SKARN OCCURRENCES IN UTAH AND THE POTENTIAL FOR ASSOCIATED GOLD MINERALIZATION

by

Julia E. Reid

CONTRACT REPORT 91-13 AUGUST 1991
UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES

THE PUBLICATION OF THIS PAPER
IS MADE POSSIBLE WITH MINERAL LEASE FUNDS

TABLE OF CONTENTS

UTAH GEOLOGICAL SURVEY
2363 Foothill Drive
Salt Lake City, Utah 84109-1491

THE UTAH GEOLOGICAL SURVEY is organized into three geologic programs with Administration, Editorial, and Computer Resources providing necessary support to the programs. The ECONOMIC GEOLOGY PROGRAM undertakes studies to identify coal, geothermal, uranium, hydrocarbon, and industrial and metallic mineral resources; to initiate detailed studies of the above resources including mining district and field studies; to develop computerized resource data bases; to answer state, federal, and industry requests for information; and to encourage the prudent development of Utah's geologic resources. The APPLIED GEOLOGY PROGRAM responds to requests from local and state governmental entities for engineering geologic investigations; and identifies, documents, and interprets Utah's geologic hazards. The GEOLOGIC MAPPING PROGRAM maps the bedrock and surficial geology of the state at a regional scale by county and at a more detailed scale by quadrangle. Information Geologists answer inquiries from the public and provide information about Utah's geology in a non-technical format.

THE UGS manages a library which is open to the public and contains many reference works on Utah geology and many unpublished documents on aspects of Utah geology by UGS staff and others. The UGS has begun several computer data bases with information on mineral and energy resources, geologic hazards, stratigraphic sections, and bibliographic references. Most files may be viewed by using the UGS Library. The UGS also manages a sample library which contains core, cuttings, and soil samples from mineral and petroleum drill holes and engineering geology investigations. Samples may be viewed at the Sample Library or requested as a loan for outside study.

The UGS publishes the results of its investigations in the form of maps, reports, and compilations of data that are accessible to the public. For information on UGS publications, contact the UGS Sales Office, 2363 Foothill Drive, Salt Lake City, Utah 84109-1491, (801) 467-7970.

ABSTRACT

A total of 146 skarn occurrences in Utah have been compiled from published literature and from the Mineral Occurrence Data System (MODS) maintained by the Utah Geological and Mineral Survey. Each occurrence represents a separate locality where calc-silicate mineralization has been described. Although most of the skarn occurrences are designated by the names of mines or prospects where they are located, this does not imply that the ore bodies are skarn-type deposits.

A total of 34 of the 146 skarn occurrences in Utah contain greater than 0.01 opt (0.34 ppm) gold and are classified as gold-bearing. In this data set, gold-bearing skarns have the following geologic characteristics. Copper is most frequently listed as the primary commodity. The most common gangue minerals reported are garnet, diopside, epidote, quartz, and wollastonite. Although dolomite host rocks are not common, magnesian minerals are found more in gold-bearing than non-gold-bearing skarns and may reflect early dolomitization or magnesian metasomatism. The most common ore minerals are chalcopyrite, pyrite, galena, and magnetite. Ore minerals that distinguish gold-bearing from non-gold-bearing skarns include covellite, enargite, argentite, arsenopyrite, bornite, chalcocite, molybdenite, pyrrhotite, sphalerite, tetrahedrite, and native gold. Elements associated with gold include: Cu, As, Te, Sb, Ag, Zn, Mo, Fe, Mn, Ba, Bi, Pb, and W. Gold-bearing skarns show a marked preference for limestone host rocks of Mississippian to Pennsylvanian age. Associated igneous rocks commonly have multiple intrusive phases and endoskarn. Gold-bearing skarns tend to have larger metamorphic aureoles than non-gold-bearing skarns and be located in the same districts as gold-bearing polymetallic replacement deposits.

Skarns in which gold is a primary or secondary commodity occur in the Bingham and Gold Hill mining districts.

The presence of gold in minor to ore-grade concentrations in numerous Utah skarns favors additional discoveries of gold in the skarn environment. Copper skarns and tungsten or tungsten-bearing skarns associated with Tertiary intrusions are especially prospective. Some exploration guides are proposed.

....

INTRODUCTION

Skarns are broadly defined as metasomatic replacements of carbonate rocks by coarse-grained calc-silicate minerals at or near the contact of an igneous intrusion (Einaudi et al., 1981). The early stages of skarn formation produce a mineral zonation that commonly consists of garnet, pyroxene, wollastonite, and marble, in a sequence outwards from the intrusive contact (Einaudi and Burt, 1982). The major portion of sulfide minerals are deposited along with hydrous minerals such as epidote, amphibole, and chlorite during a later, lower temperature stage that is usually referred to as retrograde alteration (Einaudi et al., 1981). Calc-silicate replacement of carbonate rock is termed exoskarn, whereas replacement of igneous rock involving transfer of calcium across the contact is termed endoskarn.

Skarns constitute an important category of mineral deposits and are classified based on the dominant economic metal they contain. The five major classes of skarn deposits are iron, tungsten, copper, zinc-lead, and tin. Each type has distinctive geologic features, which have been comprehensively reviewed by Einaudi et al., (1981).

Gold is present in varying amounts in all types of skarn, but is most common in copper skarns, both those related to porphyry copper mineralization and to barren intrusions (Meinert, 1989). In recent years, discoveries of skarn deposits valuable for gold content alone (Fortitude, Nevada, and Red Dome, Australia) have generated interest in isolating the geologic features that distinguish skarns containing economic amounts of gold. Meinert (1988a, 1988b, 1989) has defined a class of gold skarns which contain minor amounts of economic base metals (copper, lead, and zinc). These gold skarns have a unique geochemical signature consisting of arsenic, bismuth, and tellurium, and also have characteristic gangue and ore mineralogies, igneous and host rock associations, and tectonic settings. Ray et al. (1990) discuss the global distribution and geology of precious-metal-enriched (PME) skarns, concluding that it is not yet possible to precisely define either gold- or PME-skarns. Theodore et al. (1991) summarize geologic data and grade-tonnage figures for skarns worldwide with gold grades of at least 1 g/t (0.03 opt). They state that "gold-bearing skarns are generally calcic exoskarns associated with intense retrograde hydrosilicate alteration [and] may contain economic amounts of numerous other commodities (Cu, Fe, Pb, Zn, As, Bi, W, Sb, Co, Cd, and S) as well as gold and silver (p. 1)."

Other regional studies of gold in skarn deposits include Ettlinger and Ray (1989), relating the distribution of PME-skarns in British Columbia to tectonic terrane, and Newberry's (1986) compilation of data on Alaskan skarns. Pearson et al. (*in press*) document skarn occurrences in the Dillon, Montana, 1 degree x 2 degree quadrangle.

Skarns are part of a continuum of alteration and mineralization produced by hydrothermal systems generated by magmatic activity. Skarn deposits are spatially associated with porphyry Cu-Mo deposits and polymetallic veins and replacements (Cox and Singer, 1986). Recent studies focusing on the behavior of gold in porphyry systems show that gold mineralization can occur in multiple locations within the same system. Sillitoe and Bonham (1990) present a model showing gold in Cu-Mo porphyry, Cu skarn, polymetallic carbonate replacement/skarn, and sediment-hosted deposits. A group of papers edited by Shawe and Ashley (1990) reexamine several large porphyry systems with special attention to gold distribution. From an exploration point of view, the potential for gold skarn mineralization must be considered within the larger context of the skarn environment.

Utah contains numerous skarn deposits. Many are small, but some, notably in the Bingham district and in the Milford area of southern Utah, are economic. Gold is present in minor concentrations in a number of Utah skarns and is a major commodity in several skarn deposits in the Bingham and Gold Hill districts.

The western portion of the state, which contains Tertiary calc-alkaline intrusive centers in a miogeosynclinal sequence of carbonate rocks, is favorable for skarn formation. Its tectonic setting, east of the accreted terrane boundary, is probably most analogous to southwestern Montana, where several gold skarns have been discovered or are currently being explored, such as Carmody-Papesh, Golden Curry, Cable and Southern Cross (Meinert, 1989).

In this study, geologic data on Utah skarn occurrences and contained gold mineralization have been compiled from published sources and the Mineral Occurrence Database at the Utah Geological and Mineral Survey. The data have been used to characterize the type of skarns that occur in Utah. General exploration criteria for gold in skarns have been derived that are particularly applicable to the geologic setting of Utah.

SKARN OCCURRENCES IN UTAH

Definition

A total of 146 skarn occurrences in Utah are listed in the Appendix. Each entry represents a separate locality where calc-silicate mineralization has been described in the literature. Occurrences within the metamorphic aureole of the same intrusive body are listed separately if they are referenced individually in the literature.

Most of the skarn occurrences are coarse-grained calc-silicate replacements of carbonate rocks adjacent to an intrusive body, and contain or are associated with sulfide mineralization. Calc-silicate hornfels, or fine-grained, relatively homogenous rock with no evidence of metasomatic addition to the rock, was excluded from this study. Size was not a criteria for selection. In a number of localities, skarn mineralization extends only a few feet outwards from the intrusive contact.

Although most of the skarn occurrences are designated by the names of mines or prospects where they occur, this is not meant to imply that these localities are classified as skarn deposits. Skarn may be spatially coincident with mineralization but have no obvious genetic relationship to it. Such is the case in many polymetallic replacement deposits, for example in the Park City district, where minor amounts of silicationoccur in proximity to manto-type deposits in relatively unaltered limestone.

The following types of geologic data were compiled from the literature for each skarn occurrence:

- Metal commodities for the deposit in which skarn occurs
- Gold content (production and/or assay data)
- Mineralogy (presence of mineral)
- Host rock (formation and age)
- Igneous rock association (name, composition, texture, form, age, multiple compositional phases, endoskarn)
- Metamorphic aureole (surface extent of calc-silicate mineralization)
- Polymetallic replacement deposits (spatial association, presence of gold)

No information was compiled on the mineralogy or alteration of the associated igneous rocks, or on structural controls of mineralization. Both subjects are relevant to skarn deposits but are beyond the scope of this study, and in many cases, data are lacking. Production figures were also omitted for all but the gold-bearing skarns.

The Appendix provides geologic data for each group of similar occurrences within a district or subdistrict. The name of the first occurrence in each group is printed in bold type. Data for the group are listed in the first row. Data pertaining only to a specific deposit in the group are listed in that row.

Methods

The Mineral Occurrence Data System (MODS) at the Utah Geological and Mineral Survey was used to compile a list of skarn occurrences in Utah. The MODS database consists of computerized records for each mineral occurrence in the state, organized by county and topographic quadrangle map. Paper files for each occurrence are also available and may include additional, often valuable, material. The computer records were searched using the following key words: skarn, contact, garnet, and metasomatism. This procedure identified the majority of skarn occurrences, which are not always labeled as such on the computer records. Searches were also made for bismuth, pyrrhotite, arsenopyrite, and tungsten. A search was made for the combination of lead, zinc, and gold, or the combination of replacement deposit and gold. The paper file for each quadrangle identified by the computer listing was then reviewed, often yielding additional occurrences. This was followed by literature research of the mining districts.

For the purposes of analysis, data for each group of similar occurrences in the same district or subdistrict were combined into a set of 54 representative occurrences, which are referenced by the name of the first occurrence in the group (indicated by bold-type in the Appendix). In the following sections, discussions of skarn characteristics refer to this set of data unless otherwise noted.

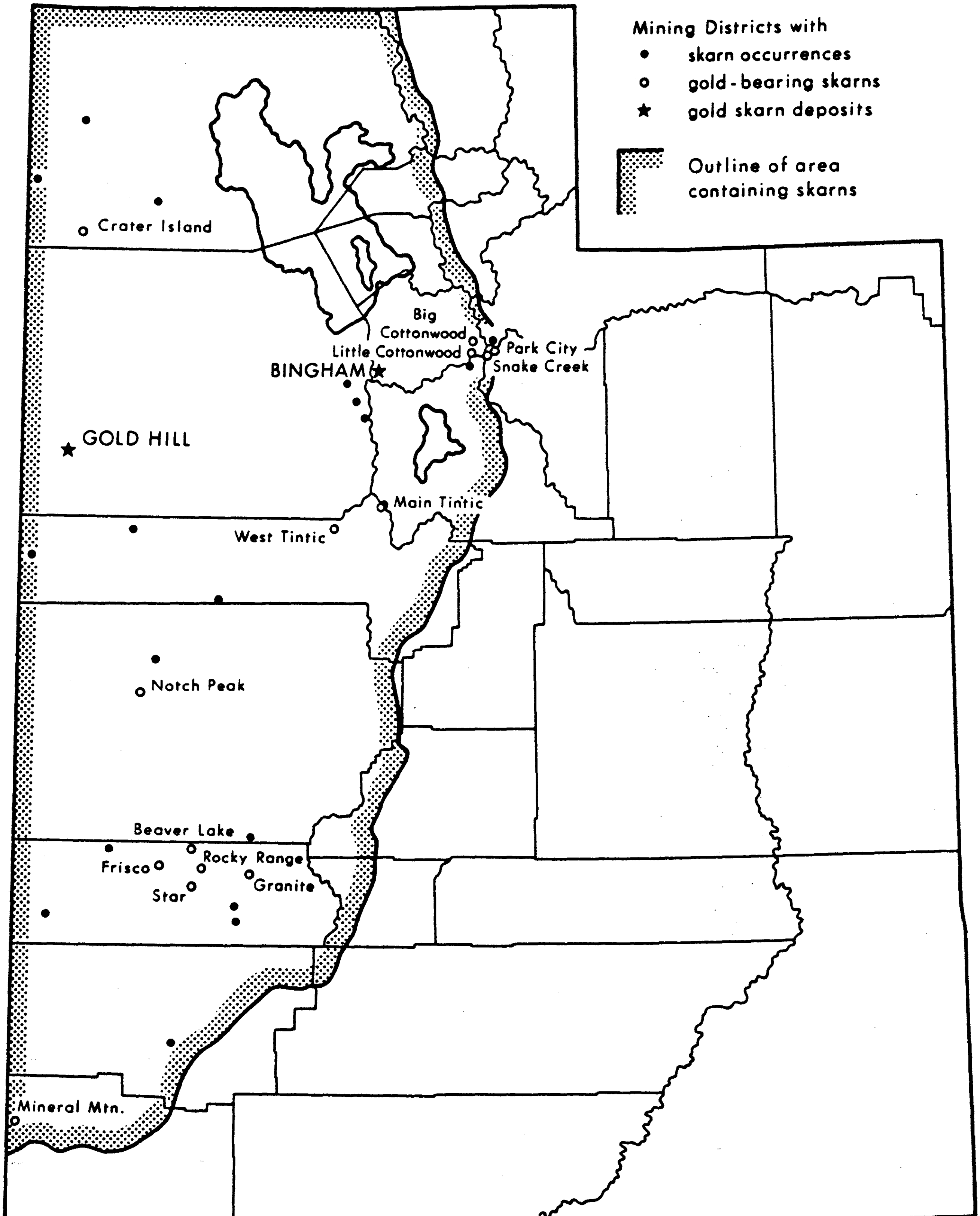


Figure 1. Skarn Occurrences in Utah

Distribution

Although the entire state was reviewed, all the skarn occurrences identified by this study are located in the western portion comprising the Basin and Range province and the mountain ranges along its eastern border (Figure 1). The majority of occurrences are in Beaver, Box Elder, Juab, Millard, Salt Lake, and Tooele Counties.

Economic commodities

Utah skarns have been mined for copper, lead, zinc, silver, gold, tungsten, molybdenum, and iron. They also have been exploited for industrial minerals. Following is a breakdown of the 54 representative skarn occurrences by primary metal commodity.

