole, has intermittently produced V and U since the early 1900s, with pre-1944 production mostly for radium and vanadium and post-1948 production for uranium and vanadium. The average pre-1944 production grade is estimated at 2.38% V_2O_5. Total Ucolo district production is estimated at 13,8000,000 lbs V_2O_5 and 1,250,000 lbs U_3O_8 making it the second largest V producer in Utah (Doelling, 1969; Chenoweth,1981). Total district metal production at modern metal prices is estimated at $120 million. The largest mines in the Ucolo district are the Deremo-Snyder-Peterson and the Wilson–Silver Bell groups.

The Ucolo district is at the southern end of the Uravan mineral belt, an arcuate belt extending from Utah's Gateway district in the north, through the Uravan, Gypsum Valley, and Slick Rock districts in Colorado. The entire Uravan mineral belt is in the Paradox Basin on the Colorado Plateau. Most of the Ucolo deposits are in the upper part of the Salt Wash Member of the Jurassic Morrison Formation, but ore deposits are also found in the overlying Brushy Basin Member (Doelling, 1969; Chenoweth,1981). The Ucolo V-U deposits occur mainly as tabular to pod-like bodies generally parallel to sedimentary structures, particularly bedding or, more rarely, as C- or S-shaped roll fronts cross-cutting bedding (USGS Model 30c). The tabular orebodies are a few inches to over 20 ft thick with an average thickness of 3 to 4 ft and up to 200 ft long and are often elongate along channel trends. Orebodies are generally more abundant in areas of greater sandstone thickness (20–40 ft thick) but can occur anywhere within the channel. Typically, a mine will consist of one or more clusters of individual orebodies connected by lower grade material. The rolls may be elongate or sinuous for several hundred feet along the channel trend. Roll-type orebodies can be up to 5 ft thick, 15 ft high, and 300 ft or more long, but are generally much smaller, averaging only 5 ft high. Roll-type orebodies often occur near the impermeable boundaries at the edges of the elongate sandstone lenses. Roll-type deposits account for only a small part of the Ucolo district's V-U production and roll-type orebodies are typically limited to a few thousand tons. Ore minerals typically fill intragranular voids and coat grains, but more rarely may replace detrital grains or carbonaceous material. Primary ore minerals include uraninite, coffinite, montroseite, corvusite, pyrite, and various base metal sulfides (Doelling, 1969; Chenoweth,1981). The district still hosts known V-U resources.

Chenoweth, W.L., 1981, The uranium-vanadium deposits of the Uravan mineral belt and adjacent areas, Colorado and Utah, in *Epis, R.C., and Callender, J.F. editors, Western Slope geology-western Colorado and eastern Utah: New Mexico Geological Society 32nd Field Conference, p. 165–170.*

Doelling, H.H., 1969, Mineral resources, San Juan County, Utah and adjacent areas, Part II—Uranium and other metals in sedimentary host rocks: Utah Geological and Mineralogical Survey Special Study 24, 64 p.

UINTA BASIN DISTRICT

The Uinta Basin (Castle Peak) mining district straddles the Uintah–Duchesne County line about 30 mi southwest of Vernal in northeastern Utah. The district has had minor U production from 19 small mines from 1949 to 1958. Total district metal production at modern metal prices is estimated at $22,000. The largest producer was probably the Eureka Group at just 40 tons of ore (Chenoweth, 1992).

The Uinta Basin district is geologically situated in the central portion of the Uinta Basin on the Colorado Plateau. Weak mineralization is scatted at numerous locations across a broad area of the central Uinta Basin, but the only productive mines are in the Upper Cretaceous Mesaverde Group and the Eocene Uinta Formation and most production was from the Uinta Formation (Chenoweth, 1992). The Uinta Basin also contains minor polymetallic, sediment-hosted deposits that are zoned on a regional scale from more Cu- and Mo-rich deposits west of the Green River (USGS Model 30b) to more uraniferous deposits to the east (USGS Model 30c). Geochemical sampling of some old uranium-Cu prospects in the Eocene Uinta Formation have shown a metal assemblage of strongly anomalous Mo, Cd, Cu, Ag, Sb, As, U, and Re (Conn and Krahulec, 2008).

Mineralization in the Uinta Basin district is hosted in cross-bedded or laminated, arkosic sandstone and is similar in character to both sediment-hosted stratiform Cu deposits and tabular sandstone uranium deposits. Mineralization is interstitial, disseminated, and associated with bleaching, decalcification, carbonized plant fossils, and abundant Fe-oxide nodules. The Uinta Basin mineralization is unique in that much of the total dollar value of the ore is frequently in Mo, running to over 1% Mo. The Mo occurs at the surface as either a black, unknown Cu-Zn-Mo oxide mineral or ferrimolybdite (Conn and Krahulec, 2008).

Chenoweth, W.L., 1992, Uranium mining in the Uinta Basin, Utah, in *T.D. Fouch, V.F. Nuccio, and T.C. Chidsey Jr., editors, Hydrocarbon and mineral resources of the Uinta Basin, Utah and Colorado: Utah Geological Association Guidebook 20, p. 345–352.*

Conn, G.R., and Krahulec, K., 2008, Sediment-hosted, polymetallic mineralization in the Uinta Basin, Duchesne and Uintah Counties, Utah, in *Longman, M.W., and Morgan, C.D., editors, Hydrocarbon systems and production in the Uinta Basin: Rocky Mountain Association of Geologists and Utah Geological Association Publication 37, p. 391–401.*

WAH WAH SUMMIT DISTRICT

The Wah Wah Summit mining district is in the Wah Wah Mountains of north-central Beaver County about 30 mi west-northwest of Milford. The district includes two Fe prospects but has no reported production; however, the West claim may have shipped some test lots of Fe ore (Bullock, 1970).

The Wah Wah Mountains are a large, northerly trending range in the east-central Basin and Range Province. The Wah Wah Summit district is on a major pass in the Wah Wah Mountains. The pass is underlain by a series of three small, east-west-trending Oligocene stocks (~30 Ma) intruded into a package of Cambrian carbonate rocks. The stocks are grossly similar to the Cactus stock in the San Francisco mining district 10 mi to the east across Wah Wah Valley. The Wah Wah Mountains were rotated slightly to the east during Basin and Range extension, resulting in gently east-dipping (5°–15°) Oligocene volcanic rocks on the east flank of the range. Erickson (1966) describes the intrusives as diorites having as much as 25% mafic minerals and magnetite-bearing, but could locally be classified as monzonites due to the high K-spar content. He notes that the western (older) stock has pyroxenes and less albitic plagioclase. In contrast, the eastern (younger) stock has more hydrous minerals including amphibole and biotite instead of pyroxene, has more quartz and K-spar, more albitic plagioclase, and is also more altered, brecciated, and pyritized. The stocks have a wide, bleached, coarse-grained marble halo, up to 2000 ft wide, with the narrowest marble zone on the western stock. The marble zone is widest on the north side of all the stocks. Locally narrow, brown, anhydrous grossularite-chlorite-diopside-vesuvianite skarns lie adjacent to the stocks (Erickson, 1966).

The two prospects explored some small Fe skarns (USGS Model 18D) developed in marbleized Cambrian carbonate rocks north of the western stock (Bullock, 1970). The mineralization occurs along northerly trending faults and consists of fissure filling and replacement of limonite, hematite, or a mixture of the two minerals. The mineralization occurs as either hard clinker chunks or soft ocherous gouge. The West claim is the larger of the two and has been developed by a 30-ft-deep shaft that has a short drift to the north in the mineralized fault zone. Ore samples from the two prospects run 46% Fe from the West claim and 57.6% Fe from the eastern Red claim (Bullock, 1970). The ores are also weakly anomalous in As, V, and Zn.

