Mineral Resources of the Southwest Tintic Mining District, Juab County, Utah

Close-up photograph of coarse-grained octahedral pyrite and enargite (black) vein from the Homestake mine on Treasure Hill.

Prepared for the Utah School and Institutional Trust Lands Administration

Ken Krahulec

March 2018

Utah Geological Survey
a division of
Utah Department of Natural Resources

TABLE OF CONTENTS

EXECUTIVE SUMMARY iii
INTRODUCTION 1
HISTORY 1
REGIONAL SETTING 6
LOCAL GEOLOGY 8
MINERALIZATION 9
Geophysical Surveys 15
SWT Porphyry Cu-Mo 15
Diamond Gulch Chalcocite Blanket 25
Possible Exploration Targets 26
SUMMARY AND CONCLUSIONS 28
ACKNOWLEDGMENTS 28
REFERENCES 28

LIST OF FIGURES

Figure 1. Tintic district location map with inset of the four Tintic subdistricts 2
Figure 2. Diagrammatic cross sections through the SWT porphyry Cu-Mo deposit and Diamond Gulch chalcocite blanket, see Plate 1 for section locations. A. Long section looking west-northwest. B. Cross section looking north-northeast 16

LIST OF TABLES

Table 1. Southwest Tintic subdistrict mining and mineral exploration history 3
Table 2. Eocene-Oligocene volcanic and sedimentary strata in the East Tintic Mountains 7
Table 3. Minerals of the Southwest Tintic mining district 10
Table 4. Estimated production from the Southwest Tintic mines 12
Table 5. Idealized horizontal mineral zonation in the SWT porphyry Cu-Mo system 18
Table 6. Southwest Tintic subdistrict mineral inventories 20
Table 7. Drill intersections used to calculate mineral inventories 22
Table 8. Summary information for the bottom of the deep drill holes that intersect the SWT porphyry Cu-Mo deposit 24
Table 9. Southwest Tintic porphyry copper system vein types 25

LIST OF APPENDICES

Appendix I. Southwest Tintic district maps I-1
Appendix II. Southwest Tintic district photographs II-1
Appendix III. Southwest Tintic district drill hole database III-1

EXECUTIVE SUMMARY

The greater Tintic mining district is Utah's second largest metal producer. The Tintic district is similar to the Bingham district in that it is localized near the intersection of the northerly trending Wasatch line and an east-west-trending mineral belt. The Southwest Tintic subdistrict is on the northwest flank of an eight-mile-diameter, Eocene-Oligocene composite stratovolcano and coincident calderas.

The first discovery in the region was the Sunbeam vein in 1869 and the Tintic district was incorporated the following year. The district was a consistent mineral producer for about 125 years until 1996. The Southwest Tintic subdistrict presents some intriguing exploration possibilities that have repeatedly drawn the interest of major mining companies such as Kennecott, Anaconda, Exxon, Western Mining, and Freeport-McMoRan from 1960 to the present day. This type of persistent episodic mineral exploration has been shown to be indicative of prospective terranes that can lead to significant mineral discoveries.

Pervasive hydrothermal alteration of the volcanic rocks through the Southwest Tintic subdistrict occurs along a northeast-trending corridor which includes the SWT (Southwest Tintic) porphyry Cu-Mo system. This alteration corridor has a partially coincident aeromagnetic low and induced polarization anomaly. The SWT porphyry Cu-Mo deposit contains about 1.5 billion tons of 0.21% Cu and 0.01% Mo as an inferred subeconomic resource at a depth of over 1000 ft. Above and north of this deposit, the shallower Diamond Gulch chalcocite blanket contains an inferred subeconomic resource of about 88 million tons at 0.156% Cu. The presence of a large sulfide system with a low-grade Cu shell, good Mo values, high total sulfide content, abundant anhydrite, and lack of a primary, copper-rich species other than chalcopyrite suggests that SWT is a high-sulfide/sulfate, low-Cu porphyry system.