Proportion of Utah Skarn Occurrences
By Primary Metal Commodity

Commodity	Percent
Copper	30
Lead-Silver	22
Tungsten	20
Iron	15
None or unknown	7
Gold	4
Zinc	2
	100

Skarns associated with Tertiary intrusions

A total of 45 of the 54 representative skarn occurrences are associated with Tertiary intrusions. Primary metal commodities in Tertiary skarns include copper (29 percent), lead-silver (27 percent), iron (16 percent), and tungsten (16 percent). Intrusive rocks are fairly equally distributed in composition between granite (rhyolite) to granodiorite and monzonite (latite) to quartz monzonite. The majority of the intrusives form stocks or plugs and have a porphyritic texture. Multiple phases of intrusion are common in 31 percent of the localities, and endoskarn is reported at 11 percent. Hosts are carbonate rocks ranging in age from late Precambrian through Jurassic, with the most common being Mississippian or Pennsylvanian (31 percent) and Cambrian or Ordovician (31 percent). The surface extent of the metamorphic aureole ranges from less than 10 feet to substantially more than 500 feet. In general, copper and iron skarns have intermediate-sized aureoles (10 to 500 feet), while tungsten and lead-silver skarns tend to have narrow aureoles (less than 10 feet).

Calcic skarns consist dominantly of garnet, calcite, quartz, diopside, epidote, wollastonite, vesuvianite, and chlorite, listed in order of decreasing frequency. Ore minerals include chalcopyrite, pyrite, magnetite-hematite, galena, bornite, scheelite, tetrahedrite-tennantite, sphalerite, native gold, molybdenite, and argentite. Magnesian skarns contain a different assemblage characterized by brucite, forsterite, serpentine, talc, tremolite, dolomite, magnesite, and magnetite. Ore minerals that are reported exclusively in Tertiary skarns include argentite, arsenopyrite, bismuth minerals, covellite, enargite, galena, marcasite, pyrrhotite, sphalerite, stibnite, tellurides, and tetrahedrite-tennantite.

Skarns associated with Mesozoic intrusions

A total of 8 of the 54 representative skarn occurrences are associated with Jurassic intrusions. These skarns are dominantly tungsten-bearing, as noted by Moore and McKee (1983). Intrusive rocks include granite, granodiorite, monzonite, and quartz monzonite stocks, and are commonly equigranular in texture. Endoskarn is described in two occurrences. Host rocks range from Cambrian through Permian but the majority are lower Paleozoic in age. The surface extent of the metamorphic aureole is generally less than for Tertiary intrusions, ranging from 10 to 300 feet from the exposed intrusive contact. Garnet, epidote, quartz, and calcite are the most common calc-silicate minerals. Ore minerals include scheelite, chalcopyrite, pyrite, bornite, and powellite. Marble is also common.

Metal zonation

Metal zonation has been described for some Utah mining districts containing skarn. The sequence is typical of porphyry deposits, with an inner copper-gold zone progressing outwards to a lead-zinc-silver zone (Cox and Singer, 1986). Zonation has been described in the Big Cottonwood district (James, 1979), the Fish Springs district (Heyn, 1981), the Gold Hill district (El-Shatoury and Whelan, 1970), the Park City district (Wilson, 1959), the Stockton district (Moore et al., 1966), the Main Tintic district (Morris and Mogenson, 1978), and the West Tintic district (Stringham, 1942; Stein et al., 1990). The late overprint of siliceous gold-silver in lead-zinc replacements has been described in the Frisco district (Stringham, 1967) and in the Star district (Abou-Zied and Whelan, 1973). Magnetite and scheelite ores commonly occur between the intrusive body and garnet skarn, as in the Rocky Range (Butler, 1913) and Big Cottonwood districts (James, 1979).

GOLD-BEARING SKARNS

A total of 34 of the 146 skarn occurrences in Utah are classified as gold-bearing (Figure 1, Appendix). On the assumption that any gold mineralization could be significant to exploration, an occurrence is included if the gold content is greater than 0.01 ounce per short ton (0.34 ppm). Also included are occurrences for which assay data are unavailable but where gold or native gold is reported. Gold-bearing skarns are listed in Table 1. Those in which gold is a primary or secondary commodity are indicated by an asterisk.

Occurrence index

An occurrence index was calculated to determine whether a particular mineral or other geologic feature is more common in gold-bearing or non-gold-bearing skarns. An index of 1 is obtained when the item is reported exclusively in gold-bearing skarns. An index of 0 is obtained when the item is reported exclusively in non-gold-bearing skarns. An index of 0.5 indicates that the item is found with equal frequency in both groups.

$$\text{Occurrence index} = \frac{\text{percent of gold-bearing skarns}}{\text{percent of gold-bearing skarns} + \text{percent of non-gold-bearing skarns}}$$

where the percent value equals the proportion of occurrences containing a particular mineral or other geologic feature.

Metal commodities

Among gold-bearing skarns, copper is most commonly listed as the primary commodity, followed by lead-silver, iron, tungsten, and gold. Among non-gold-bearing skarns, tungsten is most commonly listed, followed by copper, lead-silver, iron, and zinc.

<u>Mineralogy</u>

The percentage of occurrences in which each mineral is present are given in Table 2 for both gold-bearing and non-gold bearing skarns. It is important to remember that the data are incomplete, particularly for the smaller mining districts. In general, the less ore produced, the fewer minerals reported.

The most common gangue minerals in gold-bearing skarns are garnet, diopside, epidote, quartz, and wollastonite. The most common ore minerals are chalcopyrite, pyrite, galena, and magnetite. These minerals are present in more than 50 percent of the occurrences. These results agree substantially with those of Theodore et al. (1991) for their set of byproduct-gold skarns.

Following is a list of gangue and ore minerals more commonly found in either gold-bearing or non-gold-bearing skarns. The indices calculated for each mineral are given in Table 2. Minerals that occur in less than 10 percent of both groups have been omitted.

Unique to gold-bearing skarns (index=1)

smithsonite	covellite
	enargite

Characteristic of gold-bearing skarns (index>0.66)

apatite	argentite
muscovite	arsenopyrite
serpentine	bornite
talc	chalcocite
wollastonite	molybdenite
magnesite	pyrrhotite
pyrolusite	sphalerite
	tetrahedrite
	native gold

Characteristic of non-gold-bearing skarns (index<0.33)

biotite
limonite
opal, chalcedony

This distribution suggests that gold-bearing skarns may be distinguished from non-gold-bearing skarns by ore rather than gangue mineralogy.

The data show the following associations (not assemblages) of sulfide minerals: bornite-chalcocite-chalcopyrite-covellite; molybdenite-scheelite; and galena-sphalerite-enargite-tetrahedrite. The significance of these sulfide associations with respect to gold mineralization is not known.

A large number of the gangue minerals characteristic of gold-bearing skarns are magnesian, although dolomite host rocks are less common in gold-bearing than in non-gold-bearing skarns, as discussed in a later section on host rocks. Gold-bearing skarns can be divided into a magnesian group (12 occurrences containing at least one of the following minerals: brucite, fosterite, serpentine, spadaite, spinel, talc, tremolite, vesuvianite, dolomite, or magnesite) and a non-magnesian group (10 occurrences containing none of those minerals). Dolomite host rocks are present in 40 percent of the magnesian group, versus 10 percent in the non-magnesian group, suggesting that the magnesium cannot be wholly attributed to original host rock composition. Other hydrous minerals (actinolite, chlorite, clay, epidote, and sericite) show a strong correlation with the magnesian versus the non-magnesian group, and a number of ore minerals are more common in one group than the other. In some districts, pre-ore dolomitization or Mg-metasomatism may be the source of magnesium in the skarns. Such is the case in the Tintic district (Lovering, 1949) and the Bingham district (Atkinson and Einaudi, 1978). Possibly the hydrothermal processes that promote early dolomitization or mobilization of magnesium are in some way linked to gold mineralization.

A number of minerals are characteristic or unique to gold-bearing skarns, whereas few minerals are characteristic and none is unique to non-gold-bearing skarns. This reflects the relative diversity of the non-gold-bearing group.

Elements associated with gold

The mineralogic characteristics of gold-bearing skarns indicate that gold is associated with the following elements: copper, arsenic, tellurium, antimony, silver, zinc, molybdenum, iron, manganese, barium, bismuth, lead, and tungsten.

Sedimentary host rocks

The majority of gold-bearing skarns occur in Mississippian to Pennsylvanian carbonate host rocks. In contrast, non-gold-bearing skarns are most common in lower Paleozoic units as reflected in the slightly greater frequency of dolomitic host rocks. Dolomite is present in 27 percent of the districts containing gold-bearing skarns, and in 34 percent of the districts containing non-gold-bearing skarns.

Host Rock Age

Ages of associated host rocks	Percent of gold-bearing skarn occurrences	Percent of non-gold-bearing skarn occurrences
Triassic-Jurassic	4	6
Permian	14	9
Mississippian-Pennsylvanian	55	9
Silurian-Devonian	0	9
Ordovician	9	16
Cambrian	14	28
Precambrian	0	3
Unknown	4	20
	100	100

Igneous rock association

Two possibly diagnostic features of igneous rocks associated with gold-bearing and non-gold-bearing skarns are the presence of multiple intrusive phases (index=0.74), and the development of endoskarn (index=0.90). However, using available data, gold-bearing skarns could not be distinguished from non-gold-bearing skarns on the basis of associated igneous rock composition, texture, form, or age.

Metamorphic aureole

The metamorphic aureole tends to be significantly larger around intrusions associated with gold-bearing than non-gold-bearing skarns, although the range in size (less than 10 feet to greater than 500 feet) is the same.

Gold-bearing polymetallic replacement deposits

Gold-bearing polymetallic replacement deposits are somewhat more likely to be present in districts with gold-bearing skarns (index=0.59). Gold is generally present in polymetallic replacement deposits associated with gold-bearing skarns.

Gold-bearing and non-gold-bearing copper skarns

Criteria that distinguish gold-bearing from non-gold-bearing copper skarns are summarized in Table 3. In general, the characteristics of gold-bearing skarns, such as mineralogy, presence of endoskarn, and age of sedimentary host rocks, are confirmed and in some cases accentuated in gold-bearing copper skarns.

GOLD SKARNS

A total of 7 of the 34 gold-bearing skarn occurrences list gold as the primary or secondary commodity (Table 1, Figure 1). All of these are located in the Bingham and Gold Hill (Clifton) mining districts, with the exception of one occurrence in the Tintic district, where the gold does not seem to be genetically related to the enclosing skarn (Morris, 1968). The Parnell gold shoot in the Carr Fork mine, Bingham district, and the Midas, Alvarado, and Cane Springs deposits, in the Gold Hill district, are valuable for gold alone. Theodore et al. (1991) classify the Parnell as "porphyry Cu skarn related byproduct gold," and the Midas as a "gold-bearing skarn in which gold and silver are major commodities exploited." Alvarado and Cane Springs are listed as possible gold-bearing skarns for which grade and tonnage are unavailable.

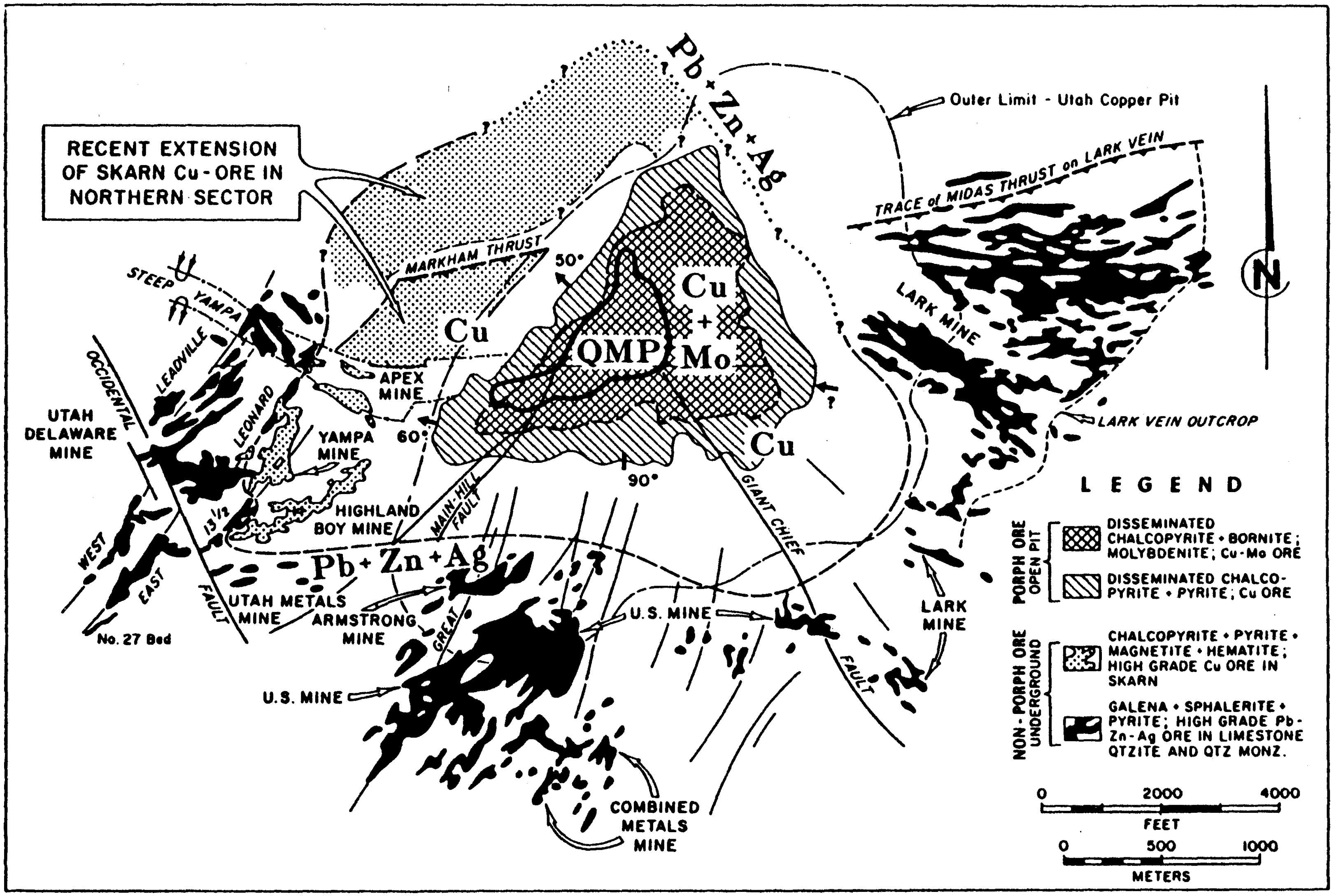
Since known gold skarns are restricted to two mining districts, the data are too limited to generalize. Furthermore, some of the occurrences classified as gold-bearing skarns may in fact contain unrecognized gold deposits.

Gold skarns in the Bingham and Gold Hill mining districts are briefly described below.

Bingham district

Copper-gold ore bodies hosted by garnet skarn at Bingham constitute one of the largest skarn deposits in the world (Einaudi, 1982; Figure 2). Skarns are primarily developed in two limestone beds of the Pennsylvanian Bingham Mine Formation on the northern and western margins of the Bingham stock, a composite intrusion of late Eocene age that hosts the porphyry copper deposit (Tooker, 1990). Ore minerals and altered wall rock zones can be related to the quartz monzonite porphyry phase of the Bingham stock (John, 1978).

As outlined by Atkinson and Einaudi (1978) and summarized by Einaudi (1982), early contact



Principal mines, surface projection of composite stoping, and metal zoning in the Bingham district. Porphyry ore zoning based on figure F-3 of John (1975); U. S. and Lark mines stoping based on Figure 1 of Rubright and Hart (1968). QMP = quartz monzonite porphyry.