A portion of the Wah Wah district is within the U.S. Bureau of Land Management Wah Wah Mountain Wilderness Study Area.

Bullock, K.C., 1970, Iron deposits of Utah: Utah Geological and Mineralogical Survey Bulletin 88, 101 p., l plate.

Erickson, M.P., 1966, Igneous complex at Wah Wah Pass, Beaver County, Utah: Utah Geological and Mineralogical Survey Special Study 17, 14 p.

WASHINGTON DISTRICT

The Washington district lies about 50 mi northwest of Cedar City in the Indian Peak Range in southwestern Beaver County and adjoining portions of Iron County. The district is located south of the smaller Indian Peak Cu-Au-Ag district. The Washington district has been a modest fluorite producer having minor Pb-Zn and subordinate Ag-Cu-Au production (Perry and McCarthy, 1977). The district is the second largest fluorite producer in the state. Total district metal production at modern metal prices is estimated at $4 million. The Cougar Spar fluorite mine and the New Arrowhead Pb-Zn mine are the most important producers in the district.

The Washington district lies on the Blue Ribbon lineament in the Basin and Range Province. The bulk of the mineralization in the Washington district was derived from fissured and replaced Paleozoic sedimentary rocks; however, Tertiary volcanic rocks associated with the Indian Peak caldera are ore hosts locally. The Indian Peak Range was rotated eastward during Miocene extension so that the Oligocene units dip moderately eastward, but mid-Miocene volcanic units dip gently. The Oligocene Wah Wah Springs Formation dacitic ash-flow tuffs are intruded by a large plug of essentially coeval granodiorite porphyry. These units are cut by a series of narrow (about 15-ft-thick), N. 65° E.-trending, steeply north-dipping Miocene rhyolite porphyry dikes. The rhyolite dikes contain accessory fluorite, secondary biotite, and fine-grained disseminated pyrite (Best and others, 1987). The Cougar Spar fluorite mine in southwestern Beaver County has been a modest producer, with about 20,000 tons of fluorite produced, but also had some minor Pb and Zn production. The mine began as an underground operation but was later operated as an open pit. The Cougar Spar fluorite vein is along a N. 15° W. fault zone that dips steeply to the east. The fault juxtaposes granodiorite on the west and dacitic tuffs on the east. The quartz-fluorite-calcite veins and breccias are less than 5 ft wide, traceable for about 200 ft on the surface, and the average grade is about 40% fluorite. About nine other small mines and prospects with fluorite are in the district (Bullock, 1976). The New Arrowhead mine had limited production, about 2200 tons, of Pb-Zn ±Cu ±Ag ±Au ore, primarily in the 1940s. The ore is hosted in the Lower Ordovician Crystal Peak Dolomite and is estimated to average about 13% Zn, 8% Pb, 0.2% Cu, 20 ppm Ag, and 0.2 ppm Au. Galena and sphalerite are the only recognized ore minerals (Perry and McCarthy, 1977). The district has about three other Pb-Zn prospects.

Best, M.G., Grant, S.K., Hintze, L.F., Cleary, J.G., Hutsinpiller, A., and Saunders, D.M., 1987, Geologic map of the Indian Peak (southern Needle) Range, Beaver and Iron Counties, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-1795, scale 1:50,000.

Bullock, K.C., 1976, Fluorite occurrences in Utah: Utah Geological and Mineral Survey Bulletin 110, 89 p.

Perry, L.I., and McCarthy, B.M., 1977, Lead and zinc in Utah, 1976: Utah Geological and Mineral Survey Open-File Report 22, 525 p.

WASHINGTON DOME DISTRICT

The Washington Dome mining district is located about 5 mi east of St. George in south-central Washington County. The district has no recorded production but includes a series of small prospects for Au-As-Hg. One prospect on the north flank of Washington Dome attempted Hg development (metacinnabar?) in the 1950s and a prospect on the east flank of the dome exposed some gypsum beds. The Au potential of the area was not initially recognized until prospectors in the 1980s received Au values from some jasperoid samples. The Washington Dome property was then extensively drilled as a grassroots Au project in the 1990s (Hayden, 2005).

The Washington Dome district is geologically situated in the transition zone from the Basin and Range Province to the Colorado Plateau. Washington Dome itself is a 2-mi-long, doubly plunging, anticlinal segment of the Sevier-age, northeast-trending Virgin anticline. The Virgin anticline is a major structural element of the transition zone, extending for 25 mi from the Arizona-Utah border on the southwest to Zion National Park on the northeast. The anticline is typically a broad to open, symmetrical fold with an amplitude of over 2000 ft and a wavelength of 4 to 6 mi. The oldest rocks exposed in the core of the dome are Early Permian Harrisburg Member of the Kaibab Formation. Just west of Washington Dome the Basin and Range-age Washington normal fault drops the Paleozoic strata under Quaternary alluvium (Hayden, 2005).

The principal Au prospects are found on the southeast flank of Washington Dome. Mineralization occurs in a 50- to 100-ft-thick silty limestone in the upper part of the Harrisburg Member of the Kaibab Formation. The mineralized zone is elongated parallel to the anticline and along reverse and normal faults over an area about 6000 ft long and 500 ft wide. The mineralization is localized at the intersection of north-south or northeast trending faults and favorable porous, permeable, and reactive silty and sandy limestone. Silicification is the dominant alteration accompanying Au mineralization, but decalcification, dissolution of gypsum, and the introduction of pyrite are also common. Jasperoid, quartz veinlets, calcite veins, and jarosite, hematite, and green As-staining (scorodite?) are all recognized locally. The area has widespread weak Au, >0.1 ppm, with strong As to 10,000 ppm, Sb to 220 ppm, Hg to 200 ppm, and Tl to 10 ppm. Three zones of weak mineralization were intersected by drilling, all on the southeast flank of the dome (Krahulec, 2011). The best hole intersected 200 ft of approximately 0.9 ppm Au from 105 to 305 ft depth. Washington Dome has the classic alteration and geochemical trace element patterns of a sediment-hosted Au system (USGS Model 19c).

Washington Dome is partially inside the Washington City limits and the private lands are being heavily developed for residential use.

Hayden, J.M., 2005, Geologic map of the Washington Dome quadrangle, Washington County, Utah: Utah Geological Survey Map 209, p. 29.

Krahulec, K., 2011, Sedimentary rock-hosted gold and silver deposits of the northeastern Basin and Range, Utah, in *Steininger, R., and Pennell, B, editors, Great Basin evolution and metallogeny: Geological Society of Nevada 2010 Symposium Proceedings v. 1, p. 31–62.*

WEBER DISTRICT

The Weber mining district is on the western slope of the Wasatch Range of central Weber County, just 3 mi northeast of downtown Ogden. The district is an insignificant F producer with a few scattered prospects and a single mine at the Norman fluorite deposit. The property was initially recognized in the late 1800s but was only in production briefly during high F prices under a federal fluorite stockpiling program in 1957. About 47 tons of ore were produced and upgraded by hand-sorting (Bullock, 1976).

The Wasatch Range is a major north-south-trending range geologically situated in the Middle Rocky Mountain province. The mineralization is hosted in Paleoproterozoic Farmington Canyon Complex. The mineralization is a narrow zone of thin fluorite stringers in a quartzose mylonite striking roughly N. 40° E. and dipping about 65° NW. The workings consist of a series of dozer cuts, some small surface cuts, and a 235-ft-long adit stretched over a strike length of about 1500 ft. The fluorite stringers range from 1 to 24 inches in width within the fault zone (Perry, 1973; Bullock, 1976). Five short channel samples across the veins average 46.5% CaF_2 and 39.5% SiO_2 (Perry, 1973).