The inferred subeconomic resource at the SWT porphyry Cu-Mo deposit hosts over 6 billion pounds of Cu and nearly 300 million pounds of Mo and has a current in-place value of just over $22 billion (at $3.20 per pound Cu and $7 per pound Mo). The adjoining Diamond Gulch chalcocite blanket hosts an additional 273 million pounds of Cu with an in-place value of about $875 million. Nearly all of these resources are on BLM land, much of it open to mineral entry and currently controlled by Freeport-McMoRan by unpatented mining claims. While these large resources are presently subeconomic, it is probable that at some point, future advances in mineral extraction technology could make these deposits viable resources. SITLA should consider acquiring all federal lands in sections 7, 8, 18, and NW¼ section 19, T. 11 S., R. 2 W. and sections 12, 13, and 24, T. 11 S., R. 3 W. This includes about 1818 acres of BLM and an additional 286 acres of Bankhead-Jones lands for a total of 2104 acres.

INTRODUCTION

The Tintic district is located in west-central Utah, about 60 miles south of Salt Lake City (figure 1). Tintic was one of the most prominent early mining districts in Utah having well over a century of continuous production. The greater Tintic district is subdivided into four subdistricts: Main Tintic, East Tintic, Southwest Tintic, and North Tintic. In addition to the town of Eureka, once flourishing mining camps of Silver City, Diamond, Mammoth, Robinson, Knightsville, Homansville, and Dividend once dotted the hillsides during the camps' heyday. Only the town of Eureka and a few houses at Mammoth-Robinson remain today (James, 1984).

The Southwest Tintic subdistrict terrain consists of an embayment on the west side of the East Tintic Mountains (plate 1). The highest peak in the area reaches 7861 ft at Buckhorn Mountain to the southeast and the lowest elevations of about 5450 ft in Tintic Valley to the west. Vegetation ranges from sparse saltbush, shadscale, and rabbitbrush at lower elevations in the foothills with increasing sagebrush, juniper, and pinyon pine at increasingly higher elevations. Temperatures in the region range from an average monthly low of 12°F in December to an average monthly high of 94°F in July with an average of just 8.6 inches of precipitation per year (US Climate Data, undated). These mild climatic conditions are conducive to year-around mining operations. No perennial streams are found in the Southwest Tintic subdistrict.

The mineral deposits of the Tintic district are scattered over 50 square miles of the East Tintic Mountains. The four combined Tintic subdistricts constitute the second largest metal producing district in the state (nearly 19 million tons of ore) with Bingham as the largest producer and Park City a close third. The total Tintic district metal production at today's metal prices would be valued at roughly $12.5 billion. Tintic's metals are more valuable than the production of the Intermountain West's other famous polymetallic vein and replacement camps at Leadville, Colorado; Telluride, Colorado; Superior, Arizona; Gilman, Colorado; Eureka, Nevada; Globe, Arizona; Aspen, Colorado; and Pioche, Nevada, in order of decreasing value (Krahulec and Briggs, 2006).

Historical production from the Tintic district has been largely derived from precious metal-rich, polymetallic subvertical chimneys and irregular, gently plunging ribbon-shaped replacement deposits hosted by Paleozoic sedimentary rocks of the Main and East Tintic subdistricts with lesser production from the Southwest Tintic and North Tintic subdistricts (Krahulec and Briggs, 2006). Most of the greater Tintic district's value has been derived from Ag-Au-Pb ores.

HISTORY

Mineralization in the Tintic mining district was discovered in December 1869 by George Rust and a party of prospectors returning from an expedition to Utah's West Desert (Tower and Smith, 1899, 1900). Located in the Southwest Tintic subdistrict, the Sunbeam was the first claim recorded in December 1869, while the Black Dragon property of the Main Tintic subdistrict was staked soon after in January 1870 (table 1). The important Mammoth and Eureka Hill deposits, also in the Main Tintic subdistrict, were discovered in February 1870. The Tintic mining district was organized in early 1870 and named in honor of Chief Tintic of the local Goshute tribe (Morris, 1968). Although little work was done on these discoveries until the fall of 1870, mining camps were quickly established at Eureka, Silver City, and Diamond by 1871. Early production was hampered by the district's