Figure 2. Map of the Bingham district, Utah (from Atkinson and Einaudi, 1978, figure 17)

metasomatism of the limestones produced wollastonite marble with trace sulfides. Main stage skarn alteration, linked to potassic alteration in the intrusion, consists of garnet, diopside, magnetite, and chalcopyrite superimposed on early stage wollastonite up to 1,500 feet from the porphyry contact. This assemblage was altered to mixtures of calcite, hematite, magnetite, siderite, and actinolite. The major introduction of sulfides occurred at this time. Late stage skarn alteration, contemporaneous with sericite-pyrite alteration of the intrusive rocks, produced pyrite, chlorite, montmorillonite, sericite, talc, and opal from early calc-silicates, with some redistribution of chalcopyrite. Lead-zinc and gold mineralization are linked to this late stage.

The Carr Fork deposit is contiguous with other skarn ore underlying an area north of the Bingham stock, which contain on the order of 4 million ounces of gold (Tooker, 1990). Average gold grades of skarn ore in the Carr Fork portion of the deposit range from 0.01 to 0.02 opt, or 0.3 to 0.7 ppm (Cameron and Garmoe, 1987; Einaudi, 1982). A strong correlation exists between copper and gold (Einaudi, 1982; Cameron and Garmoe, 1987).

Structurally controlled zones of high-grade gold mineralization occur as an overprint on copper-gold skarns in the Carr Fork mine (Cameron and Garmoe, 1987). One such zone, known as the Parnell gold shoot, contains a drill-indicated and inferred geologic resource of over 150,000 ounces of gold. The undiluted ore grade is estimated at 0.3 to 0.35 opt (10.3 to 12.0 ppm) gold. Ore consists of pyrite-quartz flooding with chalcopyrite, tennantite, arsenopyrite, and pyrrhotite. Pods of pyrite-quartz flooding are in sharp contact with copper-gold ores and appear to have altered preexisting garnet to siderite, quartz, and pyrite. Arsenic-rich pyrite-clay alteration also occurs with gold mineralization.

Gold Hill district

The variety of ores at Gold Hill makes it one of the most complex and tantalizing mining districts in Utah, yet total production is relatively small. Precious metal production from 1892 to 1961 amounted to 25,849 ounces of gold and 832,325 ounces of silver. Copper, lead, zinc, tungsten, and possibly as much as 100,000 tons of arsenic have also been mined (Tripp et al., 1989).

Skarn deposits occur in Mississippian and Pennsylvanian carbonate units in proximity to an intrusive complex consisting of a Jurassic granodiorite pluton, an Oligocene quartz monzonite pluton, and various younger phases including quartzofeldspathic dikes (Moore and McKee, 1983; Robinson; 1988). As summarized by Nolan (1935), there are two main types of silicate alteration of limestone beds. One is a dark colored, diopside-garnet rock containing tungsten, bismuth, and molybdenum minerals and locally replaced by zoisite, humite, and actinolite. The Frankie mine, a polymetallic deposit with minor gold, occurs in this type of skarn. The other type, which contains gold ore, is a light colored rock consisting of bladed wollastonite that is locally almost completely replaced by spadaite, a hydrated magnesium silicate. Gold and copper are generally the only ore metals. In both skarn types, chloritization occurs near ore.

Gold skarns occur in the Alvarado and Cane Springs mines, located near the town of Gold Hill between the two plutons, and in the Bonnemort and Midas mines, located farther south along the border of the Jurassic pluton (Figure 3). Nolan (1935) states that all four deposits are similar, although spadaite has not been recognized at the Bonnemort. Zimbelman (1991) also lists the Goldstar mine, located west of the Midas, and gives additional geochemical data for Goldstar, Midas, and Cane Springs. Nolan's (1935) descriptions indicate that gold occurs in areas of spadaite and zoisite alteration. Native gold occurs in veins with copper sulfides, pyrite, and their oxidation products. Nolan also quotes an earlier reference to native gold embedded in silicate minerals (Kemp, 1918).

Ages of skarn alteration and mineralization in the Gold Hill district are difficult to unravel due to multiple periods of igneous activity and numerous structural events. Nolan (1935, p. 92) comments that one of the

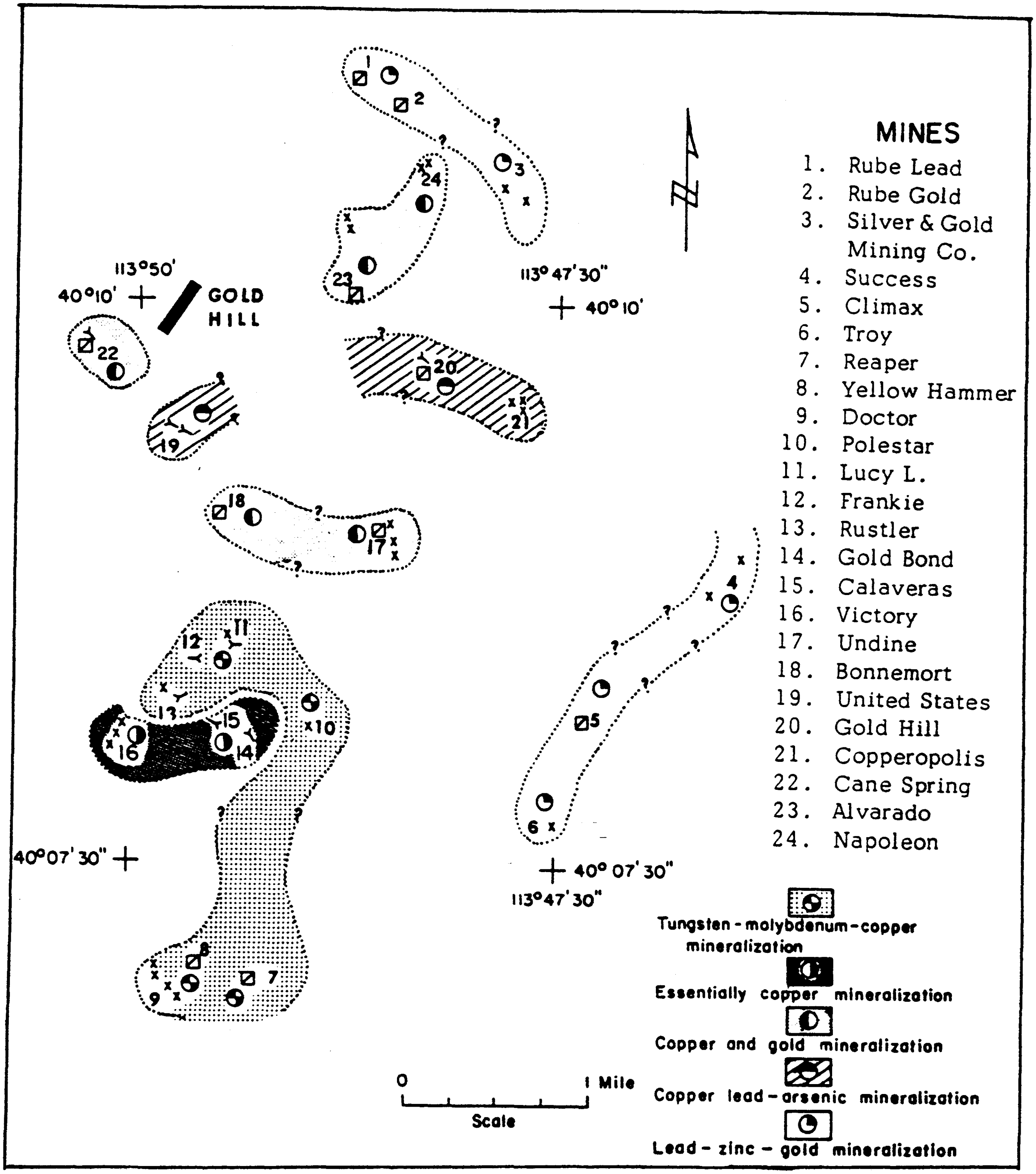


Figure 3. Map of the Gold Hill district (from El-Shatoury and Whelan, 1970, figure 9)

"most striking features in the distribution of (contact metamorphic rock) in the Gold Hill quadrangle . . . is that the silicate-mineral alteration has been effected with very little regard for the actual igneous contact." Robinson (1988) assigns a tentative late Jurassic age to the Frankie deposit, and a mid-Tertiary age to the Alvarado, Cane Springs, and Bonnemort deposits.

GOLD POTENTIAL OF THE SKARN ENVIRONMENT IN UTAH

The presence of gold in minor to ore-grade concentrations in numerous Utah skarns favors potential for additional discoveries. The gold potential of different types of Utah skarns and some aspects of the skarn environment are briefly discussed in the following sections.

Copper skarns

A strong association exists between gold and copper in skarns (Meinert, 1989; Theodore et al., 1991). Copper skarns in Utah present an obvious exploration target, particularly if known to contain trace amounts of gold. The challenge is to find ore-grade concentrations of gold within the copper skarn environment.

The highest gold grades in copper skarns are generally associated with strong retrograde alteration (Meinert, 1989). Retrograde alteration and accompanying sulfide mineralization are commonly confined to faults and fractures intersecting the skarn, and as noted by Theodore et al. (1991), these structures are important guides to ore.

Models of copper skarn deposits include an inner copper-gold-silver skarn, an intermediate zone of gold-skarn or other types of gold mineralization, and peripheral zinc-lead-silver mineralization with minor gold (Theodore et al., 1991; Cox and Singer, 1986, Model 18b). Thus copper skarns containing low-grade gold may point the way to peripheral gold skarns.

Citing studies by Greg Myers at Fortitude, Nevada, Meinert (1989) suggests that the formation of gold skarns is favored by reducing conditions, whereas the formation of copper skarns is favored by oxidizing conditions. He concludes that the distal part of the skarn system formed under reducing conditions has greater gold potential that the inner, garnet-rich part. To generalize his point, systematic changes in skarn mineralogy that indicate a change in oxidation state of the system would also be exploration guides to gold.

Tungsten and tungsten-bearing skarns

Many tungsten skarns form at relatively high temperatures and pressures (Einaudi et al., 1981) and are not known to contain gold. However, a tungsten-gold association has been reported in many skarns, as summarized by Theodore et al. (1991).

Most tungsten skarns in Utah are not gold-bearing. Of eleven skarn localities where tungsten is the primary commodity, only two contain gold: the Notch Peak and the Granite districts. Tungsten is present as scheelite in nearly half the gold-bearing skarns (Table 2), generally as a minor commodity with copper or lead-zinc-silver. Over 80 percent of these skarns are associated with Tertiary intrusions.

In Utah, tungsten or tungsten-bearing skarns associated with Tertiary intrusions may have significant gold potential. Tungsten skarns associated with Jurassic intrusions, such as those in Box Elder County, appear from the literature to be narrow bodies with little retrograde alteration or potential for gold. An important exception is the Notch Peak district, which contains gold, possibly related to a later period of mineralization.

Iron skarns

Iron replacements and contact metasomatic deposits, also referred to as tactites, are an important source of iron ore in Utah (Bullock, 1970). These deposits may be a guide to other skarn mineralization, however no evidence was seen in this study of a direct association between gold and iron ores.

Late-stage gold

Some skarn deposits show evidence of late-stage gold mineralization. Veins or zones with strong structural control crosscut and may replace both main stage and retrograde skarn alteration. The Parnell gold shoot, Bingham district, is an example. Other examples outside Utah include deposits in British Columbia (Ettlinger and Ray, 1988) and the Monte Cristo deposit, Nevada (Myers et al., 1991). This type of ore is commonly highly siliceous and/or pyritic and contains a different suite of sulfides or sulfosalts than the enclosing skarn. Mineralization may have occurred during the final stage of skarn formation, or may represent a much later epithermal overprint, as discussed by Theodore et al. (1991). It may not be restricted to the skarn zone, but may extend considerably beyond.

Carbonate-hosted polymetallic veins and replacements

In porphyry systems, skarn occurs closer to the intrusive center while polymetallic veins and replacements occur father out in weakly altered to unaltered limestone. Theodore et al. (1991) state that polymetallic vein and replacement deposits with geochemical signatures similar to gold-bearing skarns may be high-level or lateral reflections of such skarns. Carbonate-hosted polymetallic replacement deposits are common in the miogeosynclinal terrane of Utah and offer a potential exploration guide to gold-bearing skarn. It is not always clear, however, whether polymetallic replacement deposits are invariably associated with skarn mineralization at depth and what significance, if any, the presence of gold in replacements has with respect to gold in skarns.

Three Utah mining districts that produced major tonnages of lead-zinc-silver-gold replacement ores are Bingham, Tintic, and Park City (James, 1973). Bingham exposes the full spectrum of porphyry copper, copper-gold skarn, and carbonate-hosted polymetallic replacement deposits, zoned in an apparently straightforward manner outwards from a single intrusive phase (John, 1978). Tintic and Park City are primarily gold-bearing polymetallic replacement deposits, although Tintic was by far the major gold producer of the two. Minor skarn is exposed in both these districts but is essentially unmineralized. A small porphyry copper deposit has been detected at depth in the Tintic district (Morris, 1990), and a low-grade porphyry copper system is present east of the Park City district (John, 1989).

In all three districts, polymetallic replacement ores seem to be superimposed on earlier skarn mineralization. At Bingham, copper-gold ore occurs in garnet skarn or slightly farther out in white silicated limestone (Hunt, 1924). Lead-zinc-silver ore occurs beyond the copper zone, although locally the two ores are intermingled, and extends outwards into essentially unaltered black limestone (Rubright and Hart, 1968; Atkinson and Einaudi, 1978). The degree of alteration of the limestone host rocks differs in lead-zinc-silver mines around the circumference of the district (Hunt and Peacock, 1950). At Tintic, skarn is developed in an embayment along the northeast contact of the Silver City stock and coincides with the copper-gold zone (Morris, 1968). Lindgren and Loughlin (1919, p. 97) note that the "general absence of metallic minerals [in the skarn] is very striking, and in marked contrast to their presence in most bodies of contact-metamorphosed limestone and dolomite." At Park City, limestones hosting ore are relatively fresh and unaltered. A contact zone is developed adjacent to the Clayton Peak stock in the southwest portion of the district (Boutwell, 1912), and minor calc-silicate alteration appears on the lower levels of the Ontario mine (Bromfield, 1989), but skarn appears to have only a coincidental relationship with ore. One interpretation of the relationships at Tintic and Park City is that the skarn and polymetallic replacements are related to separate intrusions.

Zoning in all three districts proceeds from copper-gold to lead-zinc-silver outwards from the intrusive center, but space and time relations between the two types of mineralization differ. At Bingham, lead-zinc-silver veins crosscut skarn containing earlier copper-gold mineralization, reflecting the late, inwards collapse of the hydrothermal system (Atkinson and Einaudi, 1978). At Tintic, copper-gold chimneys occur within the zone of lead-silver replacements (Morris, 1968). At Park City, the two types of ore occur in close proximity at the Mayflower mine (Bromfield, 1989). These relationships may be significant with regard to the potential for copper-gold skarn ore at depth.

Gold grades in lead-zinc-silver ores in these districts averaged on the order of 0.02 to 0.06 opt (0.7 to 2.0 ppm) gold. At Bingham, lead-zinc-silver ores ranged from 0.03 to 0.06 opt (1.0 to 2.0 ppm) gold (Einaudi, 1982; Hunt and Peacock, 1950). Figures for Tintic are not available. At Park City, replacement ores in the Daly West, Judge, Silver King, and Ontario mines averaged 0.025 opt (0.9 ppm) gold (Barnes and Simos, 1968). However, in all three districts, the major portion of gold production came from copper ore containing chacopyrite and/or enargite. At Bingham, the average gold grade of copper skarn ore is comparable to that of lead-zinc-silver ore (Einaudi, 1982), but the tonnage of copper skarn ore, including both past production and reserves, outweighs the tonnage of lead-zinc-silver ore that has been produced (Tooker, 1990; James, 1973). At Park City, lead-zinc-silver replacements account for roughly 70 percent of the district production, but over 60 percent of the gold came from intrusive-hosted veins in the Mayflower mine in which gold occurs with chalcopyrite (Bromfield, 1989; Quinlan and Simos, 1968). At Tintic, where replacement ores account for over 90 percent of district production, rich gold ores occur with copper in veins or in siliceous replacements (Morris, 1990).