Bullock, K.C., 1976, Fluorite occurrences in Utah: Utah Geological and Mineral Survey Bulletin 110, 89 p.

Perry, L.I., 1973, Norman fluorspar deposit, Weber County, Utah: Utah Geological and Mineral Survey Report of Investigation 85, 8 p.

WEST DIP DISTRICT

The West Dip (West Mercur) mining district is located on the southwest flank of the Oquirrh Mountains 15 mi south of Tooele in Tooele County. The district is a significant Au producer with a poorly documented historical production of about 36,900 ounces of Au between 1897 and 1941. Early Au production was severely hampered by the difficult metallurgy of the ores (Gilluly, 1932). Total district metal production at modern metal prices is estimated at $41 million. The district was heavily explored in the 1980s and 1990s for Au without ensuing development. The largest producers are the La Cigale and Daisy Au mines.

West Dip lies on the south flank of the Bingham–Park City mineral belt in the Basin and Range Province. West Dip is elongated on the southwest limb of the Ophir anticline. The Ophir anticline is a closed, asymmetrical thrust-cored anticline with a steep northeast limb and a gentler limb on the southwest, where Paleozoic sedimentary rocks dip about 55° west-southwest (Kroko and Bruhn, 1992). Mineralization occurs in association with the West Mercur fault along the range front and, to a much lesser extent, the subparallel Lakes of Killarney fault about a mile to the east. The West Mercur fault is approximately bedding-parallel (dipping 40°–60° southwest) and appears to have developed near the base of the Upper Mississippian Manning Canyon Shale. The southwest-dipping (55°–80°) Lakes of Killarney fault appears to be stratigraphically controlled near the contact between the Long Trail Shale and the Mercur member of the Middle Mississippian lower Great Blue Limestone in the footwall (Gilluly, 1932).

The old underground workings along the West Mercur fault, including the La Cigale, Omaha, and Daisy Au mines, generally consist of shafts inclined to the west-southwest. In many of these workings, the footwall is upper Great Blue Limestone and the hanging wall may be Manning Canyon Shale or lithified Quaternary alluvium (Gilluly, 1932). Better grade Ag mineralization occurs in jasperoids to the north and Au grades increase southward in argillized, bioclastic limestone having remobilized carbon (USGS Model 26a). The carbonate rocks adjacent to a narrow dike, east and uphill of the main West Dip workings, are also reportedly anomalous in Au, As, Hg, Sb, and Tl. The main West Dip ore deposits are associated with bleached, decalcified, argillized, weakly silicified host rocks and contain microscopic Au. As at the Mercur deposits, directly across the Ophir anticline to the east, geochemical work found the highest Au grades were associated with argillized and Fe-stained carbonate rocks. Some spotty, refractory ore grade pods of sedimentary rock-hosted Au mineralization having high carbon and pyrite were drilled near the Daisy mine. The mineralization at West Dip is very similar to the ores in the Mercur district, but the ores are higher in the stratigraphic section, underlying the Manning Canyon Shale rather than the Long Trail Shale at Mercur.

Gilluly, James, 1932, Geology and ore deposits of the Stockton and Fairfield quadrangles, Utah: U.S. Geological Survey Professional Paper 173, 171 p., plate 1, scale 1:62,500.

Kroko, C.T., and Bruhn, R.H., 1992, Structural controls on gold distribution, Mercur gold deposit, Tooele County, Utah, in *Wilson, J.R., editor, Field guide to geologic excursions in Utah and adjacent areas of Nevada, Idaho and Wyoming: Geological Society of America Miscellaneous Publication 92-3, p. 325–332.*

WEST SAN RAFAEL DISTRICT

The West San Rafael mining district is in the northwestern San Rafael Swell in Emery County about 8 mi southeast of Emery. The district is a poorly documented series of small U and Mn prospects. The district has no recorded production. The A.Y. Clark U mine has the most surface disturbance in the district and may have shipped some test lots of U ore.

The West San Rafael district is geologically situated on the northwestern flank of the San Rafael Swell of the Colorado Plateau. Nearly all of the prospects are in the Upper Jurassic Brushy Basin Member of the Morrison Formation. The U prospects developed small tabular lenses of mineralization in mudstone and sandstone, mostly associated with fracture systems. Carnotite is the only reported ore mineral. The Mn prospects explored small accumulations of pyrolusite and lesser psilomelane and manganite. No references to these prospects are found outside the Utah Mineral Occurrence System (UMOS).

WEST TINTIC DISTRICT

The West Tintic mining district is in north-central Juab County 34 mi northwest of Nephi. The most notable production in the West Tintic district came from the Scotia mine, which produced about 3000 tons of high-grade Au-Ag-Pb ore (Butler and others, 1920), including several hundred tons of 2400 ppm Ag ore. However, West Tintic is also the second largest W producer in the state. Total district metal production at modern metal prices is estimated at $4.3 million.

The West Tintic district is geologically situated on the Deep Creek–Tintic mineral belt in the Basin and Range Province. The district is in a window of lower plate Paleozoic carbonate rocks overridden by Proterozoic rocks in the upper plate of the Sheeprock thrust. The lower plate Paleozoic strata generally strike northerly and dip very steeply to the east (Stringham, 1942). The range has been rotated eastward an indeterminate, but possibly significant, amount (25°–35°) by post-mineral, listric, extensional faulting. This resulted in deeper levels of the intrusive-hydrothermal system being exposed on the west side of the district and progressively shallower levels of the system exposed to the east.

Mineralization at West Tintic is zoned from: (1) weak porphyry Cu-Mo mineralization in the southwest (USGS Model 17), to (2) W-Cu-Fe skarns adjacent to the Tertiary monzonite stocks (USGS Model 14a), to (3) Pb-Zn replacement deposits in Paleozoic-age carbonate rocks (USGS Model 19a), to (4) minor Au occurrences along the Sheeprock thrust to the north and east. The exposed Little Bingham porphyry Cu-Mo-style mineralization occurs in a light gray, medium- to coarse-grained granite (~39 Ma) with coarse pink K-spar phenocrysts. Copper mineralization occurs as low-sulfide chalcopyrite veins and disseminations in weakly altered granite. The mafic minerals are destroyed, but K-spar is generally stable. Copper grades are low, probably averaging about 0.1% Cu, but the deposit appears to be open under cover to the east and south.

The discovery outcrop at the Scotia mine was in a thrust sliver of Precambrian phyllite that dipped about 60° N. The exact age and correlation of the remaining, deeper host strata are uncertain, but are tentatively interpreted as Silurian Laketown Dolomite (Stringham, 1942). Scotia mineralization occupies either northerly trending open fissures or east-northeasterly trending, steeply north-dipping quartz-sulfide veins and associated small blanket replacement bodies. These Ag-Au-Pb replacement deposits occur as irregular, gentle northeast-dipping, easterly elongated pods along the subsidiary thrust faults and narrow aplite porphyry sills. The Scotia ores are nearly completely oxidized, but the primary minerals recognized include galena, arsenopyrite, pyrite, sphalerite, famatinite, and chalcopyrite in a gangue of a little quartz (Stringham, 1942).

Butler, B.S., Loughlin, G.F., Heikes, V.C., and others, 1920, The ore deposits of Utah: U.S. Geological Survey Professional Paper 111, 672 p.

Stringham, B.F., 1942, Mineralization in the West Tintic mining district, Utah: Bulletin of the Geological Society of America, v. 53, p. 267–290.