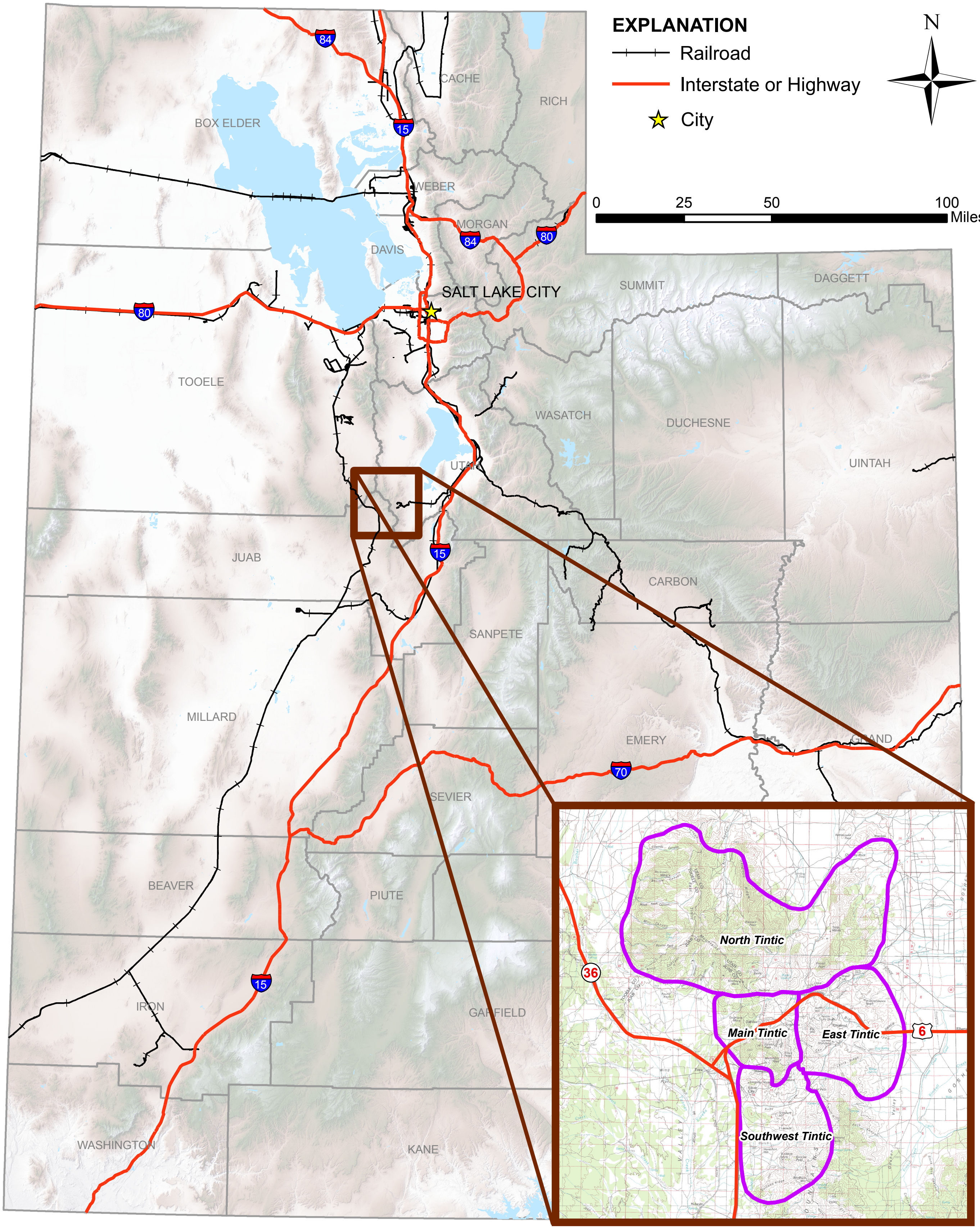


Figure 1. Tintic district location map with inset of the four Tintic subdistricts.