Jones and Leveille (*in press*) present a geochemical model to explain the relatively low content of gold in the lead-zinc-silver zone of most porphyry copper deposits, and the formation of distal epithermal gold deposits beyond that zone. They show that where conditions favor the formation of lead-zinc-silver ores, gold is highly soluble as bisulfide complexes. They suggest that the bulk of the gold remains in solution until being precipitated at a more distal location.

The formation of carbonate-hosted lead-zinc-silver replacement deposits involves widespread, relatively low temperature hydrothermal activity with a large component of meteoric water. For this reason, their presence in a district may indicate that remobilization and concentration of gold has occurred along favorable structures.

<u>Jurassic and Tertiary igneous activity</u>

The majority of igneous intrusions in the eastern Great Basin of Utah are Tertiary in age. A few isolated intrusions with no associated volcanics occur in Box Elder,.Tooele, and Millard Counties and yield Jurassic ages (Moore and McKee, 1983). These may represent the easternmost extent of Jurassic intrusive activity. Cretaceous plutonism, which occurred farther inboard from the continental margin (Cox et al., 1991), apparently did not extend to Utah.

The coincidence of Jurassic and subsequent Tertiary magmatism may be important for the eventual formation of gold deposits. In the Gold Hill district, stocks of both ages are present. Polymetallic skarns near the Jurassic stock contain some gold, while skarns near the Tertiary stock contain gold ore. It is interesting to speculate whether repeated magmatism helped to concentrate gold. Other districts in Utah containing Mesozoic intrusions might be examined for evidence of later Tertiary activity. In general, the region of Utah encompassing Jurassic magmatic activity is prospective for gold.

EXPLORATION GUIDES

Characteristics of gold-mineralized skarns that might serve as exploration guides have been proposed by Meinert (1989) and Theodore et al. (1991) based on surveys of skarn deposits worldwide. In addition, the following criteria are proposed as being particularly applicable to gold exploration in the skarn environment within Utah. They are based on empirical observations derived from this compilation and from other published work referenced in the preceding sections.

District-wide:

- Multiple phases of intrusion, especially the combination of equigranular and porphyry phases with late porphyry dikes.

- Presence of endoskarn.

- Mississippian to Pennsylvanian host rocks, especially those containing interbedded reactive and non-reactive units.

- Dolomitization or evidence of magnesian metasomatism.

- Gold-bearing polymetallic replacement deposits with anomalous bismuth.

- Coincidence of Mesozoic and mid-Tertiary magmatic activity.

Within the skarn zone:

- Copper and/or tungsten mineralization (lead-silver and iron are also permissive).

- A large metamorphic aureole.

- Structurally-controlled retrograde alteration cutting main stage skarn.

- Ore minerals:

	argentite	enargite
	arsenopyrite	molybdenite
	bornite	native gold
	chalcocite	pyrrhotite
	chalcopyrite	sphalerite
	covellite	tetrahedrite

- Associated elements: Cu, As, Te, Sb, Ag, Zn, Mo, Fe, Mn, Ba, Bi, Pb, and W

Skarn deposits in the following Utah mining districts appear, based solely on literature research, to have potential for gold exploration. The listing is alphabetical.

Beaver County: Frisco, Granite, Lincoln, Rocky Range, and Star
Box Elder County: Crater Island
Juab County: West Tintic
Millard County: Notch Peak
Tooele County: Gold Hill, Stockton
Washington County: Mineral Mountain

ACKNOWLEDGEMENTS

This study was funded by the Utah Geological and Mineral Survey as a Mineral Lease Project (contract #89 3574). I thank the UGMS for their support and liberal extension policy. Mike Shubat served as technical advisor and also assisted me in using the computerized records at the UGMS. Bob Gloyn was, as always, a source of stimulating discussions. I thank Jane Hammarstrom and Ed Tooker of the U. S. Geological Survey for their reviews of this report. I also thank Tom Faddies, Jim Garmoe, Virginia Gillerman, Thon Gin, Leon Hansen, Dick Klatt, and Paula Wilson for discussions of Utah geology, and Dave Severson for his excellent drafting. Some of the ideas expressed in this report are prevalent in the exploration community but difficult to attribute to an individual. I take responsibility for the misapplication thereof.

REFERENCES

Abou-Zied, S., and Whelan, J. A., 1973, Geology and mineralogy of the Milford Flat quadrangle, Star district, Beaver County, Utah: Utah Geological and Mineral Survey Spec. Studies 46.

Atkinson, W. W., Jr., and Einaudi, Marco T., 1978, Skarn formation and mineralization in the contact aureole at Carr Fork, Bingham, Utah: Economic Geology, v. 73, p. 1326-1365.

Barnes, Marvin P., and Simos, John G., 1968, Ore deposits of the Park City district with a contribution on the Mayflower lode, *in* Ridge, John D., ed., Ore deposits of the United States, 1933-1967 (Graton-Sales volume) v. 2: New York, AIME, p. 1102-1126.

Barosh, Patrick J., 1960, Beaver Lake Mountains, their geology and ore deposits, Beaver County, Utah: Utah Geological and Mineral Survey Bull. 68, 89 p.

Best, M. G., Grant, S. K., and Holmes, R. D., 1979, Geologic map of the Miners Cabin Wash and Buckhorn Spring quadrangles, Beaver County, Utah: U. S. Geological Survey Open-File Report 79-1612, 1:24,000.

Boutwell, John M., 1905, Economic geology of the Bingham mining district, Utah: U. S. Geological Survey Prof. Paper 38, 413 p.

_____1912, Geology and ore deposits of the Park City district, Utah: U. S. Geological Survey Prof. Paper 77, 231 p.

_____1935, Copper deposits at Bingham, Utah, *in* Copper resources of the world: Washington, XVI International Geologic Congress, p. 347-359.

Bromfield, Calvin S., 1989, Gold deposits in the Park City mining district, Utah, *in* Shawe, Daniel R., and Ashley, Roger P., eds., Gold-bearing polymetallic veins and replacement deposits -- Part I: U. S. Geological Survey Bull. 1857-C, p. C14-C26.

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 Bull. 1491.

Bullock, Kenneth C., 1970, Iron deposits of Utah: Utah Geological and Mineral Survey Bull. 88, 101 p.

Bullock, Kenneth C., 1981, Minerals and mineral localities of Utah: Utah Geological and Mineral Survey Bull. 117, 177 p.

Butler, B. S., 1913, Geology and ore deposits of the San Francisco and adjacent districts: U. S. Geological Prof. Paper 80, 212 p.

Butler, B. S., Loughlin, G. F., Heikes, V. C., et al.,1920, The ore deposits of Utah: U. S. Geological Survey Prof. Paper 111, 648 p.

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

Callaghan, Eugene, 1973, Mineral resource potential of Piute County, Utah, and adjoining area: Utah Geological and Mineral Survey Bull. 102.

Cameron, Donald E., and Garmoe, W. J., 1987, Geology of skarn and high-grade gold in the Carr Fork mine, Utah: Economic Geology, v. 82, p. 1319-1333.

Cox, Dennis P., Ludington, Steve, Sherlock, Maureen G., Singer, Donald A., Berger, Byron R., and Tingley, J. V., 1991, Mineralization patterns in space and time in the Great Basin of Nevada, *in* Raines, Gary L., Lisle, Richard E., Schafer, Robert W., and Wilkinson, William H., eds., Geology and ore deposits of the Great Basin: Reno, Nevada, Geological Society of Nevada, p. 193-198.

Cox, Dennis P., and Singer, Donald A., eds., 1986, Mineral deposit models: U. S. Geological Survey Bull. 1693, 379 p.

Cox, Leslie J., Duttweiler, Karen A., et al., 1989, Mineral resources of the Wah Wah Mountains Wilderness Study Area, Beaver and Millard Counties, Utah: U. S. Geological Survey Bull. 1747-B, 21 p.

Crawford, A. L., and Buranek, A. M., 1942, Tremolite deposits of the Mineral Range, Millard County, Utah: Utah Geological and Mineral Survey Circ. 2, 7 p.

_____1957, Tungsten reserves discovered in the Cottonwood-American Fork mining district, Utah: Utah Geological and Mineral Survey Reprint 55.

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

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

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

Einaudi, Marco T., 1982, Descriptions of skarns associated with porphyry copper plutons: Southwestern North America, *in* Titley, Spencer R., ed., Advances in geology of the porphyry copper deposits: Tucson, Arizona, University of Arizona Press, p. 139-183.

Einaudi, M. T., and Burt, D. M., 1982, Introduction -- terminology, classification, and composition of skarn deposits, *in* A special issue devoted to skarn deposits: Economic Geology, v. 77, p. 745-754.

Einaudi, M. T., Meinert, L. D., and Newberry, R. J., 1981, Skarn deposits, *in* Skinner, Brian J., ed., Seventy-fifth anniversary volume, 1905-1980, Economic Geology: New Haven, Connecticut, Economic Geology Publishing Company, p. 317-391.

El-Shatoury, H. M., and Whelan, J. A., 1970, Mineralization in the Gold Hill mining district, Tooele County, Utah: Utah Geological and Mineral Survey Bull. 83, 37 p.

Eppinger, Robert G., Winkler, Gary R., et al., 1990, Preliminary assessment of the mineral resources of the Cedar City 1 degree x 2 degree quadrangle, Utah: U.S. Geological Survey Open-File Report 90-34,146 p.

Erickson, M. P., 1966, Igneous complex at Wah Wah Pass, Beaver County, Utah: Utah Geological and Mineral Survey Spec. Studies 17, 14 p.

Ettlinger, A. D., and Ray, G. E., 1989, Precious metal enriched skarns in British Columbia: An overview and geological study: British Columbia Ministry of Energy, Mines, and Petroleum Resources Paper 1989-

3, 128 p.

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

Gehman, H. M., Jr. 1958, Notch Peak intrusive, Millard County, Utah -- Geology, petrogenesis, and economic deposits: Utah Geological and Mineral Survey Bull. 62, 50 p.

Gilluly, James, 1932, Geology and ore deposits of the Stockton and Fairfield quads, Utah: U. S. Geological Survey Prof. Paper 173, 171 p.

Hansen, Leon A., 1961, The stratigraphy of the Carr Fork mines, Bingham district, Utah, *in* Cook, Douglas R., ed., Geology of the Bingham mining district and northern Oquirrh Mountains: Utah Geological Society Guidebook to the Geology of Utah Number 16, p. 71-81.

Heyn, Paul V., 1981, Outline of exploration and past production, Fish Springs mining district, and Utah International Inc.'s Crypto Project, Juab County, Utah: Unpublished report, Utah Geological and Mineral Survey files.

Hintze, L. F., 1974, Preliminary geologic map of the Notch Peak quadrangle, Millard County, Utah: U. S. Geological Survey Misc. Field Studies Map MF-636, 1:48,000.

Hobbs, S. W., 1945, Tungsten deposits in Beaver County, Utah: U. S. Geological Survey Bull. 945-D, 111 p.

Hunt, Richard N., 1924, The ores in the limestones at Bingham, Utah: AIME Trans., v. 70, p. 856-883.

Hunt, R. N., and Peacock, H. G., 1950, Lead and lead-zinc ores of the Bingham district, Utah, *in* Lead-zinc-symposium and proceedings of section F: 18th International Geology Congress, Great Britain, 1948, pt. 7, p. 92-96.

James, Allan H., 1973, Lead and zinc resources in Utah: Utah Geological and Mineralogical Survey Spec. Studies 44, 66 p.

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

John, David A., 1989, Evolution of hydrothermal fluids in the Park Premier stock, Central Wasatch Mountains, Utah: Economic Geology, v. 84, p. 879-902.

John, Edward C., 1975, Mineral zones of the Bingham district, *in* Bray, R. Eldon, and Wilson, John C., eds., Guide Book to the Bingham mining district, Soc. of Econ. Geologists, October 23, 1975: Bingham Canyon, Utah, Kennecott Copper Corp., p. 59-72.

John, Edward C., 1978, Mineral zones in the Utah Copper orebody: Economic Geology, v. 73, p. 1250-1259.

Jones, Brian K., and Leveille, Richard A., *in press*, Application of metal zoning and metal ratios to gold exploration in porphyry systems: Journal of Geochemical Exploration.

Keith, J. D., Dallmeyer, R. D., Kim, C. S., and Kowallis, B. J., 1989, A re-evaluation of the volcanic history and mineral potential of the central east Tintic Mountains, Utah: Utah Geological and Mineral Survey Open-

File Report 166, 85 p.

Kemp, J. F., 1918, Notes on Gold Hill and vicinity, Tooele County, Utah: Economic Geology, v. 13, p. 257-258.

Kerr, Paul F., et al., 1957, Marysvale, Utah uranium area: Geological Society of America Special Paper 64, p. 168-179.

Lindgren, Waldemar, and Loughlin, G. F., 1919, Geology and ore deposits of the Tintic mining district, Utah: U. S. Geological Survey Prof. Paper 107, 276 p.

Lindsey, David A., Zimbelman, David R., et al., 1989, Mineral resources of the Fish Springs Range Wilderness Study Area, Juab County, Utah: U. S. Geological Survey Bull. 1745-A, 18 p.

Lovering, T. S., 1949, Rock alteration as a guide to ore -- East Tintic district, Utah: Economic Geology Monograph 1, 64 p.

Lufkin, J. L., 1965, Geology of the Stockton stock and related intrusives, Tooele County, Utah: Brigham Young University Geol. Studies, v. 12, p. 149-164.

Lundby, William, 1987, Mineral resources of a part of the Notch Peak Wilderness Study Area (UT-050-078), Millard County, Utah: U. S. Bureau of Mines Mineral Land Assessment Open-File Report MLA-51-87, 43 p.

Mackin, J. H., 1968, Iron ore deposits of the Iron Springs district, southwestern Utah, *in* Ridge, J. D., ed., Ore deposits of the United States 1933-1967 (Graton-Sales Volume), v. 2: New York, AIME, p. 992-1019.

Meinert, Lawrence D., 1988a, Gold in skarn deposits -- A preliminary overview, *in* Zachrisson, E., ed., Proceedings of the Symposium of the 7th Quadrennial International Association of the Geochemistry of Ore Deposits: Stuttgart, E. Schweizerbart'sche, p. 363-374.

_____1988b, Gold and silver in skarn deposits, *in* Goode, A. D. T., Smyth, E. L., Birch, W. D., and Bosma, L. I., compilers, Bicentennial Gold 88, extended abstracts, poster programme, v. 2: Geological Society of Australia, p. 614-616.

_____1989, Gold skarn deposits -- Geology and exploration criteria, *in* Keays, Reid R., Ramsay, W. R. H., and Groves, David L., eds., The geology of gold deposits: The perspective in 1988: New Haven, Connecticut, Economic Geology Publishing Co., Economic Geology Monograph 6, p. 537-552.

Myers, Greg, Dennis, Michael D., Wilkinson, William H., and Wendt, Clancy J., 1991, Precious-metal distribution in the Mount Hamilton polymetallic skarn system, Nevada, *in* Raines, Gary L., and Lisle, Richard E., Schafer, Robert W., and Wilkinson, William H., eds., Geology and ore deposits of the Great Basin: Reno, Geological Society of Nevada, p. 393-404.

Miller, D. M., and Schneyer, J. D., 1985, Geologic map of the Tecoma quad, Box Elder County, Utah, and Elko County, Nevada: Utah Geological and Mineral Survey Map 77.

Moore, William J., Curtin, G. C., Roberts, R. J., and Tooker, E. W., 1966, Distribution of selected metals in the Stockton district, Utah: U. S. Geological Survey Prof. Paper 550-C, p. C197-C205.

Moore, William J., and McKee, Edwin H., 1983, Phanerozoic magmatism and mineralization in the Tooele

1 degree x 2 degree quadrangle, Utah, *in* Miller, David R., Todd, Victoria R., and Howard, Keith A., eds., Tectonic and stratigraphic studies in the eastern Great Basin: Geological Society of America Memoir 157, p. 183-190.