WHITE CANYON DISTRICT

The White Canyon (Hite) mining district is located about 50 mi west of Monticello in central San Juan County. The district is located between the Red Canyon district to the west, Fry Canyon district to the south, and Deer Flat district to the east. These districts are all part of the White Canyon U mining area. Copper prospecting began in the White Canyon area in the 1880s but led to little development. The first U production in the district started in 1949 and continued into the 1980s (Chenoweth, 1993). The Happy Jack mine was the first producer and largest mine in the White Canyon district. Early production was hampered by the high Cu content of the U ores (Chenoweth, 1993). Nearly all production was from underground mines accessed by tunnels except for a small open pit at the Happy Jack mine. The White Canyon district is a large mining district and ranks as the third largest U producing district in the state. Total district metal production at modern metal prices is estimated at $121 million.

The White Canyon district is on the Monument Upwarp in the Paradox Basin on the Colorado Plateau. The rocks of the Monument Upwarp, west of the Comb Ridge monocline, generally dip gently west. This area is part of the deeply incised Red Rock Plateau/White Canyon Slope, sandwiched between the Colorado River on the west and Comb Ridge to the east. The host strata for the sandstone U ±Cu ore (USGS Model 32c) in the White Canyon district is the Upper Triassic Shinarump Conglomerate Member of the Chinle Formation. Mineralization is typically associated with westerly flowing stream channels down-cutting into the underlying Lower Triassic Moenkopi Formation mudstone. Individual orebodies are hosted in the basal sandstone, are tabular to lenticular, are associated with carbonaceous trash, and contain from a few tons to more than 15,000 tons of ore. Productive orebodies are 2 to 10 ft thick, 50 to 150 ft wide, and 300 to 500 ft long (Doelling, 1969).

The ore minerals are fine grained, in the interstices of the sandstone, and associated with asphaltite and carbonaceous trash. The unoxidized ore/sulfide minerals are uraninite, chalcopyrite, bornite, chalcocite, covellite, domeykite, tennantite, pyrite, and less commonly galena, sphalerite, and ilsemannite. Vanadium only occurs in trace amounts as montroseite. The Happy Jack ore has trace amounts of Co and has the reported Co minerals of erythite, cobaltzippyite, smaltite, and skutterudite. Gangue minerals include calcite, dolomite, manganosiderite, jarosite, limonite, gypsum, and barite. Ore grades average approximately 0.26% U_3O_8, 0.06% V_2O_5, and 0.7% Cu. The underlying Moenkopi Formation mudstone is commonly bleached near orebodies (Doelling, 1969; Chenoweth, 1993).

Chenoweth, W.L., 1993, The geology and production history of the uranium-vanadium deposits in the White Canyon district, San Juan County, Utah: Utah Geological Survey Miscellaneous Publication 93-3, 24 p.

Doelling, H.H., 1969, Mineral resources, San Juan County, Utah and adjacent areas, Part II—Uranium and other metals in sedimentary host rocks: Utah Geological and Mineralogical Survey Special Study 24, 64 p.

WHITE MOUNTAIN DISTRICT

The White Mountain mining district is in central Beaver County about 17 mi southwest of Milford. Very little information is available on the mineralization in the White Mountain district. The area has historical prospects for clay, alunite, sulfur, uranium, and precious metals, but no recorded mineral production. The area had numerous brief, unsuccessful mineral exploration projects from the 1980s into the early 2000s. These programs were primarily focused on clay, alunite, and precious metals.

White Mountain lies on the Wah Wah–Tushar mineral belt in the Basin and Range Province of southwestern Utah. The district encompasses an east-west-trending belt about 2 mi wide by 8 mi long of locally intense alteration, but weak mineralization. The hydrothermal activity is related to an early Miocene bimodal igneous suite related to the Blawn Formation (Steven and Morris, 1987). Alteration/mineralization is typical of shallow epithermal conditions including siliceous sinters, opaline silicification, hot-spring sulfur, and hydrothermal alunite deposits. Prospects on this trend have primarily been explored for alunite, clay, and Au-Ag-Hg mineralization. Recognized minerals reported from the prospects include alunite, kaolinite, quartz, hematite, limonite, pyrite, sulfur, and autunite. The White Mountain alunite deposit, located about 1.25 mi west-northwest of White Mountain proper, contains an estimated 88 million tons of 14.5% Al_2O_3 and 3.15% K_2O (Steven and Morris, 1987). The deposit is hosted by Blawn Mountain Formation tuffs and rhyolites (Best and others, 1989).

The Brimstone sulfur prospect is in the extreme southwest corner of the White Mountain district near the west range front fault. The prospect is a hot-spring type deposit (USGS Model 25M) having native sulfur associated with siliceous sinter and an east-west zone of vuggy, opaline silicification of the host Blawn Formation rhyolitic tuffs (Nackowski and Levy, 1959). Cinnabar (mercury) is also reported from the property. High-grade samples run up to 10% S and 1.8% Hg.

Extensive stratabound jasperoids on the Long Lick property are found in a window of Mississippian limestones through Tertiary volcanic cover. The Mississippian carbonate rocks have been variously assigned to the Great Blue Limestone, Woodman Formation, Monte Cristo Limestone, and formation of Rose Spring Canyon, but importantly includes a sequence of favorable-looking silty limestone host rocks. The jasperoids typically are weakly anomalous in Au-As-Ag, averaging roughly 0.2 ppm Au, 100 ppm As, and 1 ppm Ag.

Best, M.G., Lemmon, D.M., and Morris, H.T., 1989, Geologic map of the Milford quadrangle and east half of the Frisco quadrangle, Beaver County, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-1904, scale 1:24,000.

Nackowski, M.P., and Levy, E., 1959, Mineral Resources of the Delta-Milford area: Bulletin of the University of Utah, v. 50, no. 18, 112 p.

Steven, T.A., and Morris, H.T., 1987, Summary mineral resource appraisal of the Richfield 1° x 2° quadrangle, west-central Utah: U.S. Geological Survey Circular 916, 24 p.

WHITE PINE DISTRICT

The White Pine mining district is located about 20 mi south-southeast of Salt Lake City in the Wasatch Range of southeastern Salt Lake County. The district is an insignificant Mo producer. The White Pine Fork area was explored for porphyry Mo mineralization in the 1960s. The Gladstone (Gad Valley) mine in the northeast corner of the district is the only producer with nominal reported production.

The White Pine district is geologically situated on the Bingham–Park City mineral belt in the Middle Rocky Mountain province. Mineralization is associated with the Oligocene White Pine granite, which is a small stock intruding the larger Little Cottonwood quartz monzonite batholith. The White Pine stock is white to light-gray, fine- to medium-grained, phaneritic, slightly porphyritic, monzogranite containing rare, large K-spar phenocrysts and megacrysts. Biotite is the only mafic phase in the White Pine stock and it lacks the mafic xenoliths common in the Little Cottonwood batholith. Narrow dikes of aplite, quartz porphyry, alaskite, and lamprophyre cut both the White Pine stock and Little Cottonwood batholith. A light, red-brown color anomaly, resulting from the oxidation of pyrite in fractures and veins, is coincident with a zone of weak, mostly fracture-controlled alteration and is partly coincident with the White Pine stock, but also overlaps west into Red Pine Fork. Disseminated scheelite (up to 1000 ppm W) and fluorite have been recognized in this area of alteration (Sharp, 1958).

The White Pine granite is also cut by a small, elongated, about 400-ft-wide by 600-ft-long, Mo-rich, magmatic-hydrothermal breccia pipe. The breccia is mostly homolithic, subangular to subrounded, poorly sorted, granitic clasts altered to a “greisen-like” assemblage of medium-grained quartz-muscovite-K-spar-pyrite granitic fragments with cockscomb quartz crystals filling open space between the fragments. Mineralization consists of quartz and fine-grained molybdenite, the latter often in tight aggregates surrounding the breccia fragments. A high-grade sample taken from the short series of adits driven into the northwest corner of the breccia pipe at stream level ran over 1.2% Mo (Buranek, 1944). The Mo content is reportedly higher near the margins of the breccia pipe (Sharp, 1958). Both the granite and breccia pipe are cut by rare coarse-grained, crystalline, milky white, quartz veins, rarely up to 2 ft wide. The White Pine Fork drainage hosts a small, low-fluorine, porphyry Mo resource (USGS Model 21b) including the breccia pipe and extending about 2800 ft down canyon to the north-northwest. The White Pine porphyry Mo has a subeconomic inferred resource of 16 million tons at 0.1% Mo (Bromfield and Patten, 1981).