Table 1. *Southwest Tintic subdistrict mining and mineral exploration history.*

Year	Event
1869	Sunbeam vein discovered
1870	Tintic district organized
1872	About a dozen mines in production, led by the Mammoth and Sunbeam
1873	Mammoth acquired by the McIntyre brothers and becomes largest Cu producer in Utah
1878	Utah Southern Railroad reaches Ironton (Silver City)
1879	Mammoth stamp and pan-amalgamation mill begins successful operation
1883	Oregon Short Line Railroad completes spur to Silver City
1880-95	Most productive period for the Southwest Tintic district
1890s	Tintic is the most productive district in Utah
1893	Swansea relocated and shaft deepened
1895	Swansea sulfide production increases and Silver City booms
1898	Swansea and Joe Bowers still in production
1899	Tower and Smith complete USGS report on the Tintic district
1909-11	Old Susan Pb-Ag mine in operation
1914	Swansea Consolidated continue ore shipments
1918	Laclede Mining Company assembles 500 acres around Treasure Hill, Thomas Weir manager
1919	Lindgren and Loughlin complete USGS Professional Paper on the Tintic district
1930-34	Great Depression — minor scavenging of high-grade ore from Tintic mines and dumps
1940-44	Four Mintintic holes drilled by Longyear - Bear Creek Mining Co. - Calumet & Hecla Copper JV
1949	Halloysite mining begun at the Dragon mine
1957	D.R. Cook, Utah Geological Society Guidebook of the East Tintic Mountains
1958	D.R. Cook, BCMC, 1958 SWT recommendation
1960-61	BCMC mapping and sampling Horseshoe Hill, land acquisition, and IP
1962-68	SWT-01 to -30 for chalcocite blanket; Diamond Gulch CC discovered in 1963
1964	H.T. Morris, geologic maps of the Eureka and Tintic Mountain quadrangles
1967-68	M.D. Regan and J.C. Wilson BCMC proposed deep PCD target
1968	Morris publishes AIME paper on the Main Tintic district
1968-70	BCMC completes holes SWT-31 to 37; SWT PCD discovered in SWT-31 in 1968
1971	BCMC hole SWT-37 deepened
1972	BCMC hole SWT-38 drilled
1973-82	BCMC SWT-30 deepened for assessment requirements
1976	BCMC in-situ PCD assessment
1981	BCMC Weir exam, three angle holes drilled to test the high-sulfidation veins
1981	G. Ballantyne Kennecott secondary biotite study
1982	T. Faddies-M.J. Sweeney Kennecott deepen hole SWT-32
1982-83	Anaconda exam of Treasure Hill area
1983	Sunshine Mining Company purchase Kennecott's Tintic Division (Burgin and Trixie)
1982-84	Exxon Weir Treasure Hill exam, 10 holes drilled
1987-89	Centurion - Western Mining Corp. JV
1988	North Lily commissions the Silver City heap leach facility
1991-92	Centurion - Crown JV; 7 holes completed
1993-94	Kennecott - Centurion JV; 22 holes completed
1994	Kennecott hole STD-6 intersects the longest intercept of greater than 0.2% Cu
1996	End of roughly 125 years of continous mineral production in the Tintic district
2001	“Eureka Mills” was added to the EPA's National Priorities List
2010	DOGM closes Southwest Tintic subdistrict underground mine workings
2010-11	Quaterra - Freeport-McMoRan JV completed 5 holes in the Treasure Hill area
2014	Freeport-McMoRan buys out Quaterra
2017	Freeport-McMoRan starts deep drilling on the SWT porphyry Cu-Mo deposit

Note: Bear Creek Mining Company (BCMC) was a wholly owned exploration subsidiary of Kennecott Exploration Company.

remote location which resulted in high shipping costs for the ores. During this period, only the richest ores could be shipped to processing facilities, some as far away as Swansea, Wales (James, 1984). By 1872, the Sunbeam, Shoebridge, Showers, Morning Glory, and Joe Bowers mines in the Southwest Tintic subdistrict were operating or being developed.

The Utah Southern Railroad was completed to Ironton, five miles southwest of Eureka in 1878. In response to the arrival of the railroad, district production nearly doubled in 1879. By 1880, Diamond had two unsuccessful smelters, the Shoebridge mine had a 15-stamp mill, and the Swansea had become the most productive mine in the Southwest Tintic subdistrict (appendix II, photos 10 and 11). During the early 1880's, the Salt Lake and Western Railroad connected Silver City, Mammoth, and Eureka with the Utah Southern Railroad at Ironton, further enhancing the profitability and production of the mining operations (Krahulec and Briggs, 2006).