Morris, Hal T., 1968, The Main Tintic Mining district, Utah, *in* Ridge, John D., ed., Ore deposits of the United States, 1933-1967 (Graton-Sales volume) v. 2: New York, AIME, p. 1043-1073.

_____1990, Gold in the Tintic mining district, Utah, *in* Shawe, Daniel R., and Ashley, Roger P., eds., Gold-bearing polymetallic veins and replacement deposits -- Part II: U. S. Geological Survey Bull. 1857-F, p. F1-F11.

Morris, Hal T., and Mogensen, A. Paul, 1978, Tintic mining district, Juab and Utah Counties, Utah, *in* Shawe, Daniel R., ed., Guidebook to mineral deposits of the central Great Basin: Nevada Bureau of Mines and Geology Report 32, p. 69-75.

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

Newberry, R. J., 1986, Compilation of data on Alaskan skarns: Alaska Division of Geological and Geophysical Surveys PDF 86-21, 835 p.

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

Nutt, Constance J., Zimbelman, David R., et al., 1990, Mineral resources of the Deep Creek Mountains Wilderness Study Area, Juab and Tooele Counties, Utah: U. S. Geological Survey Bull. 1745, 40 p.

Pearson, R. C., Trautwein, C. M., Moll, S. H., et al., *in press*, Map showing mineral resource assessment for copper and molybdenum in porphyry and stockwork deposits and for tungsten, gold, copper, and silver in skarn deposits, Dillon 1 degree x 2 degree quadrangle, Idaho and Montana: U. S. Geological Survey Miscellaneous Investigations Series Map I-1803G.

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

Quinlan, J. J., and Simos, J. G., 1968, The Mayflower mine, *in* Geology of the Park City mining district, Utah: Utah Geological Society Guidebook to the Geology of Utah 22, p. 40-55.

Ray, G. E., Ettlinger, A. D., and Meinert, L. D., 1990, Gold skarns: Their distribution, characteristics and problems in classification, *in* Geological fieldwork, 1989: British Columbia Ministry of Energy, Mines and Petroleum Resources Paper 1990-1, p. 237-246.

Robinson, Jamie, 1988, Geologic map of the Gold Hill, Utah 7.5' quadrangle: Utah Geological and Mineral Survey Open-File Report 118, 1:24,000, 25 p.

Rowley, Peter D., and Barker, Daniel S., 1978, Geology of the Iron Springs mining district, Utah, *in* Shawe, Daniel R., ed., Guidebook to mineral deposits of southwestern Utah: Utah Geological Association Pub. 7, p. 49-58.

Rubright, Richard D., 1978, Geology of the Ophir district, Utah: Utah Geological Association Publication 7, p. 35-39.

Rubright, R. D., and Hart, Owen J., 1968, Non-porphyry ores of the Bingham district, Utah, *in* Ridge, John D., ed., Ore deposits of the United States, 1933-1967 (Graton-Sales Volume), v. 1: New York, AIME, p. 886-908.

Shawe, Daniel R., and Ashley, Roger P., eds., 1990, Gold in porphyry copper systems: U. S. Geological Survey Bull. 1857-E, 55 p.

Sillitoe, Richard H., and Bonham, Harold F., Jr., 1990, Sediment-hosted gold deposits: Distal products of magmatic-hydrothermal systems: Geology, v. 18, no. 2, p. 157-161.

Smith, Robert K., 1972, The mineralogy and petrology of the contact metamorphic aureole around the Alta stock, Utah: University of Iowa, Ph.D. dissertation, 215 p.

Stein, Holly J., Kelley, David L., Kaminsky, Jon F., and Gordan, Ian R., 1988, Field trip guide for the West Tintic mining district, western Utah: U. S. Geological Survey Open-File Report 88-558, 12 p.

______1990, The geology and ore deposits at the West Tintic mining district, Utah (Abstr.), *in* Geology and ore deposits of the Great Basin: Reno, Nevada, April 1-5, 1990, Geological Society of Nevada - U. S. Geological Survey, p. 59.

Steven, Thomas A., and Morris, Hal T., 1984, Mineral resource potential of the Richfield 1 degree x 2 degree quadrangle, West-Central Utah: U. S. Geological Survey Open-File Report 84-521, 53 p.

Stoeser, Douglas B., Campbell, David L., et al., 1990, Mineral resources of the Notch Peak Wilderness Study Area, Millard County, Utah: U. S. Geological Survey Bull. 1749-C, 28 p.

Stringham, B. F., 1942, Mineralization in the West Tintic district: Geological Society of America Bull., v. 53, no. 2, p. 267-290.

Stringham, B. F., 1967, Hydrothermal alteration near the Horn Silver mine, Beaver County, Utah: Utah Geological and Mineral Survey Spec. Studies 16, 35 p.

Sweeney, Mary Jo, 1980, Geochemistry of garnets from the North Ore Shoot, Bingham district, Utah: Salt Lake City, University of Utah, M.S. thesis, 154 p.

Theodore, Ted G., Orris, Greta J., Hammarstrom, Jane M., and Bliss, James D., 1991, Gold-bearing skarns: U. S. Geological Survey Bulletin 1930, 61 p.

Thompson, K. C., 1973, Mineral deposits of the Deep Creek Mountains, Tooele and Juab Counties, Utah: Utah and Geological Mineral Survey Bull. 99, 76 p.

Tooker, Edwin W., 1990, Gold in the Bingham district, Utah, *in* Gold in porphyry copper systems: U. S. Geological Survey Bull. 1857-E, p. E1-E16.

Townsend, James W., 1953, Investigation of lead-zinc deposits at the Harrington-Hickory mine, Beaver County, Utah: U. S. Bureau of Mines Rept. of Investigations 4953, 20 p.

Tripp, Bryce T., Shubat, Michael A., Bishop, Charles E., and Blackett, Robert E., 1989, Mineral occurrences of the Tooele 1 degree x 2 degree quadrangle, west-central Utah: Utah Geological and Mineral Survey Open-File Report 153, 85 p.

Whelan, J. A., 1982, Geology, ore deposits and mineralogy of the Rocky Range, Utah: Utah Geological and Mineral Survey Spec. Studies 57, 35 p.

Wilson, Clark L., 1959, Park City mining district, *in* Wasatch and Uinta Mountains: International Association of Petroleum Geologists, 10th Annual Field Conference Guidebook, p. 182-188.

Wilson, Paula N., and Parry, W. T., *in press*, Thermal and chemical evolution of hydrothermal fluids at the Ophir Hill mine, Ophir district, Utah, *in* Allison, M. Lee, ed., Geology and mineral resources of Utah: Utah Geological Association 1990 Guidebook.

Wray, W. B., 1965, Geology and ore deposits of the Rebel mine area, Beaver County, Utah: Salt Lake City, University of Utah, B.S. dissertation, 89 p.

Wren, James H., 1969, Beaver View lode claim group, Fotheringham lode claims, miscellaneous data: Unpublished report, Utah Geological and Mineral Survey files.

Zimbelman, David R., 1991, Geology and geochemistry of gold deposits within and close to the Delta 1 degree x 2 degree quadrangle, west-central Utah, *in* Raines, Gary L., and Lisle, Richard E., Schafer, Robert W., and Wilkinson, William H., eds., Geology and ore deposits of the Great Basin: Reno, Nevada, Geological Society of Nevada, p. 263-277.

COUNTY	DISTRICT	OCCURRENCE	GOLD MINERALIZATION	TYPE SAMPLE
			troy ounces of gold per short ton	
Beaver	Beaver Lake	Skylark	0.028 opt (0.96 ppm)	Gossan ore from dump.
	Frisco	Imperial	Reported.	Unknown.
	Granite	Strategic Metals	Reported high-grade.	Mined in late 1930s.
		Beaver View	0.1 to 0.3 opt (3.42 to 10.27 ppm)	Average grade 1946-1949.
		King of the Hills	Reported.	Unknown.
	Rocky Range	Hidden Treasure	Native Au reported; 0.01 opt (0.34 ppm)	Unknown.
		Maria mine	0.01 to 0.03 opt (0.34 to 1.03 ppm)	Copper skarn ore.
		Old Hickory mine	0.01 to 0.03 opt (0.34 to 1.03 ppm)	ASARCO assay certificates.
	Star	Harrington-Hickory mine	0.03 opt (1.01 ppm)	1944-1949 ore grade.
Box Elder	Crater Island	Copper Blossom	94 ounces gold.	1938-1948 production.
Juab	Main Tintic	North Star *	34,000 ounces gold.	Total production.
	West Tintic	Iron King, NE shaft	0.282 and 0.15 opt (9.66 and 5.14 ppm)	1913 ore shipments.
Millard	Notch Peak	Scheelite Queen area	Up to 0.20 opt (7 ppm)	Granite-tactite fault breccia contact.
		Pine Peak area	Up to 0.16 opt (5 ppm)	Tactite near granite contact.
Salt Lake	Big Cottonwood	Maxfield mine	0.165 opt (5.65 ppm)	1902-1940 ore grade.
		Scottish Chief mine	0.023 opt (0.79 ppm)	1906-1930 ore grade.
		Mountain Lake mine	0.01 opt (0.34 ppm)	Big Cottonwood tunnel.
		Woodlawn-Kentucky-Utah	0.04 opt (1.49 ppm)	1915-1923 ore grade.
		Michigan Utah mine	0.025 opt (0.86 ppm)	1901-1919 ore grade.
	Bingham	Carr Fork mine *	0.01 opt (0.34 ppm)	Grade of reserves.
			Locally 0.1 to 2.3 opt (3.4 to 78.8 ppm)	Silicified, pyritized skarn.
		Parnell gold shoot *	0.122 opt (4.20 ppm)	Grade of geologic resource.
		Highland Boy mine	0.07 opt (2.40 ppm)	Average grade Cu-garnet skarn.
		Utah-Apex mine	Similar to Highland Boy.	
	Little Cottonwood	South Hecla mine	0.03 opt (1.03 ppm)	1911-1919 ore grade.
Tooele	Gold Hill	Midas *	2.72 opt (93.15 ppm)	Pre-1896 ore grade (95 tons).
		Alvarado *	0.20 to 1.70 opt (6.85 to 58.22 ppm)	Head grades.
			Trace to 0.17 opt (5.82 ppm)	18 channel samples, 1960.
		Cane Springs *	1.07 opt (36.64 ppm); 0.47 opt (16.10 ppm)	1914, 46 tons; 1931-35, 1,631 tons.
			Trace to 0.62 opt (21.23 ppm)	12 channel samples, 1935 and 1960.
		Gold Hill (early mining)	Native gold reported.	1892-1895 ore.
		Bonnemort *	1.1 opt (37.67 ppm)	1916 ore grade.
		Frankie	0.12 to 0.24 opt (4.11 to 8.22 ppm)	1916 assays.
			0.008 opt (0.27 ppm)	1917-1919 ore grade.
Wasatch	Park City	Jones-Bonanza shaft	Native gold reported.	Unknown.
	Snake Creek	Green Monster mine	0.035 opt (1.20 ppm)	1900-1953 ore grade.
		West Park mine	0.055 opt (1.88 ppm)	1946-1950 ore grade.
Washington	Mineral Mountain	Emma mine	Up to 0.066 opt (2.25 ppm)	Dump samples.
		* Gold as primary or secondary commodity.		

Table 1. Gold mineralization in Utah skarns

OCCURRENCE	PRODUCTION	Short tons	Au	Ag	Pb	Cu	REFERENCES
	Description		oz.	oz.	lbs.	lbs.	
Skylark	No data.						UGMS files
Imperial	District.		38,888	19,147,666	403,889,900	45,358,600	1,2
Strategic Metals	District W production.						UGMS files
Beaver View	As above.						3
King of the Hills	As above.						UGMS files
Hidden Treasure	District.	753,623	3,259	759,813	3,700	32,810,494	4
Maria mine	As above.						4
Old Hickory mine	As above.						UGMS files
Harrington-Hickory mine	1944-1949	11,031	326	80,774	2,316,763	89,970	5
Copper Blossom	District (mainly Cu Blossom)		94	1,194	91	23,666	6
North Star *	No data.						7
Iron King, NE shaft	No data.						8
Scheelite Queen area	District W production.						9
Pine Peak area	As above.						9
Maxfield mine	1902-1940	5,368	886	278,062	2,114,992	150,304	10
Scottish Chief mine	1906-1930	218	5	4,796	47,960	3,924	10
Mountain Lake mine	No data.						11
Woodlawn-Kentucky-Utah	1915-1923	406	18	11,065	97,253	3,965	10
Michigan Utah mine	1901-1919	50,681	1,267	836,236	9,244,214	1,216,344	12
Carr Fork mine *	Pre-mining reserves.	67,222,000	671,000	18,971,000		2.5 billion	13
							14
Parnell gold shoot *	Drill indicated resource.	881,600	107,555	224,808		17,984,640	13
Highland Boy mine	Carr Fork mines, 1919-1947	4,627,138	219,653	10,326,900	536,193,112	114,230,129	15,16
Utah-Apex mine	As above.						
South Hecla mine	1911-1919	44,302	1,329	773,513	5,617,494	1,196,154	12
Midas *	Pre-1904		-1,500				17
Alvarado *	1890s		-6,000				17,18
							18
Cane Springs *	1890s		-5,000				18
							18
Gold Hill (early mining)	No data.						17
Bonnemort *	No data.						18
Frankie	1917-1919	3,056	24	4,584	42,784	293,376	18
							18
Jones-Bonanza shaft	No data.						19
Green Monster mine	1950-1953	120	4	90		7,200	UGMS files
West Park mine	No data.						UGMS files
Emma mine	None.						20

REFERENCES

1. Butler, 1913
2. Perry and McCarthy, 1976
3. Wren, 1969
4. Whelan, 1982
5. Townsend, 1953
6. Doelling, 1980
7. Lindgren and Loughlin,1919
8. Butler, 1920
9. Lundby, 1987
10. James, 1979
11. Crawford and Buranek, 1957
12. Calkins and Butler, 1943
13. Cameron and Garmoe, 1987
14. Atkinson and Einaudi, 1978
15. Einaudi, 1982
16. Hansen, 1961 (corrected gold figure, pers. comm., 1991)
17. Nolan, 1935
18. El-Shatoury and Whelan, 1970
19. Boutwell, 1912
20. Morris, 1980

Table 1 continued.

TABLE 2. Gold-Bearing and Non-Gold-Bearing Skarns

Data are given as the proportion of skarn occurrences in which a mineral or other geologic characteristic is present.

$$\text{Index} = \frac{\text{\% occurrences in gold-bearing skarns}}{\text{\% occurrences in gold-bearing skarns} + \text{\% occurrences in non-gold-bearing skarns}}$$

Data set refers to representative occurrences shown in bold type in the Appendix.
Number of gold-bearing skarn occurrences = 22
Number of non-gold-bearing skarn occurrences = 32

	Index	% of gold-bearing occurrences	% of non-gold-bearing occurrences
actinolite	.65	23	13
apatite	.81	14	3
biotite	.27	4	13
brucite	.74	9	3
chlorite	.59	32	22
clay	.42	4	6
clinozoisite	.59	9	6
diopside	.61	55	34
epidote	.55	55	44
fluorite	.49	18	19
fosterite	.49	9	9
garnet	.50	91	91
kspar	.59	9	6
muscovite	.69	14	6
opal, chalcedony	.27	4	13
phlogopite	.42	9	13
plagioclase	.74	9	3
quartz	.52	55	50
scapolite	0.0	0	6
sericite	.42	4	6
serpentine	.84	32	6
spadaite	1.0	4	0
spinel	.59	4	3
talc	.81	14	3
tourmaline	.65	23	13
tremolite	.59	41	28
vesuvianite	.45	23	28
wollastonite	.69	55	25
calcite	.46	45	53
dolomite	.49	9	9
magnesite	.69	14	6
rhodochrosite	.74	9	3
siderite	.74	9	3
smithsonite	1.0	18	0
barite	.74	9	3
gypsum	0.0	0	6
argentite	.78	23	6
arsenopyrite	.69	14	6
bismuth minerals	.49	9	9
bornite	.68	45	22
chalcocite	.88	23	3
chalcopyrite	.63	86	50
covellite	1.0	9	0
enargite	1.0	14	0
galena	.64	55	31
marcasite	.59	4	3

TABLE 2 continued.