Bromfield, C.S., and Patten, L.L., 1981, Mineral resources of the Lone Peak Wilderness Study Area, Utah and Salt Lake Counties, Utah: U.S. Geological Survey Bulletin 1491, 117 p.

Buranek, A.M., 1944, The molybdenum deposits of White Pine Canyon near Alta, Salt Lake County, Utah: Utah Geological and Mineralogical Survey Circular 28, 6 p.

Sharp, B.J., 1958, Mineralization in the intrusive rocks in Little Cottonwood Canyon, Utah: Bulletin of the Geological Society of America, v. 69, p. 1415–1430.

WILDCAT DISTRICT

The Wildcat (Wildcat Range) mining district lies on Wildcat Mountain about 50 mi west of Tooele in central Tooele County. The district was organized in 1891, but the most productive period was 1918–24. The district has produced a small amount of fluorite (904 tons) and Ag-Pb ore (182 tons). Total district metal production at modern metal prices is estimated at $284,000. The Silver Queen mine is the only producer (Smith and Wadsworth, 1954; Bullock, 1976).

The Wildcat district lies in the Great Salt Lake Desert in the Basin and Range Province. The Silver Queen mine is in a shallow pediment in an embayment on the very north end of Wildcat Mountain. The mine exploits small fluorite veins and associated Ag-Pb-Cu replacement deposits. The veins are associated with highly fractured, dolomitized, thick-bedded limestone intercalated with quartzite beds of the Pennsylvanian-Permian Oquirrh Group (Clark and others, 2016). The mineralized zone occurs below a quartzite unit which may have acted as an impermeable barrier to ascending hydrothermal fluids. Latite dikes cut the sedimentary units in the mineralized area. The veins trend to the north-northeast and east-northeast and range from a few inches to about 5 ft thick; however, the mineralization is not continuous along the length of the veins. The mineralogy of the veins is colorless to yellow, green, and blue fluorite cubes, barite, witherite, quartz, dolomite, siderite, galena, chalcopyrite, and pyrite (Smith and Wadsworth, 1954; Bullock, 1976). Samples collected by the U.S. Bureau of Mines averaged 58.3% fluorite, 20.7% calcite, 12.6% silica, 0.75% Cu, and 140.1 ppm Ag (Snedden and others, 1947). Selective mining and hand-sorted shipping grades averaged 88.9% fluorite.

The district is completely covered by the Utah Test and Training Range South, restricting prospecting and mining activity.

Bullock, K.C., 1976, Fluorite occurrences in Utah: Utah Geological and Mineral Survey Bulletin 110, 89 p.

Clark, D.L., Oviatt, C.G., and Page, D., 2016, Geologic map of Dugway Proving Ground and adjacent areas, Tooele County, Utah: Utah Geological Survey Map 274DM, scale 1:75,000.

Smith. J.F., Jr., and Wadsworth, A.H., Jr., 1954, Silver Queen deposit, Tooele County: U.S. Geological Survey Bulletin 1005, p. 45–48.

Snedden, H.D., Batty, J.V., Long, W.J., and Dean, K.C. 1947, Concentration of Utah fluorite ores: U.S. Bureau of Mines Report of Investigation 4143, 27 p.

WILLARD DISTRICT

The Willard mining district is in extreme eastern Box Elder County just a few miles southeast of Brigham City. The district has produced a small amount of iron ore (about 4000 tons) and has some Cu, Pb, and Zn shows, albeit with no recorded base metal production (Bullock, 1970). Total district metal production at modern metal prices is estimated at $236,000. The Wasatch Iron and Gold Company property is the only recognized producer in the district.

The Willard district lies on the western face of the Wasatch Range of the Middle Rocky Mountain province. The district is underlain by Neoproterozoic Mineral Fork Tillite thrust over Cambrian quartzite, shale, and carbonate rocks by the Willard thrust. No intrusive igneous rocks are recognized in the Willard district.

Mineralization (Fe ±Cu) occurs in northwest-trending fault zones associated with the Willard thrust and in its upper plate (Doelling, 1980). Bullock (1970) reported a few thousand tons of iron ore were shipped as smelter flux from the Wasatch Iron and Gold mine fissure fillings and replacement deposits along these northwest-trending faults. The main western orebody was reportedly about 20 ft wide by 160 ft long and averaged about 48% Fe. The ore was composed of hematite, magnetite, specularite, and had minor malachite (Bullock, 1970). Doelling (1980) reported that the remaining small, scattered Pb-Ag "pods and bunches" of ore in the mine workings are too discontinuous to be economically extracted. Most of the other base metal prospects in the district display minor Cu-staining along narrow veins, fractures, or local narrow replacements.

Bullock, K.C., 1970, Iron deposits of Utah: Utah Geological and Mineral Survey Bulletin 88, 101 p., l plate.

Doelling, H.H., 1980, Geology and mineral resource of Box Elder County, Utah: Utah Geological and Mineral Survey Bulletin 115, 251 p.

WILLOW SPRINGS DISTRICT

The Willow Springs mining district lies in the Deep Creek Range about 50 mi south of Wendover in southwesternmost Tooele County and adjoining portions of Juab County. The district encompasses a large area of the central Deep Creek Range. The Willow Springs district was organized in 1891, it was intermittently productive from then until 1982, and was a significant Au-Pb producer. Total district metal production at modern metal prices is estimated at $16 million. The Oro del Rey Au-Ag-Pb mine was the largest producer in the district and the workings include eight adits and one shaft scattered over 1200 ft of strike (Thompson, 1973).

The Deep Creek Range is a significant mountain chain in the Basin and Range Province of western Utah. The rocks in the Willow Springs district generally dip homoclinally west, and the east side of the range has a precipitous slope. Host rocks for mineralization range from Proterozoic metasedimentary rocks on the east to Devonian carbonate rocks on the west (Thompson, 1973). The district's most significant mines were the Eagles Nest, Oro del Rey, Devils pit, and Evelyn (from north to south) which all developed a narrow Au-Pb-Ag quartz-sulfide vein set cutting the Lower Cambrian Prospect Mountain Formation. The vein set generally trends north-northeast but is somewhat sinuous and is offset by numerous cross faults with mostly modest displacement. The Au-Ag-Pb vein typically dips nearly perpendicular to the west-dipping bedding in the quartzite, or typically about 75° east except for the Eagles Nest mine in the north where the vein dips about 45° west. The vein can have a wide selvage of bleached, silicified, and quartz-sulfide veinlets, which can make the precise vein margins indistinct. The Au-Ag-Pb veins have been traced intermittently for about 10,000 ft. The vein reportedly horsetails to the north. The vein ranges from a few inches wide up to 5 ft but only averages about 1.5 ft. The immediate margins of the vein are typically Fe-stained for a few inches to several feet and generally carries Au. The Au-Ag-Pb vein is not continuously mineralized but is thought to have discrete north-plunging ore shoots. The vein is locally parallel to a propylitized rhyolite dike of unknown age. The primary sulfides, where seen, generally make up less than 10% of the vein and are predominantly auriferous fine-grained pyrite, argentiferous galena, and lesser chalcopyrite and sphalerite. The Au generally occurs as fine-grained (<1 mm) native gold. The gauge minerals are quartz, barren crystalline pyrite, and minor specularite. In addition to Au, Ag, and Pb, the vein is weakly to moderately anomalous in As, Cu, Mo, and Sb. The average grade of shipments in 1945 was 60 ppm Au, 86 ppm Ag, 3.5% Pb, and 0.85% Cu. However, short individual channel samples of the vein run up to 207 ppm Au, 686 ppm Ag, 46.5% Pb, and 14.4% Cu (Thompson, 1973; Hannigan, 1990).