By 1899, the Tintic mining district had become the largest producer in Utah, overtaking the Park City and Bingham districts (Lindgren and Loughlin, 1919). In 1907, the Tintic district reached its peak gold production followed in 1912 by its copper production peak (Lindgren and Loughlin, 1919). Another notable event in 1912 was the first discovery of ore in the East Tintic subdistrict (Morris and Mogensen, 1978). Annual ore production from the Main Tintic subdistrict reached its all-time peak of more than 420,000 tons in 1912. Fifty-four mines were active within the Tintic district by 1916. Once considered a deleterious contaminant of the Pb-Ag ores, Zn was initially recovered from the Scranton mine in the North Tintic subdistrict in 1906 and from ores at Main Tintic and East Tintic in 1912 (Krahulec and Briggs, 2006).

In 1918, the Laclede Mining Company acquired the West Morning Glory Mining Company and assembled a block of 62 patented mining claims totaling about 500 acres generally south and east Treasure Hill in the Southwest Tintic subdistrict (table 1). Thomas Weir became the general manager of the company. This property, later known as the Weir tract, became a central land position in mineral exploration from the 1960s to the 2010s.

The Tintic mining district as a whole saw its peak silver production in 1925 and its peak lead production in 1926. During this period, mines of the Main Tintic subdistrict were still in production and were joined by the important production of ores from the East Tintic subdistrict. Like most mining districts in the United States, the Tintic mining camp suffered through difficult years due to low demand during the Great Depression of the 1930s (Krahulec and Briggs, 2006).

The revival of the Tintic mining district began in early 1943 when the United States Geological Survey (USGS) began a multi-year study under the direction of Thomas Lovering. During the 1940s and 1950s a number of companies conducted exploration in the greater Tintic mining district. Bear Creek Mining Company, a wholly-owned exploration subsidiary of Kennecott Copper Corporation, undertook an exploration program in the Southwest Tintic subdistrict through a joint venture with E.J. Longyear Company and Calumet and Hecla, Inc. during the late 1940s. Bear Creek Mining Company also ran an exploration program in the Southwest Tintic subdistrict during the 1960s and 70s. This later exploration effort delineated a low-grade chalcocite blanket south of Treasure Hill in 1962–63 and eventually resulted in the discovery of a deep, SWT (Southwest Tintic) porphyry Cu-Mo system southwest of Horseshoe Hill in 1968–69 (table 1). Neither deposit was economic and the property was dropped in the 1980s (Krahulec and Briggs, 2006).

The earliest reported production from the

Dragon iron mine was from an open-pit during the late 1890s. Intermittently mined for smelter flux over the next several decades, these oxidized iron ores contained erratic values of silver and trace amounts of gold. After acquiring control of the property in July 1929, International Smelting and Refining attempted to identify the abundant clay material at the site and find a market. It was initially identified as halloysite in 1938. Extensive research by the Filtrol Corporation determined that halloysite could be used as a filter catalyst by the petroleum refining industry. They acquired an option on the property from the International Smelting and Refining Company and commenced production in 1949. Initially mined by underground methods and later from an open-pit, the Dragon clay mine continued operations with few interruptions until 1976, when the primary use of halloysite was replaced with a synthetic product (appendix II, photo 9). During this period, Filtrol Corporation produced approximately 1,350,000 tons of halloysite from the Dragon mine, valued at roughly $50,000,000 (Morris, 1985), equivalent to over $115,000,000 today.

Most of the Pb-Zn smelters in the western United States were closed with the passage of the Clean Air Act of 1971. In Utah, the United States Smelting, Refining and Mining Company's (USSRMC) custom mill at Midvale ceased operations in 1971, as did the International Smelter at Tooele. The effects of these closures rippled throughout the base metal mining camps of the west, including Tintic. Then the closure of the Ruth porphyry Cu operation near Ely, Nevada, in May 1978 and its dedicated smelter at McGill, Nevada, in June 1983 reduced the market for fluxing ores (Krahulec and Briggs, 2006).