	Index	Gold-bearing	Non-gold-bearing
molybdenite	.74	27	9
pyrite	.56	73	56
pyrrhotite	.74	18	6
sphalerite	.77	32	9
stibnite	0.0	0	3
tellurides	1.0	4	0
tennantite	.59	4	3
tetrahedrite	.81	27	6
scheelite	.59	45	31
wolframite	.59	4	3
powellite, wulfenite	.47	14	16
native gold	.87	41	6
native silver	.59	4	3
magnetite	.57	55	41
hematite	.59	23	16
specularite	.54	18	16
limonite	.28	14	34
pyrolusite	.69	14	6
marble	.50	32	31
jasperoid	0.0	0	9
Anomalous bismuth	.65	59	31
Host Rock:			
Triassic-Jurassic	.43	4	6
Permian	.61	14	9
Miss.-Penn.	.86	55	9
Silurian-Devonian	0.0	0	9
Ordovician	.36	9	16
Cambrian	.33	14	28
Precambrian	0.0	0	3
Igneous Rock Association:			
quartz monzonite, monzonite, latite	.50	45	50
granite, rhyolite, granodiorite, diorite	.52	50	46
stock, plug	.50	55	56
dikes, sills	.66	23	12
batholith	.46	5	6
Tertiary	.50	81	81
Mesozoic	.47	14	16
multiple intrusions	.74	45	16
endoskarn	1.0	32	0
Primary metal commodity:			
copper	.59	36	25
lead-silver	.68	32	15
iron	.59	18	12
tungsten	.24	9	28
gold	.60	4	3
zinc	0.0	0	3

TABLE 3. Gold-Bearing and Non-Gold-Bearing Copper Skarns

Data are given as an index calculated from the proportion of skarn occurrences in which a mineral or other geologic feature is present. Features present in less than 10% of both groups are excluded.

$$\text{Index} = \frac{\text{\% occurrences in gold-bearing skarns}}{\text{\% occurrences in gold-bearing skarns} + \text{\% occurrences in non-gold-bearing skarns}}$$

Data set refers to representative occurrences shown in bold type in the Appendix.
Number of gold-bearing copper skarn occurrences = 9
Number of non-gold-bearing copper skarn occurrences = 9

	Mineralogy	Other geologic features
Unique to gold-bearing copper skarns (index = 1)		
	apatite	Endoskarn
	arsenopyrite	
	covellite	
	enargite	
	pyrrhotite	
	sphalerite	
	tetrahedrite	
Characteristic of gold-bearing copper skarns (index > .66)		
	actinolite	Mississippian-Pennsylvanian host rocks
	chlorite	Multiple intrusive phases
	clinozoisite	Proximity to polymetallic replacements
	diopside	Anomalous bismuth in district
	quartz	
	serpentine	
	tourmaline	
	bornite	
	chalcocite	
	molybdenite	
	scheelite	
	native gold	
Not characteristic of either group (index = .5)		
	garnet	
	vesuvianite	
	galena	
Characteristic of non-gold-bearing copper skarns (index < .3)		
	bismuth minerals	
	specularite	
	opal, chalcedony	
Unique to non-gold-bearing copper skarns (index = 0)		
	biotite	
	jasperoid	

APPENDIX. Skarn Occurrences in Utah

EXPLANATION OF APPENDIX

DISTRICT	Mining district.
SUBDISTRICT	Subdistrict where applicable.
METALS	Metal commodities present in deposit listed in order of economic importance as can best be determined.
SKARN OCCURRENCES	Mine, prospect, or locality where skarn is present. <u>Does not imply a skarn-type deposit</u>. Similar occurrences are grouped together with the name of the lead locality appearing in bold. Geologic characteristics that apply to the majority of occurrences are listed in that row. Geologic characteristics reported only for specific localities are listed in the appropriate row.
AU IN SKARN	Gold content of skarn is greater than 0.01 opt (0.3 ppm). Also includes occurrences with reported gold or native gold for which assay data are unavailable.

SILICATES & OTHERS (x indicates mineral is present)

act	actinolite	opal,chal	opal, chalcedony
ap	apatite	phlog	phlogopite
biot	biotite	plag	plagioclase
bruc	brucite, periclase	qtz	quartz
chl	chlorite	scap	scapolite
clay	clay	ser	sericite
clinozois	clinozoisite, zoisite	serp	serpentine
diop	diopside	spa	spadaite
ep	epidote	spin	spinel
fl	fluorite	talc	talc
fo	forsterite	tour	tourmaline
gar	andradite-grossularite	trem	tremolite
kspar	orthoclase, adularia	ves	vesuvianite, idocrase
musc	muscovite	wol	wollastonite

CARBONATES

cal	calcite	rhod	rhodochrosite
dol	dolomite, ankerite	sid	siderite
mags	magnesite	smith	smithsonite

SULFATES

bar	barite	gyp	gypsum

SULFIDES and SULFOSALTS

arg	argentite	marc	marcasite
apy	arsenopyrite	moly	molybdenite
bism	bismuth minerals	py	pyrite
bor	bornite	po	pyrrhotite
cc	chalcocite	sph	sphalerite
cpy	chalcopyrite	stib	stibnite
cov	covellite	tenn	tennantite
enar	enargite	tet	tetrahedrite
gal	galena		

TUNGSTATES

sch	scheelite	wolf	wolframite

MOLYBDATES

p/w	powellite, wulfenite

NATIVE ELEMENTS

Au	native gold	Ag	native silver

EXPLANATION OF APPENDIX continued

OXIDES			
mgt	magnetite	lim	limonite, goethite
hem	hematite	pyr	pyrolusite
spec	specularite		

OXIDIZED

Pb	anglesite, cerrusite, plumbojarosite
Cu	azurite, chalcanthite, chrysocolla, cuprite, malachite, tenorite

ROCK

mar	marble	jasp	jasperoid

BI Bismuth minerals reported and/or bismuth anomalies in district.

IGNEOUS ROCK ASSOCIATION
Refers to the intrusive rock that is spatially associated with skarn alteration. Multiple phases of intrusion are noted where present. Endoskarn noted when calc-silicate minerals are described in the intrusive rock adjacent to skarn.

METAMORPHIC AUREOLE
Distances refer to the surface extent of calc-silicate mineralization away from the intrusive contact. Does not include marble, recrystallization, bleaching, or other metamorphic effects.
PB-ZN-AG-AU REPLACEMENTS
Gold-bearing polymetallic replacement deposits occur in proximity to skarn occurrence.

MAJOR REFERENCES

1. Bullock, 1970
2. Barosh, 1960
3. Butler, 1913
4. Perry and McCarthy, 1976
5. Earll, 1957
6. Steven and Morris, 1984
7. Everett, 1961
8. Hobbs, 1945
9. Best et al., 1979
10. Whelan, 1982
11. Wray, 1965
12. Townsend, 1953
13. Cox et al., 1989
14. Erickson, 1966
15. Doelling, 1980
16. Miller and Schneyer, 1985
17. Eppinger et al., 1990
18. Rowley and Barker, 1978
19. Mackin, 1968
20. Crittenden et al., 1961
21. Lindsey et al., 1989
22. Heyn, 1981
23. Lindgren and Loughlin, 1919
24. Keith et al., 1989
25. Stein et al., 1988
26. Butler et al., 1920
27. Stein et al., 1990
28. Stringham, 1942
29. Nutt et al.,1990
30. Thompson, 1973
31. Bullock, 1981
32. Crawford and Buranek, 1942
33. Stoeser et al., 1990
34. Lundby, 1987
35. Hintze, 1974
36. Gehman, 1958
37. James, 1979
38. Calkins and Butler, 1943
39. Boutwell, 1912
40. Crawford and Buranek, 1957
41. Smith, 1972
42. Einaudi, 1982
43. Atkinson and Einaudi, 1978
44. Tooker, 1990
45. Cameron and Garmoe, 1987
46. Rubright and Hart, 1968
47. Boutwell, 1935
48. Hunt, 1924
49. Boutwell, 1905
50. Sweeney, 1980
51. Callaghan, 1973
52. Kerr et al., 1957
53. Nolan, 1935
54. Robinson, 1988
55. El-Shatoury and Whelan, 1970
56. Gilluly, 1932
57. Wilson and Parry, in press
58. Rubright, 1978
59. Moore et al., 1966
60. Lufkin, 1965
61. Bromfield and Patten, 1981
62. Morris, 1980

COUNTY	DISTRICT	SUBDISTRICT	7.5' QUAD	METALS	SKARN OCCURRENCES	AU in SKARN
Beaver	Antelope (see Millard County)					
	Beaver Lake		Beaver Lake Mtns. 15'	Fe Cu Pb Zn Ag	**Skylark**	x
					Bat Ridge	
					Black Rock	
					Beaver Copper	
					Galena	
					Norma #3	
					Copper Mountain	
					North Star	
					Ute	
	Bradshaw		Cave Canyon	W Cu F	**2 R's mine (Skyline)**	
	Frisco		Frisco	Pb Zn Ag Cu W Au	**Imperial**	x
					Cupric	
					Washington	
					King David	
					Peacock Copper group	
					Drum	
	Granite (Mineral Mtns)		Cave Canyon	Fe	**Iron mine**	
		SE Mineral Mtns	Adamsville 15'	W Pb Zn Ag Cu Mo Be	**Strategic Metals (Big Pass, Blue Star)**	x
					Beaver View (Beaver Tungsten)	x
					Daily Metals	
					Garnet No. 1 claim	
					Oak Basin group	
					Contact claim	
					Solomons Hollow group	
					Porcupine Hollow group	
					Molly group	
					Ward group (Silver Star claims)	
					Major Fault	
					King of the Hills mine	x
					Bismuth mine	
					Major Bismuth	
	Indian Peak		Miners Cabin Wash	Cu Pb Ag	**Blue Jay mine**	
	Lincoln		Cave Canyon	Cu Ag Pb Zn W Fe	**Creole mine**	
	Rocky Range		Milford	Cu Fe W Pb Zn Ag Au	**Hidden Treasure**	x
					Maria mine	x
					Bawana ore body	
					Montreal mine	
					Old Hickory mine	x
					Sunrise mine	
					Copper Ranch	
					Candy B anomaly	
	Star	North Star	Milford	Pb Zn Ag Cu W Fe	**Copper King**	
					Rebel mine	
					Harrington-Hickory mine	x
					Little May Lily mine	
					Washington	
	Wah Wah Pass		Wah Wah Summit	Fe	**Wah Wah Pass prospects**	
Box Elder	Crater Island	Copper Blossom area	Crater Island	Cu Ag Au Pb	**Copper Blossom**	x
		Desolate Point area	Lucin 4SW	Cu W	**Desolate Point**	
					North Desolate Point	
		Sheepwagon stock area	Crater Island	W Mo Cu	**Taylor NW**	
					Taylor Central	

COUNTY	DISTRICT	SUBDISTRICT	7.5' QUAD	METALS	SKARN OCCURRENCES	Au in SKARN
Box Elder	*Crater Island*	*Sheepwagon stock area*			Taylor South	
	Lucin	East Canyon area	Tecoma	Cu	**Six Shooter Canyon**	
					East Canyon	
	Newfoundland		Desert Peak	W Cu Pb Ag	**Desert Flower**	
			Groome		Newfoundland Cu mine	
	Rosebud		Rocky Pass Peak	W Cu	**Lone Pine**	
					Compressor mine	
					A & W mine	
					Rocky Pass	
					Magnitude	
			Emigrant Pass		Tactite	
			Bovine		Bovine Mtn Tungsten	
Iron	Iron Springs	Iron Springs	Cedar City NW	Fe Cu Pb	**Numerous**	
		Pinto Iron	Page Ranch		Numerous	
Juab	Detroit (Drum Mtns)		Topaz Mtn. 15'	Au Cu	**Dyke No. 1 claim (Copperhead)**	
	Fish Springs		Fish Springs SW	Zn Fe Cu Ag Pb Mo W	**Crypto deposit**	
	Tintic	Main Tintic	Eureka	Ag Au Pb	**North Star**	x
				Fe Au Ag Cu	**Black Jack**	
					Dragon	
		West Tintic	Cherry Creek	Fe Cu Au Ag	**Iron King, Northeast shaft**	x
					Iron King, Southwest shaft	
				Cu Pb Ag	**Murphy**	
				W Pb Cu	**Tintic Western**	
					Bates Shaft	
					Sullivan Shaft	
					Great Western King	
	Spring Creek	Trout Creek properties	Ibapah Peak	W Zn Be	**Trout Creek mine**	
Millard	Antelope		Pinnacle Pass	W Pb Ba	**Pinnacle mine**	
				Cu	**Tremolite No. 1**	
	House Range	Northern	Marjum Pass	?	**Dome Canyon Nos. 1-16**	
	Notch Peak		Notch Peak 15'	W Mo Cu	**Klondike**	
					South Pit mine	
					Yellow Bird	
					Horseshoe	
					Scheelite Queen	x
					Lady Mae	
					Baldy Peak	
					Pine Peak	x
					Brown Queen	
					Bell Base Lode	
					Bonnie May	
Salt Lake	Big Cottonwood	Argenta area	Mt. Aire	Pb Zn Ag Cu Au	**Maxfield mine**	x
					Newman and Afton groups	
					Sunnyside mine	
		Mt. Evergreen area	Brighton	Cu Fe	**Evergreen mine, New York tunnel**	
		Scott Hill area	Brighton	Pb Ag Cu Au	**Scottish Chief mine**	x
					American Tunnel	
		Upper Big Cottonwood	Brighton	Fe Cu W	**Big Cottonwood mine**	
				Cu Fe W Pb Au	Mountain Lake mine	x
					Great Western prospect	
					Relief shaft	
		Big & Little Cottonwd	Brighton	Ag Pb Cu Zn Au W	**Woodlawn-Kentucky-Utah group**	x
					Michigan Utah mine	x

COUNTY	DISTRICT	SUBDISTRICT	7.5' QUAD	METALS	SKARN OCCURRENCES	AU in SKARN
Salt Lake	*Big Cottonwood*	*Big & Little Cottonwd*	*Brighton*		Solitude	
					Scotia	
					Alta and Clayton Peak stocks	
	Bingham	Carr Fork area	Bingham Canyon	Cu Au Mo Ag	**Carr Fork mine**	x
				Au Cu	Parnell gold shoot	x
		Northern sector	Bingham Canyon	Cu Au Mo Ag	North Ore Shoot	x
				Cu Pb Zn Au Ag	**Highland Boy mine**	x
					Utah-Apex mine	x
	Little Cottonwood		Brighton	Ag Pb Cu Au Fe	**Alta Consolidated**	
			Dromedary Peak	Cu Ag Pb Au W Sb	**South Hecla mine**	x
Sevier	Henry		Marysvale Canyon	Cu	**Trinity prospect**	
Summit	Park City	Bonanza Flat area	Brighton	Pb Ag Cu	**Jupiter mine**	
			Heber City	Ag Pb Cu	**Wabash mine**	
Tooele	Bingham	see Salt Lake County				
	Gold Hill (Clifton)		Clifton	Au Ag Cu	**Midas**	x
			Gold Hill	Au Ag Cu	Alvarado	x
					Cane Springs	x
					Gold Hill (early development)	x
				Cu Au	**Bonnemort**	x
				Cu W Ag Pb Au	**Frankie**	x
				W	**Star Dust mine**	
					B. Estelle mine	
					Fraction lode	
					Tuolumne claim	
					Copper Cup claim	
	Mercur		Mercur		**Chloride Point**	
					Eagle Hill	
	Ophir		Ophir, Stockton	Pb Ag Zn Cu	**Ophir Hill mine**	
					Cliff mine	
					Hidden Treasure mine	
	Stockton (Rush Valley)		Stockton	Pb Zn Ag Au Cu	**Honerine**	
					Soldier Canyon	
					Small occurrences in Settlement and	
					Middle Canyons and Tickville Gulch.	
Utah	American Fork	Silver Lake	Dromedary Peak	W Mo	**Metals Coalition mine**	
Wasatch	Park City	Bonanza Flat area	Brighton	Ag Pb Cu Au Zn	**Jones-Bonanza shaft**	x
					West Quincy shaft	
	Snake Creek		Brighton	Cu Ag Au Fe	**Green Monster mine**	x
					West Park mine	x
					Steamboat tunnel	
Washington	Mineral Mtn		Goldstrike	Fe Cu Au Ag	**Emma mine**	x
					Marble prospect	