Elsewhere in the Willow Springs district, the Cougar Hill mine on the west side of the district produced minor Hg and the Roy Ag-Pb and Dewey Ag-Cu mines to the north had nominal production (Thompson, 1973; Hannigan, 1990).

Hannigan, B.J., 1990, Mineral resources of a part of the Deep Creek Mountains Study Area (UT-020-060/UT-050-020): U.S. Bureau of Mines Open-File Report MLA 1-90, 186 p.

Thomson, K.C., 1973, Mineral deposits of the Deep Creek Mountains, Tooele and Juab Counties, Utah: Utah Geological and Mineralogical Survey Bulletin 99, 76 p.

WILSON MESA DISTRICT

The Wilson Mesa district is a part of the Moab U mining area and is located about 11 mi east of Moab in Grand County. The first claims in the district were recorded in 1907 for placer gold, but only a trivial amount of gold was recovered. The district became a small U-V producer and the Valley View mine was the largest producer. Total district metal production at modern metal prices is estimated at $223,000. The U-V deposits were small underground mining operations developed by adits.

Wilson Mesa is in the Paradox Basin on the Colorado Plateau. The district is on the northwest flank of the La Sal Mountain Oligocene (about 27 Ma), calc-alkaline laccolithic complex and the rocks in the district dip to the west. All the U-V production in the district has come from tabular, sandstone-hosted U deposits in the Upper Jurassic Salt Wash Member of the Morrison Formation (UGSG Model 30c). As with many other Salt Wash-hosted districts, the thickest sandstone channels typically host the largest deposits and the orebodies are associated with gray and brown reduced zones and accumulations of carbonaceous trash. The orebodies are shallow and oxidized, and the principal ore minerals are carnotite, vanadium mica, and tyuyamunite. The production average grades are 0.29% U_30_8 and 1.5% V_2O_5 (Doelling, 1969, 1974).

Wilson Mesa also encompasses a few very small placer gold (USGS Model 39a) prospects/mines on an elevated alluvial bench on the extreme west side of the district (Johnson, 1973; Lane, 1989).

Doelling, H.H., 1969, Mineral resources, San Juan County, Utah and adjacent areas, Part II—Uranium and other metals in sedimentary host rocks: Utah Geological and Mineralogical Survey Special Study 24, 64 p.

Doelling, H.H., 1974, Uranium-vanadium occurrences of Utah: Utah Geological and Mineral Survey Open-File Report 18, unpaginated.

Johnson, M.G., 1973, Placer gold deposits of Utah: U.S. Geological Survey Bulletin 1357, 26 p.

Lane, M.E., 1989, Mineral investigation of the Negro Bill and Mill Creek Canyon Wilderness Study Areas, Grand County, Utah: U.S. Bureau of Mines MLA 28-89, 15 p.

YOST DISTRICT

The Yost mining district lies on the north flank of the western Raft River Mountains in northwestern Box Elder County about 83 mi west-northwest of Brigham City. The district has no official recorded production, but Doelling (1980) reported that the mine workings suggest that a very small volume of Pb-Ag and possibly some W ore may have been produced.

The district hosts two primary styles of mineralization: rusty quartz veins and distal disseminated Ag-Au deposits similar to Black Pine, Idaho. The Jones Creek distal disseminated Ag-Au occurrence (USGS model 26a) is located on the north flank of the central Raft River Mountains about 2.5 mi south of the Idaho state line and 5.7 mi east of the village of Yost. The property was initially discovered by the Battle Mountain Exploration Company while doing Au reconnaissance in the region of the Black Pine carbonate-hosted Au mine, 21 mi to the east-northeast in Idaho. Battle Mountain acquired the Jones Creek property in 1988, drilled about a dozen shallow (less than 400 ft deep) vertical holes in 1990–91, and calculated a subeconomic inferred resource of approximately 1 million tons averaging about 0.68 ppm Au (totaling about 20,000 ounces Au). Battle Mountain dropped the property in 1991. The Jones Creek deposit is associated with a small, detached, erosional remnant of Ordovician Pogonip Group limestone sitting on a low ridge of Neoproterozoic Elba Quartzite. Oxide mineralization, greater than 0.45 ppm Au, occurs at the surface in both the limestone and underlying quartzite in an area a few hundred ft in diameter and about 100 ft thick. Mineralization has subequal Au and Ag having strong As (>500 ppm) and little else. Since Au occurs in both the upper and lower plate rocks, mineralization is presumed to be post-detachment, potentially middle Miocene (Krahulec, 2011).

The rusty W-bearing quartz veins may be metamorphogenic and are primarily hosted in Neoproterozoic mica schist and quartzite and Cambrian rocks. The veins locally have some fresh pyrite, galena, molybdenite, and scheelite (Doelling, 1980). A particularly strong set of northeast-trending veins is found at the George Creek W mine. These veins are readily mappable from aerial photography and occur in the schist member of the Neoproterozoic Elba Quartzite in the George Creek drainage (SE¼ section 20, T. 14 N., R. 14 W.).

Several adits and shafts scattered in the Johnson Creek drainage south of Yost are also associated with low-angle detachment faulting. The mineralization here is primarily argentiferous galena with weak Au values along shear zones in the metamorphosed Paleozoic section, principally the Pogonip Group carbonates (Doelling, 1980).

Doelling, H.H., 1980, Geology and mineral resources of Box Elder County, Utah: Utah Geological and Mineral Survey Bulletin 115, 251 p.

Krahulec, K., 2011, Sedimentary rock-hosted gold and silver deposits of the northeastern Basin and Range, Utah, in Steininger, R., and Pennell, B, editors, Great Basin evolution and metallogeny: Geological Society of Nevada 2010 Symposium Proceedings, v. I, p. 31–62.

Appendix A. Elemental symbols used in the text.

Element Symbol	Element	Element Symbol	Element
Ag	Silver	Mn	Manganese
As	Arsenic	Mo	Molybdenum
Au	Gold	Nb	Niobium
B	Boron	Ni	Nickel
Ba	Barium	O	Oxygen
Be	Beryllium	P	Phosphorus
Bi	Bismuth	Pb	Lead
Ca	Calcium	Pr	Praseodymium
Cd	Cadmium	Rb	Rubidium
Ce	Cerium	Re	Rhenium
Cl	Chlorine	S	Sulfur
Co	Cobalt	Sb	Antimony
Cu	Copper	Se	Selenium
Dy	Dysprosium	Si	Silicon
Er	Erbium	Sm	Samarium
F	Fluorine	Sn	Tin
Fe	Iron	Ta	Tantalum
Ga	Gallium	Tb	Terbium
Gd	Gadolinium	Te	Tellurium
Ge	Germanium	Th	Thorium
H	Hydrogen	Ti	Titanium
Hf	Hafnium	Tl	Thallium
Hg	Mercury	U	Uranium
Ho	Holmium	V	Vanadium
In	Indium	W	Tungsten
K	Potassium	Y	Yttrium
La	Lanthanum	Yb	Ytterbium
Li	Lithium	Zn	Zinc
Lu	Lutetium	Zr	Zirconium

Appendix B. U.S. Geological Survey mineral deposit model numbers recognized in Utah.