SKARN	**SILICATES & OTHERS**						**clin**								**opal**									
OCCURRENCES	**act**	**ap**	**biot**	**bruc**	**chl**	**clay**	**zois**	**diop**	**ep**	**fl**	**fo**	**gar**	**kspar**	**musc**	**chal**	**phlog**	**plag**	**qtz**	**scap**	**ser**	**serp**	**spa**	**spin**	**talc**
Skylark								x	x			x		x										
Bat Ridge																								
Black Rock																								
Beaver Copper																								
Galena																								
Norma #3																								
Copper Mountain																								
North Star																								
Ute																								
2 R's								x	x	x		x						x						
Imperial					x			x	x	x		x		x				x						
Cupric																								
Washington																								
King David																								
Peacock Copper																								
Drum																								
Iron																								
Strategic Metals								x	x	x		x												
Beaver View																								
Daily Metals																								
Garnet No. 1																								
Oak Basin																								
Contact																								
Solomons Hollow																								
Porcupine Hollow																								
Molly																								
Ward																								
Major Fault																								
King of the Hills																								
Bismuth																								
Major Bismuth																								
Blue Jay												x												
Creele							x		x	x		x			x			x						
Hidden Treasure								x	x			x		x		x		x			x			
Maria																								
Bawana																								
Montreal																								
Old Hickory																								
Sunrise																								
Copper Ranch																								
Candy B																								
Copper King		x			x			x				x						x			x			
Rebel									x				x											
Harrington-Hickory																								
Little May Lily																								
Washington										x														
Wah Wah Pass					x			x			x	x					x							
Copper Blossom									x			x						x						
Desolate Point									x									x						
North Desolate Pt.																								
Taylor NW									x			x						x						
Taylor Central																								

SKARN	SILICATES & OTHERS					clin								opal									
OCCURRENCES	act	ap	biot	bruc	chl	clay	zois	diop	ep	fl	fo	gar	kspar	musc	chal	phlog	plag	qtz	scap	ser	serp	spa	spin	talc
Taylor South																							
Six Shooter Canyon									x			x									x			
East Canyon																								
Desert Flower			x		x	x			x			x		x				x						
Newfoundland Cu																								
Lone Pine									x			x						x						
Compressor																								
A & W																								
Rocky Pass																								
Magnitude																								
Tactite																								
Bovine Mtn																								
Numerous	x	x			x			x	x			x			x	x		x	x					
Numerous																								
Dyke No. 1								x	x			x												
Crypto								x				x	x								x			
North Star												x						x						
Black Jack						x						x											x	
Dragon																								
Iron King, NE												x												
Iron King, SW	x				x				x			x									x			x
Murphy	x				x				x			x						x						
Tintic Western							x		x			x			x			x						
Bates Shaft																								
Sullivan Shaft																								
Great Western King																								
Trout Creek	x		x							x		x		x				x						
Pinnacle																								
Tremolite No. 1			x																					
Dome Canyon												x												
Klondike			x					x	x			x					x							
South Pit																								
Yellow Bird																								
Horseshoe																								
Scheelite Queen																								
Lady Mae																								
Baldy Peak																								
Pine Peak																								
Brown Queen																								
Bell Base Lode																								
Bonnie May																								
Maxfield mine								x	x			x						x						
Newman and Afton																								
Sunnyside mine																								
Evergreen mine																								
Scottish Chief												x						x						
American Tunnel																								
Big Cottonwood	x			x	x				x		x	x				x					x			x
Mountain Lake																								
Great Western																								
Relief shaft																								
Woodlawn-Kentucky																		x						
Michigan Utah																								

SKARN	SILICATES & OTHERS					clin								opal									
OCCURRENCES	**act**	**ap**	**biot**	**bruc**	**chl**	**clay**	**zois**	**diop**	**ep**	**fl**	**fo**	**gar**	**kspar**	**musc**	**chal**	**phlog**	**plag**	**qtz**	**scap**	**ser**	**serp**	**spa**	**spin**	**talc**
Solitude																								
Scotia																								
Alta-Clayton Peak				x				x			x	x				x								
Carr Fork	x				x	x		x	x			x			x			x		x				x
Parnell						x												x						
North Ore Shoot	x	x	x		x	x		x	x			x	x				x	x						
Highland Boy	x				x			x	x	x		x						x			x			
Utah-Apex mine																								
Alta Consolidated	x		x					x			x	x						x						
South Hecla												x												
Trinity								x	x			x			x	x			x					
Jupiter												x						x						
Wabash					x							x						x						
Midas								x				x										x		
Alvarado							x	x				x						x			x	x		
Cane Springs																								
Gold Hill																								
Bonnemort							x	x																
Frankie	x	x						x				x						x						
Star Dust																								
B. Estelle																								
Fraction lode																								
Tuolumne																								
Copper Cup																								
Chloride Point								x				x												
Eagle Hill										x		x						x		x				
Ophir Hill					x			x	x	x		x	x			x		x		x				x
Cliff																								
Hidden Treasure																								
Honerine					x			x	x	x		x						x						
Soldier Canyon																								
Settlement, Middle																								
Canyons																								
Metals Coalition												x												
Jones-Bonanza												x												
West Quincy																								
Green Monster																								
West Park																								
Steamboat																								
Emma				x	x						x										x		x	
Marble prospect																								

SKARN				CARBONATES						SULFATES		SULFIDES and SULFOSALTS										
OCCURRENCES	tour	trem	ves	wol	cal	dol	mags	rhod	sid	smith	bar	gyp	arg	apy	bism	bor	cc	cpy	cov	enar	gal	marc	moly
Skylark		x								x								x			x		
Bat Ridge																							
Black Rock																							
Beaver Copper																							
Galena																							
Norma #3																							
Copper Mountain																							
North Star	x																						
Ute																							
2 R's	x		x	x	x													x					
Imperial		x	x	x	x	x	x											x			x		x
Cupric																							
Washington																							
King David													x										
Peacock Copper																							
Drum																							
Iron																							
Strategic Metals		x		x	x													x					x
Beaver View																							
Daily Metals																							
Garnet No. 1																							
Oak Basin																							
Contact	x																						
Solomons Hollow																							
Porcupine Hollow																							
Molly																							
Ward																							
Major Fault																							
King of the Hills																							
Bismuth																							
Major Bismuth																							
Blue Jay					x											x		x			x		
Creole	x	x	x	x	x										x	x		x			x		
Hidden Treasure	x	x	x	x			x									x	x	x	x				x
Maria																							
Bawana																							
Montreal																							
Old Hickory																							
Sunrise																							
Copper Ranch																							
Candy B																							
Copper King		x			x											x		x			x		
Rebel				x																			
Harrington-Hickory								x		x													
Little May Lily																							
Washington			x																				
Wah Wah Pass			x		x																		
Copper Blossom																x		x					
Desolate Point					x																		
North Desolate Pt.																							
Taylor NW																		x					x
Taylor Central																							

SKARN					**CARBONATES**						**SULFATES**		**SULFIDES and SULFOSALTS**										
OCCURRENCES	tour	trem	ves	wol	cal	dol	mags	rhod	sid	smith	bar	gyp	arg	apy	bism	bor	co	cpy	cov	enar	gal	marc	moly
Taylor South																							
Six Shooter Canyon		x																					
East Canyon																							
Desert Flower		x			x											x		x					
Newfoundland Cu																							
Lone Pine					x																		
Compressor																							
A & W																							
Rocky Pass																							
Magnitude																							
Tactite																							
Bovine Mtn																							
Numerous	x	x	x	x	x		x					x				x		x			x	x	
Numerous																							
Dyke No. 1			x												x								
Crypto																							
North Star				x							x									x	x		
Black Jack					x																		
Dragon																							
Iron King, NE		x		x																			
Iron King, SW							x		x									x					
Murphy				x	x				x							x		x			x		x
Tintic Western		x		x	x			x										x			x		
Bates Shaft																							
Sullivan Shaft																							
Great Western King																							
Trout Creek						x																	
Pinnacle					x						x										x		
Tremolite No. 1		x																x					
Dome Canyon																							
Klondike		x	x	x														x					x
South Pit																							
Yellow Bird																							
Horseshoe																							
Scheelite Queen																							
Lady Mae																							
Baldy Peak																							
Pine Peak																							
Brown Queen																							
Bell Base Lode																							
Bonnie May																							
Maxfield mine				x	x										x						x		
Newman and Afton																							
Sunnyside mine																							
Evergreen mine																x	x	x					
Scottish Chief					x								x					x			x		
American Tunnel																							
Big Cottonwood																x	x	x			x		
Mountain Lake																							
Great Western																							
Relief shaft																							
Woodlawn-Kentucky					x					x			x					x			x		
Michigan Utah								x															

SKARN					CARBONATES						SULFATES		SULFIDES and SULFOSALTS										
OCCURRENCES	tour	trem	ves	wol	cal	dol	mags	rhod	sid	smith	bar	gyp	arg	apy	bism	bor	co	cpy	cov	enar	gal	marc	moly
Solitude																							
Scotia																							
Alta-Clayton Peak			x		x	x	x									x		x					
Carr Fork					x				x							x		x					x
Parnell									x					x				x					
North Ore Shoot					x				x							x		x					
Highland Boy	x	x		x	x						x			x		x		x		x	x	x	
Utah-Apex mine																							
Alta Consolidated		x	x		x								x					x			x		
South Hecla				x						x					x	x		x		x	x		
Trinity		x		x	x													x					
Jupiter					x																x		
Wabash												x						x					
Midas			x	x										x				x					
Alvarado		x	x	x	x											x	x	x			x		
Cane Springs																			x				x
Gold Hill																							
Bonnemort				x													x	x					
Frankie	x				x											x	x	x					
Star Dust																							
B. Estelle																							
Fraction lode																							
Tuolumne																							
Copper Cup																							
Chloride Point																							
Eagle Hill																							
Ophir Hill	x		x		x								x	x	x			x			x		
Cliff																							
Hidden Treasure																							
Honerine			x	x		x								x				x			x		
Soldier Canyon																							
Settlement, Middle																							
Canyons																							
Metals Coalition		x		x																			x
Jones-Bonanza													x					x			x		
West Quincy																							
Green Monster													x			x		x					
West Park																							
Steamboat																							
Emma						x																	
Marble prospect																							

SKARN							TUNGST.		MOL	NATIVE		OXIDES					OXIDIZED		ROCK		OTHER	BX
OCCURRENCES	py	po	sph	stib	tenn	tet	sch	wolf	p/w	Au	Ag	mgt	hem	spec	lim	pyr	Pb	Cu	mar	jasp	MINERALS	
Skylark	x											x		x	x	x	x	x	x			
Bat Ridge																						
Black Rock																						
Beaver Copper																						
Galena																						
Norma #3																						
Copper Mountain																						
North Star																						
Ute																						
2 R's	x						x											x				
Imperial	x		x				x					x		x		x						x
Cupric																						
Washington																						
King David																					alunite,	
Peacock Copper																					wurtzite	
Drum																						
Iron												x							x		calc-silicates	
Strategic Metals	x						x															
Beaver View																						
Daily Metals																						
Garnet No. 1																						
Oak Basin																						
Contact																						
Solomons Hollow																						
Porcupine Hollow																						
Molly																						
Ward																						
Major Fault																						
King of the Hills																						
Bismuth																						x
Major Bismuth																						x
Blue Jay															x			x	x	x		
Creole	x						x					x	x		x	x	x	x			amethyst	x
Hidden Treasure	x						x		x			x	x					x				
Maria																						
Bawana																						
Montreal																						
Old Hickory																						
Sunrise																						
Copper Ranch																						
Candy B																						
Copper King	x		x				x					x					x	x				x
Rebel									x					x							allanite,titanite	
Harrington-Hickory						x															vanadinite,	
Little May Lily																					corkite	
Washington																						
Wah Wah Pass												x	x									x
Copper Blossom													x		x			x	x			
Desolate Point	x						x		x				x		x			x	x			
North Desolate Pt.																						
Taylor NW	x						x		x						x			x				
Taylor Central																						

SKARN							**TUNGST.**		**MOL**	**NATIVE**		**OXIDES**					**OXIDIZED**		**ROCK**		**OTHER**	**BI**
OCCURRENCES	**py**	**po**	**sph**	**stib**	**tenn**	**tet**	**sch**	**wolf**	**p/w**	**Au**	**Ag**	**mgt**	**hem**	**spec**	**lim**	**pyr**	**Pb**	**Cu**	**mar**	**jasp**	**MINERALS**	
Taylor South																						
Six Shooter Canyon	x														x			x	x			x
East Canyon																						
Desert Flower	x						x		x						x			x	x			x
Newfoundland Cu																						
Lone Pine							x		x		x						x	x	x			x
Compressor																						
A & W																						
Rocky Pass																						
Magnitude																						
Tactite																						
Bovine Mtn																						
Numerous	x											x	x		x			x				
Numerous																						
Dyke No. 1										x									x	x		x
Crypto			x									x							x			
North Star																	x					x
Black Jack												x	x		x						halloysite,	x
Dragon																					enstatite	x
Iron King, NE													x					x				
Iron King, SW	x	x										x									sphene	
Murphy	x											x		x				x				
Tintic Western	x			x			x					x		x								
Bates Shaft																						
Sullivan Shaft																						
Great Western King																						
Trout Creek															x						beryl, psilomelane	
Pinnacle	x											x					x	x				
Tremolite No. 1																		x	x			
Dome Canyon															x					x	mica	
Klondike	x						x	x											x			x
South Pit																						
Yellow Bird																						
Horseshoe																						
Scheelite Queen																						
Lady Mae																						
Baldy Peak																						
Pine Peak																						
Brown Queen																						
Bell Base Lode																						
Bonnie May																						
Maxfield mine	x		x			x				x											sepiolite	x
Newman and Afton																						
Sunnyside mine																						
Evergreen mine												x		x				x			calc-silicates	
Scottish Chief										x	x						x	x	x		massicot,	
American Tunnel																					pyromorphite	
Big Cottonwood	x	x					x					x						x			borates,others	
Mountain Lake																						
Great Western																						
Relief shaft																						
Woodlawn-Kentucky			x			x			x	x							x	x			calc-silicates	x
Michigan Utah							x					x				x					ludwigite	

SKARN						TUNGST.		MOL	NATIVE		OXIDES					OXIDIZED		ROCK		OTHER	BI
OCCURRENCES	**py**	**po**	**sph**	**stib**	**tenn**	**tet**	**sch**	**wolf**	**p/w**	**Au**	**Ag**	**mgt**	**hem**	**spec**	**lim**	**pyr**	**Pb**	**Cu**	**mar**	**jasp**	**MINERALS**	
Solitude																						
Scotia																						
Alta-Clayton Peak	x											x										
Carr Fork	x	x										x	x								halloysite,	x
Parnell	x				x																saponite	x
North Ore Shoot	x						x					x	x								allanite	x
Highland Boy	x	x	x			x						x		x				x			tellurides,	x
Utah-Apex mine																					ilvaite	x
Alta Consolidated	x								x	x		x					x	x				
South Hecla			x			x	x			x		x					x				ludwigite	x
Trinity	x											x		x				x				
Jupiter	x					x								x			x	x				
Wabash	x														x	x						
Midas	x																					x
Alvarado	x									x												x
Cane Springs																						
Gold Hill																						
Bonnemort	x									x								x	x			x
Frankie	x						x			x								x			humite,conichal	x
Star Dust							x														calc-silicates	
B. Estelle																						
Fraction lode																						
Tuolumne																						
Copper Cup																						
Chloride Point																						
Eagle Hill																						
Ophir Hill	x	x	x		x		x	x													sphene	x
Cliff																						
Hidden Treasure																						
Honerine	x	x	x			x																x
Soldier Canyon																						
Settlement, Middle																						
Canyons																						
Metals Coalition	x						x												x			x
Jones-Bonanza	x		x							x									x		calc-silicates	
West Quincy						x																
Green Monster	x									x		x									calc-silicates	
West Park																						
Steamboat																						
Emma												x	x		x			x	x			
Marble prospect																						

SKARN	HOST ROCK		IGNEOUS ROCK ASSOCIATION				Multiple	Endo-
OCCURRENCES	Formation	Age	Name	Composition/texture	Form	Age	phases	skarn
Skylark	Fish Haven Dol,	Ord,Sil		qtz monz, qtz dior porph		Olig		
Bat Ridge	Laketown Dol							
Black Rock								
Beaver Copper								
Galena								
Norma #3								
Copper Mountain								
North Star								
Ute								
2 R's	Kaibab Ls	Perm	Mineral Mtns batholith	qtz monz	batholith	Olig-Mio		
Imperial	(ls)	Camb	Cactus stock	qtz monz (porph)	stock,	Olig		x
Cupric					apophyses			
Washington								
King David								
Peacock Copper								
Drum								
Iron	Kaibab Ls	Perm		qtz monz				
Strategic Metals	Redwall Ls	Miss	Mineral Mtns batholith	porph. granite to qtz monz	batholith	Mio		
Beaver View								
Daily Metals								
Garnet No. 1								
Oak Basin								
Contact								
Solomons Hollow								
Porcupine Hollow								
Molly								
Ward								
Major Fault								
King of the Hills								
Bismuth								
Major Bismuth								
Blue Jay	Orr, Wah Wah Summit	Camb		qtz latite porph		Olig		
Creole	Kaibab Ls	Perm	Lincoln stock	qtz monz	stock	Olig-Mio		
Hidden Treasure	Toroweap	Perm		equigranular qtz monz		Olig	x	
Maria								
Bawana								
Montreal								
Old Hickory								
Sunrise								
Copper Ranch								
Candy B								
Copper King	Kaibab-Plympton	Perm		porph. qtz monz		Olig?		
Rebel								
Harrington-Hickory								
Little May Lily								
Washington								
Wah Wah Pass	Orr, Weeks	Camb		dior and rhy porph		Tert		
Copper Blossom	(ls)	Perm	Crater Island stock	monz, granodior	stock	Jur	x	
Desolate Point	Pogonip, Eureka	Ord	Crater Island stock	monz, granodior	stock	Jur		
North Desolate Pt.	Qtzite							
Taylor NW	(ls, dol)	Ord	Sheepwagon stock	granodior	stock	Jur		
Taylor Central								

SKARN	HOST ROCK		IGNEOUS ROCK ASSOCIATION				Multiple	
OCCURRENCES	Formation	Age	Name	Composition/texture	Form	Age	phases	ndoskar
Taylor South								
Six Shooter Canyon	Laketown Dol,	Sil, Dev	McGinty stock	monzogranite	stock	Eoc		
East Canyon	Simonson Dol							
Desert Flower	Garden City	Ord	Newfoundland stock	qtz monz	stock	Jur		
Newfoundland Cu								
Lone Pine	Guilmette Ls,	Dev	Immigrant Pass pluton	granodior	pluton	Eoc		
Compressor	Simonson Dol							
A & W								
Rocky Pass								
Magnitude								
Tactite								
Bovine Mtn								
Numerous	Homestake Ls	Jur	Granite Mtn pluton	qtz monz porph	laccolith	Mio		
Numerous			Iron Mtn pluton		laccolith			
Dyke No. 1	(ls, dol)	Camb		qtz monz porph, qtz dior	dikes,plugs	Tert		
Crypto	(ls, dol)	M. Paleo	concealed intrusive	equigran qtz monz	stock	Tert		
North Star	Ajax Dol, Opohonga Ls	Camb, Ord	Silver City stock	monz	stock	Olig	x	
Black Jack	Ajax Dol, Opohonga Ls	Camb,Ord	Silver City stock	monz	stock	Olig	x	
Dragon							x	
Iron King, NE	(ls, dol)	Ord?	West Tintic stock	qtz monz	stock	Tert		
Iron King, SW								?
Murphy	Pogonip Ls	Ord		granite porph		Tert		
Tintic Western	Pogonip Ls	Ord	West Tintic stock	qtz monz	stock	Tert	x	
Bates Shaft								
Sullivan Shaft								
Great Western King								
Trout Creek	Trout Creek	Precamb Z		alaskite		Tert		
Pinnacle	(qtzites, carb)	Camb	Mineral Mtns batholith	hornblende granodior	batholith	Olig-Mio		
Tremolite No. 1	(dol)	Camb		granodior	pluton	Tert		
Dome Canyon		Camb	Painter Springs	qtz monz		Jur		
Klondike	Orr	Camb	Notch Peak intrusive	porph. granite		Jur-Cret		x
South Pit								
Yellow Bird								
Horseshoe								
Scheelite Queen								
Lady Mae								
Baldy Peak								
Pine Peak								
Brown Queen								
Bell Base Lode								
Bonnie May								
Maxfield mine	Gardison Ls	Miss	Argenta complex	dior	dikes,	Tert (Cret?)		
Newman and Afton					sills			
Sunnyside mine								
Evergreen mine	(ls)	Miss	Alta stock	granodior, qtz monzodior	stock	Eoc-Olig	x	
Scottish Chief	Thaynes	Tri	Alta-Clayton Peak	dior	dikes	Eoc-Olig	x	
American Tunnel								
Big Cottonwood	Gardison, Deseret,	Miss	Alta-Clayton Peak	granodior	stock	Eoc-Olig	x	
Mountain Lake	Humbug							
Great Western								
Relief shaft								
Woodlawn-Kentucky	(ls)	Miss	Clayton Peak stock	granodior	stock	Eoc-Olig		
Michigan Utah								

SKARN	**HOST ROCK**		**IGNEOUS ROCK ASSOCIATION**				**Multiple**	
OCCURRENCES	**Formation**	**Age**	**Name**	**Composition/texture**	**Form**	**Age**	**phases**	**ndoskar**
Solitude								
Scotia								
Alta-Clayton Peak			Alta-Clayton Peak	granodior	stock	Eoc-Olig	x	
Carr Fork	Oquirrh Group	Penn	Bingham stock	qtz monz porph	dike	Eoc	x	x
Parnell								
North Ore Shoot								
Highland Boy	Oquirrh Group	Penn	Bingham stock	qtz monz porph	dike	Eoc	x	x
Utah-Apex mine								x
Alta Consolidated	Maxfield, Gardison Ls	Camb,Miss	Alta-Clayton Peak	granodior, alaskite	stock,dike	Eoc-Olig	x	
South Hecla	Deseret, Maxfield Ls	Miss, Camb	Alta stock	granodior porph	stock	Eoc-Olig	x	
Trinity	(qtzite, ls)					Tert		
Jupiter	Thaynes	Tri	Clayton Peak stock	granodior porph	stock	Eoc-Olig		
Wabash	(ls)			granodior porph		Eoc-Olig		
Midas	Oquirrh Group	Penn	Gold Hill stock	granodiorite	stock	?		
Alvarado	Ochre Mtn	Miss		felsic	dikes	Eoc-Olig	x	
Cane Springs								
Gold Hill								
Bonnemort	Oquirrh Group	Penn		felsic	dikes	Eoc-Olig	x	
Frankie	Oquirrh Group	Penn	Gold Hill stock	granodior	stock	Jur		x
Star Dust			Gold Hill stock	?	stock	Jur?		
B. Estelle								
Fraction lode								
Tuolumne								
Copper Cup								
Chloride Point	(ls)			monz	sill	Tert		
Eagle Hill	(ls)		Eagle Hill	rhy	plug	Tert		
Ophir Hill	Ophir, Madison Ls	Camb,Miss		rhy porph	dikes	Tert		
Cliff								
Hidden Treasure								
Honerine	Oquirrh Group	Penn		qtz monz porph	dikes	Tert		
Soldier Canyon								
Settlement, Middle								
Canyons								
Metals Coalition	(ls)	Miss	Little Cottonwood stk	porph qtz monz	stock	Olig-Mio		
Jones-Bonanza	(ls)		Clayton Peak stock	granodior	stock	Eoc-Olig		
West Quincy								
Green Monster	Deseret, Gardison Ls	Miss	Clayton Peak stock	granodior	stock	Eoc-Olig		
West Park								
Steamboat								
Emma	Callville Ls	Penn	Mineral Mtn stock	alkali-fs granite porph	stock	Mio		x
Marble prospect								

SKARN OCCURRENCES	METAMORPHIC AUREOLE	Pb-Zn-Ag-Au REPLACEMENTS	COMMENTS	MAJOR REFERENCES
Skylark	Up to 20 ft., generally <10 ft.			1,2,3
Bat Ridge				
Black Rock				
Beaver Copper				
Galena				
Norma #3				
Copper Mountain				
North Star				
Ute				
2 R's		Cave, Hecla mines		4,5
Imperial	Up to 0.25 miles from exposed contact.	Horn Silver, King David mines		6,4,3
Cupric				
Washington				
King David				
Peacock Copper				
Drum				
Iron				1
Strategic Metals	Tactite stringers up to 200 ft. Scheelite		Anomalous Be in tactite.	6,7,8
Beaver View	zone up to 30 ft. wide, 300 ft. long.			
Daily Metals				
Garnet No. 1				
Oak Basin				
Contact				
Solomons Hollow				
Porcupine Hollow				
Molly				
Ward				
Major Fault				
King of the Hills				
Bismuth				
Major Bismuth				
Blue Jay			Coarse skarns.	6,9
Creole	Skarn up to 100 ft.	Rattler, Lincoln, Harriet mines	Skarn at Rattler, Lincoln.	4
Hidden Treasure	250 to 500 ft.			10
Maria				
Bawana				
Montreal				
Old Hickory				
Sunrise				
Copper Ranch				
Candy B				
Copper King	Up to 100 ft., extensive marble.	North Star, East Star, White Rock	Skarn along fissures,	11,12,3
Rebel			dissem. gar in marble.	
Harrington-Hickory			Minor skarn in South	
Little May Lily			Star district.	
Washington				
Wah Wah Pass	200 to 2,000 ft.		Bi geochem anomaly.	13,1,14
Copper Blossom	150 to 300 ft.			15
Desolate Point	150 to 300 ft.			15
North Desolate Pt.				
Taylor NW	5 to 15 ft. wide, 0.5 miles long.			15
Taylor Central				

SKARN OCCURRENCES	METAMORPHIC AUREOLE (Distance from igneous contact)	Pb-Zn-Ag-Au REPLACEMENTS	COMMENTS	MAJOR REFERENCES
Taylor South				
Six Shooter Canyon	Narrow.	Lucin district, Copper Mtn. area		16,15
East Canyon				
Desert Flower	Less than 10 ft., spotty occurrences 1 to 5 miles along contact.			15,7
Newfoundland Cu				
Lone Pine	Less than 10 ft., spotty occurrences up to 5 miles along contact.			15,7
Compressor				
A & W				
Rocky Pass				
Magnitude				
Tactite				
Bovine Mtn				
Numerous	Fe-ore replacements up to 250 ft. thick.			17,18,1,19
Numerous				
Dyke No. 1	Local. Up to 100 ft. Marble beyond.		Gold not in skarn.	20
Crypto	Mineralized zone 3 miles x 0.75 miles.	Utah, Galena, Emma mines		21,22
North Star	400 to 500 ft.	Centennial-Eureka mine	Veins hosted by skarn.	23
Black Jack	400 to 500 ft.; slight effects to 2,000 ft.	Centennial-Eureka mine	Halloysite production.	24,1,23
Dragon				
Iron King, NE	Up to 750 ft.	Scotia mine		25,26
Iron King, SW				
Murphy	Up to 2,500 ft. east of contact.	Scotia mine		25
Tintic Western	Up to 2,500 ft. from contact.	Scotia mine		27,25,28,26
Bates Shaft				
Sullivan Shaft				
Great Western King				
Trout Creek	Pockets along fault structures.			29,30
Pinnacle	Narrow, fault-controlled.			6,31,7
Tremolite No. 1	Tremolite body 1,500x1,200x100 ft.			6,32
Dome Canyon				UGMS files
Klondike	Up to 2.5 miles from exposed contact.			33,34,35,36
South Pit				
Yellow Bird				
Horseshoe				
Scheelite Queen				
Lady Mae				
Baldy Peak				
Pine Peak				
Brown Queen				
Bell Base Lode				
Bonnie May				
Maxfield mine	2 to 3 ft.	Maxfield mine	Polymetallic replacement.	37
Newman and Afton				
Sunnyside mine				
Evergreen mine				37,38
Scottish Chief	Ore replacements <1 ft.	Copper Apex group		37,39
American Tunnel				
Big Cottonwood	Up to 50 ft. wide.			31,37,1,40
Mountain Lake				
Great Western				
Relief shaft				
Woodlawn-Kentucky		Woodlawn-Kentucky-Utah, Cardiff, Columbus Rexal		37,31,38
Michigan Utah				

SKARN OCCURRENCES	METAMORPHIC AUREOLE	Pb-Zn-Ag-Au REPLACEMENTS	COMMENTS	MAJOR REFERENCES
Solitude				
Scotia				
Alta-Clayton Peak				31,41
Carr Fork	Copper skarn extends 1,500 ft. from QMP.	Utah-Apex and others		42,43
Parnell			Strong structural control.	44,45
North Ore Shoot	1,500 ft.	UTAH Apex, Lark mines		44,50
Highland Boy		Utah-Apex and others		42,46,47,48,49
Utah-Apex mine				
Alta Consolidated		Alta Consolidated, Emma mines	Skarn lower grade than	38
South Hecla		South Hecla, Emma mines	replacemts and fissures.	40,38
Trinity	Sporadic.			51,52
Jupiter		Daly West , Judge, Silver King,	Polymetallic replacement.	31,39
Wabash		Ontario		31,39
Midas				30,53
Alvarado		Gold Hill, United States, and Rube	Arsenic replacements at	54,55,53
Cane Springs		Gold mines	Gold Hill, U.S. mines.	
Gold Hill				
Bonnemort				55,53
Frankie				54,55
Star Dust	Ore zone 5 to 40 ft. wide.			7
B. Estelle				
Fraction lode				
Tuolumne				
Copper Cup				
Chloride Point	Less than 1 foot.			56
Eagle Hill	Less than 1 foot.			56
Ophir Hill	Fine-grain calc-silicates on flts, fissures.	Ophir district	Polymetallic replacement.	57,58,56
Cliff				
Hidden Treasure				
Honerine	Narrow zones bordering dikes, fissures.	Stockton district	Polymetallic replacement.	59,60,56
Soldier Canyon				
Settlement, Middle				
Canyons				
Metals Coalition			Bi,As,Sb geochem.	61,40
Jones-Bonanza		Valeo mine, Hawkeye-McHenry	Polymetallic replacement.	39
West Quincy				
Green Monster				UGMS files
West Park				
Steamboat				
Emma	3 feet; 300 to 3,600 ft. marmorization.			17,62
Marble prospect				