USGS Mineral Deposit Models	USGS Mineral Deposit Models
11D THORIUM VEIN	25C COMSTOCK EPITHERMAL VEIN
13 PEGMATITE	25E EPITHERMAL QUARTZ-ALUNITE AU
14A W SKARN	25F VOLCANOGENIC U
15A W VEIN	25G EPITHERMAL MN
15C SN GREISEN	25H RHYOLITE HOSTED SN
16 CLIMAX MO	25L HYDROTHERMAL KAOLIN
17 PORPHYRY CU	25M FUMAROLIC SULFUR
18A PORPHYRY CU SKARN	26A SEDIMENT-HOSTED AU-AG
18B CU SKARN	26B FLUORITE DEPOSITS
18C PB-ZN SKARN	27A HOT-SPRING HG
18D FE SKARN	27D SIMPLE SB
18E CARBONATE-HOSTED ASBESTOS	27E VEIN BARITE
18F AU-BEARING SKARN	30B SEDIMENT-HOSTED CU
19A POLYMETALLIC REPLACEMENT	30C SANDSTONE U
19B REPLACEMENT MN	32C KIPUSHI CU-PB-ZN
19C DISTAL DISSEMINATED AG-AU	34B SEDIMENTARY MN
21B PORHYRY MO, LOW-F	36A LOW-SULFIDE AU QUARTZ VEINS
22C POLYMETALLIC VEINS	39A PLACER GOLD AU-PGE
25B CREEDE EPITHERMAL VEIN	39C SHORELINE PLACER TI

Model nomenclature from:
Cox D.P., and Singer, D.A., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, 379 p.

duBray, E.A., and Stoeser, D.B., 1995, Preliminary compilation of descriptive geoenvironmental mineral deposit models: U.S. Geological Survey Open-File Report 95-831, 1995, 272 p.

Appendix C. Mineral formula for selected Utah minerals. Formula are from WebMineral.com (http://webmineral.com).

Mineral	Formula
Acanthite	Ag_2S
Actinolite	$Ca(Mg,Fe)_3(SiO_2)_4$
Adularia	$KAlSi_3O_8$
Aikinite	$PbCuBiS_3$
Allanite	$(Ca,Ce)(Al_2,Fe)(Si_2O_7)(SiO_4)O(OH)$
Alunite	$KAl_3(SO_4)_2(OH)_6$
Anatase	TiO_2
Andalusite	Al_2SiO_5
Andersonite	$Na_2Ca(UO_2)(CO_3)_3\cdot 6(H_2O)$
Andradite	$Ca_3Fe_2(SiO_4)_3$
Anglesite	$Pb(SO_4)$
Anhydrite	$Ca(SO_4)$
Ankerite	$Ca(Fe,Mg,Mn)(CO_3)_2$
Apatite	$Ca_5(PO_4)_3(OH,F,Cl)$
Argentite	Ag_2S
Argyrodite	Ag_8GeS_6
Arsenopyrite	$FeAsS$
Aurichalcite	$(Zn,Cu)_5(CO_3)_2(OH)_6$
Austenite	$CaZn(AsO4)(OH)$
Autunite	$Ca(UO_2)_2(PO_4)_2\cdot 12(H_2O)$
Azurite	$Cu_3(CO_3)_2(OH)_2$
Barite	$BaSO_4$
Bayleyite	$Mg_2(UO_2)(CO_3)_3\cdot 18(H_2O)$
Becquerelite	$Ca(UO_2)_6O_4(OH)_6\cdot 8(H_2O)$
Bertrandite	$Be_4(Si_2O_7)(OH)_2$
Beryl	$Be_3Al_2Si_6O_{18}$
Beyerite	$(Ca,Pb)Bi_2(CO3)_2O_2$
Bieberite	$Co(SO_4)\cdot 7(H_2O)$
Bindheimite	$Pb_2Sb_2O_{6.75}(OH)_{0.25}$
Biotite	$K(Mg,Fe)_3[AlSi_3O_{10}(OH,F)_2$
Bismite	Bi_2O_3
Bismuth	Bi
Bismuthinite	Bi_2S_3
Bismutite	$Bi_2(CO_3)O_2$
Bixbyite	$Mn_{1.5}Fe_{0.5}O_3$
Bornite	Cu_5FeS_4
Boulangerite	$Pb_5Sb_4S_{11}$
Bournonite	$PbCuSbS_3$
Brochantite	$Cu_4(SO_4)(OH)_6$
Brockite	$(Ca,Th,Ce)(PO_4)\cdot(H_2O)$
Brookite	TiO_2
Calcite	$CaCO_3$
Canfieldite	Ag_8SnS_6
Carnotite	$K_2(UO_2)_2(VO_4)_2\cdot 3(H_2O)$
Cassiterite	SnO_2
Celadonite	$K(Mg,Fe)(Fe,Al)Si_4O_{10}(OH)_2$
Celestite	$SrSO_4$
Cerussite	$Pb(CO_3)$
Chalcanthite	$Cu(SO_4)\cdot 5(H_2O)$
Chalcedony	SiO_2
Chalcocite	Cu_2S
Chalcophyllite	$Cu_{18}Al_2(AsO_4)_3(SO_4)_3(OH)_{27}\cdot 36(H_2O)$
Chalcopyrite	$CuFeS_2$
Chlorargyrite	$AgCl$
Chlorite	$(Fe,Mg,Al)_6(Si,Al)_4O_{10}(OH)_8$
Chromite	$FeCr_2O_4$
Chrysocolla	$(Cu,Al)_2H_{1.75}(Si_2O_5)(OH)_4\cdot 0.25(H_2O)$
Cinnabar	HgS
Clausthalite	$PbSe$
Clinoclase	$Cu_3(AsO_4)(OH)_3$
Cobaltite	$CoAsS$
Coffinite	$U(SiO_4)_{0.9}(OH)_{0.4}$
Conichalcite	$CaCu(AsO_4)(OH)$
Copper (native)	Cu
Cornwallite	$Cu_5(AsO_4)_2(OH)_4\cdot(H_2O)$
Corvusite	$(Na,Ca,K)V_8O_{20}\cdot 4(H_2O)$
Covellite	CuS
Crandallite	$CaAl_3(PO_4)_2(OH)_5\cdot(H_2O)$
Cryptomelane	$KMn_6Mn_2O_{16}$
Cuprite	Cu_2O
Danalite	$Fe_4Be_3(SiO_4)_3S$
Danburite	$CaB_2(SiO_4)_2$
Diaspore	$AlO(OH)$
Dickite	$Al_2Si_2O_5(OH)_4$
Digenite	Cu_9S_5
Diopside	$CaMg(Si_2O_6)$
Djurleite	$Cu_{31}S_{16}$
Dolomite	$CaMg(CO_3)_2$
Doloresite	$H_8V_6O_{16}$
Domeykite	Cu_3As
Dufrénoysite	$Pb_2As_2S_5$
Dyscrasite	Ag_3Sb
Electrum	(Au,Ag)
Enargite	Cu_3AsS_4
Epidote	$Ca_2(Fe,Al)_3(SiO_4)_3(OH)$
Erythrite	$Co_3(AsO_4)_2\cdot 8(H_2O)$
Famatinite	Cu_3SbS_4
Ferroselite	$FeSe_2$
Fluorite	CaF_2
Forsterite	$Mg_2(SiO_4)$
Freibergite	$(Ag,Cu,Fe)_{12}(Sb,As)_4S_{13}$
Galena	PbS
Garnet	$Ca_3(Fe,Al)_2(SiO_4)_3$
Goethite	$FeO(OH)$
Gold (native)	Au
Greenockite	CdS
Gypsum	$Ca(SO_4)\cdot 2(H_2O)$
Halloysite	$Al_2Si_2O_5(OH)_4$
Hematite	Fe_2O_3
Hemimorphite	$Zn_4Si_2O_7(OH)_2\cdot(H_2O)$
Hewettite	$CaV_6O_{16}\cdot 9H_20$
Huebnerite	$MnWO_4$
Humite	$(Mg,Fe)_7(SiO_4)_3(F,OH)_2$
Hummerite	$KMgV_5O_{14}\cdot 8(H_2O)$
Hydrozincite	$Zn_5(CO_3)_2(OH)_6$
Illite	$(K,H_3O)(Al,Mg,Fe)_2(Si,Al)_4O_{10}[(OH)_2,(H_2O)]$

Appendix C. Continued.

Mineral	Formula
Ilmenite	$FeTiO_3$
Ilmenorutile	$(Ti,Nb,Fe)O_2$
Ilsemannite	$Mo_3O_8\bullet(H_2O)$
Jalpaite	Ag_3CuS_2
Jamesonite	$Pb_4FeSb_6S_{14}$
Jarosite	$KFe_3(SO_4)_2(OH)_6$
Jordisite	MoS_2
Juanitaite	$Cu_7Ca_{2.5}Fe_{0.5}Bi(AsO_4)_4(OH)_{11}\bullet 2(H_2O)$
Kaolinite	$Al_2Si_2O_5(OH)_4$
Laumontite	$CaAl_2Si_4O_{12}\bullet 4(H_2O)$
Lepidocrocite	$FeO(OH)$
Leucoxene	$FeTiO_3$
Liebigite	$Ca_2(UO_2)(CO_3)_3\bullet 11(H_2O)$
Limonite	(Fe,O,OH,H_2O)
Luzonite	Cu_3AsS_4
Magnesioferrite	$MgFe_2O_4$
Magnetite	Fe_3O_4
Malachite	$Cu_2(CO_3)(OH)_2$
Manganite	$MnO(OH)$
Marcasite	FeS_2
Mawsonite	$Cu_6Fe_2SnS_8$
Melantorite	$Fe(SO_4)\bullet 7(H_2O)$
Metatorbernite	$Cu(UO_2)_2(PO_4)_2\bullet 8(H_2O)$
Metatyuyamunite	$Ca(UO_2)_2V_2O_8\bullet 3(H_2O)$
Mixite	$BiCu_6(AsO_4)_3(OH)_6\bullet 3(H_2O)$
Mohite	Cu_2SnS_3
Molybdenite	MoS_2
Monazite	$(Ce,La,Nd,Y,Th,U)PO_4$
Montmorillonite	$Na_{0.2}Ca_{0.1}Al_2Si_4O_{10}(OH)_2(H_2O)_{10}$
Montroseite	$(V,Fe,V)O(OH)$
Mordenite	$(Ca,Na_2,K_2)Al_2Si_{10}O_{24}\bullet 7(H_2O)$
Natrolite	$Na_2Al_2Si_3O_{10}\bullet 2(H_2O)$
Olivenite	$Cu_2(AsO_4)(OH)$
Orpiment	As_2S_3
Orthoclase	$KAlSi_3O_8$
Paramontroseite	VO_2
Parapierrotite	$Tl(Sb,As)_5S_8$
Pascoite	$Ca_3V_{10}O_{28}\bullet 17(H_2O)$
Pearceite	$Ag_{16}As_2S_{11}$
Periclase	MgO
Phlogopite	$KMg_3(Si_3Al)O_{10}(F,OH)_2$
Pitchblende	UO_2
Powellite	$CaMoO_4$
Prehnite	$Ca_2Al_2Si_3O_{10}(OH)$
Proustite	Ag_3AsS_3
Pseudobrookite	$(Fe^{3+},Fe^{2+})_2(Ti,Fe^{2+})O_5$
Psilomelane	$Ba\bullet(H_2O)Mn_5O_{10}$
Pyrargyrite	Ag_3SbS_3
Pyrite	FeS_2
Pyrolusite	MnO_2
Pyrophyllite	$Al_2Si_4O_{10}(OH)_2$
Pyrrhotite	$Fe_{0.95}S$
Rauvite	$Ca(UO_2)_2V_{10}O_{28}\bullet 16(H_2O)$

Mineral	Formula
Realgar	AsS
Rhodochrosite	$Mn(CO_3)$
Rhodonite	$MnSiO_3$
Roquesite	$CuInS_2$
Roscoelite	$K(V,Al,Mg)_2AlSi_3O_{10}(OH)_2$
Samarskite	$(Y,Ce,U,Ca,Th,Fe)(Nb,Ta,Ti)_2(O,OH)_6$
Scapolite	$Na_2Ca_2Al_5Si_7O_{24}Cl$
Scheelite	$Ca(WO_4)$
Scorodite	$FeAsO_4\bullet 2(H_2O)$
Sericite	$KAl_3Si_3O_{10}(OH)_{1.8}F_{0.2}$
Siderite	$Fe(CO_3)$
Silver (native)	Ag
Smithsonite	$Zn(CO_3)$
Spadaite	$Mg(SiO_2)(OH)_2\bullet(H_2O)$
Sphalerite	$(Zn,Fe)S$
Spinel	$MgAl_2O_4$
Stannite	Cu_2FeSnS_4
Staurolite	$(Fe,Mg)_2Al_9(Si,Al)_4O_{20}(O,OH)_4$
Stibiconite	$Sb_3O_6(OH)$
Stibnite	Sb_2S_3
Stilbite	$NaCa_4Al_8Si_{28}O_{72}\bullet 30(H_2O)$
Stolzite	$Pb(WO_4)$
Stromeyerite	$AgCuS$
Strontianite	$Sr(CO_3)$
Sylvanite	$(Au,Ag)_2Te_4$
Tennantite	$Cu_{11}FeAs_4S_{13}$
Tenorite	CuO
Tetrahedrite	$Cu_9Fe_3Sb_4S_{13}$
Thorite	$ThSiO_4$
Titanite (sphene)	$CaTiSiO_5$
Tooeleite	$Fe_{7.6}(AsO_4)_{4.7}(SO_4)_{1.3}(OH)_6\bullet 4.7(H_2O)$
Topaz	$Al_2SiO_4(F,OH)_2$
Torbernite	$Cu(UO_2)_2(PO_4)_2\bullet 11(H_2O)$
Tourmaline	$(Na,Ca)(Mg,Li,Al,Fe)_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$
Tremolite	$Ca_2Mg_5(Si_8O_{22})(OH)_2$
Tungstenite	WS_2
Turquoise	$CuAl_6(PO_4)_4(OH)_8\bullet 4(H_2O)$
Tyrolite	$CaCu_5(AsO_4)_2(CO_3)(OH)_4\bullet 6(H_2O)$
Tyuyamunite	$Ca(UO_2)_2(VO_4)_2\bullet 6(H_2O)$
Uraninite	UO_2
Uranophane	$CaH_2(SiO_4)_2(UO_2)\bullet 5(H_2O)$
Vanadinite	$Pb_5(VO_4)_3Cl$
Vanoxite	$V_6O_{13}\bullet 8(H_2O)$
Variscite	$Al(PO_4)\bullet 2(H_2O)$
Vesuvianite	$Ca_{10}Mg_2Al_4(Si_2O_7)_2(SiO_4)_5(OH)_4$
Volborthite	$Cu_3V_2O_7(OH)_2\bullet 2(H_2O)$
Wolframite	$FeMn(WO_4)_2$
Wollastonite	$CaSiO_3$
Wulfenite	$Pb(MoO_4)$
Xenotime	YPO_4
Zippeite	$K_4(UO_2)_6(SO_4)_3(OH)_{10}\bullet 4(H_2O)$
Zircon	$Zr(SiO_4)$
Zunyite	$Al_{13}Si_5O_{20}(OH)_{16}F_2Cl$