Mineral exploration continued in the Tintic district throughout the 1980s and 1990s. Asarco installed a new headframe, hoist, and rehabilitated the Chief No. 2 shaft to a depth of 1450 ft in 1981 and carried out an unsuccessful underground exploration program at the site until December 1984. Anaconda Copper drilled several exploration holes in the central and eastern parts of the district (James, 1984). A joint venture between Western Mining Corporation Holdings Ltd. and Centurion Mines Corporation conducted exploration programs for gold ore in the Main Tintic subdistrict during the late 1980s. Centurion also did some trenching and drilling of the northern portions of the Southwest Tintic subdistrict in the early 1990s. The Southwest Tintic subdistrict was re-examined by Kennecott for a second porphyry Cu and volcanic-hosted, Cu-Au massive sulfide mantos during the early 1990s (Krahulec and Briggs, 2006). This program drilled the best hole in the history of the SWT porphyry Cu-Mo programs (table 1). Although mineralization was intersected, no development ensued, and the property was again dropped.

By 1996, all production from the Tintic district had been halted, bringing over a century and a quarter of nearly continuous mineral production to an end. Sporadic base and precious metals production from the Tintic mining district continued intermittently until the spring of 2002 (Krahulec and Briggs, 2006). Exploration and development programs began again in 2009–2014 re-examining the old camps' mineral potential, primarily in the East and Southwest Tintic subdistricts. Freeport-McMoRan Copper and Gold Inc. began another renewed deep drilling program in the Southwest Tintic subdistrict in late 2017 attempting to find a second porphyry Cu deposit or a higher-grade portion of the known SWT porphyry Cu-Mo deposit (table 1).

In summary, the Southwest Tintic subdistrict presents some intriguing exploration possibilities that have repeatedly drawn the interest of major mining companies such as Kennecott, Freeport-McMoRan, Exxon, Anaconda, and Western

Mining. This type of episodic mineral exploration of a district has been shown to be potentially indicative of exceptionally prospective geologic terrane which could yet result in important discoveries (Sillitoe, 1995).

REGIONAL SETTING

The greater Tintic district is localized near the intersection of the northerly trending Wasatch line and the east-west-trending Deep Creek-Tintic mineral belt. Both of these lineaments are long-lived structural zones with geologic histories dating back into the Paleozoic. In many respects this setting is similar to the Bingham district: Eocene-Oligocene intermediate intrusive complex localized at the intersection of the Wasatch line and an east-west mineral belt (Krahulec, 1996).

The East Tintic Mountains are typical Basin and Range block-faulted mountains and has a major north-south-trending normal fault along the west side of the range and no clearly defined fault to the east. Gravity data suggest thickness of 5000 to 7000 ft of alluvial fill in Tintic Valley on the west side of this range (Mabey and Morris, 1967). Most displacement is along the westernmost range-bounding normal fault, but there is about 500 ft of normal throw along a subsidiary fault about 1700 ft farther east in the SWT area.

Elevation of the Paleozoic basement and dips on Oligocene volcanics suggest 10° to 25° of eastward rotation of the range, similar to the Oquirrh Mountains to the north. This rotation explains why the majority of the intrusive rocks are exposed on the more deeply eroded west side of the range while the east flank is dominated by young volcanic rocks (Keith and others, 1991).

The presence of calderas along the Deep Creek-Tintic mineral belt was first suggested by Shawe (1972). A caldera structure was inferred for the large East Tintic Mountains volcanic pile initially by Morris (1975) and later modified by Hannah and others (1991). Evidence for this caldera structure is supported by: (1) a rapid thickening of the volcanic section, (2) a basal megabreccia lahar with an upper lacustrine tuffaceous section, (3) an inferred caldera rim marked by intrusives and alteration, and (4) a large, circular magnetic high corresponding to a thickened volcanic package and postulated large underlying intrusive body (Hannah and others, 1991). Keith and others (1991), Moore and others (2007), and Keith and others (2009) developed a more complex nested caldera model based on detailed geological mapping. They proposed three separate, but incompletely delimited, calderas (table 2). The oldest caldera formed in the southern East Tintic Mountains with the eruption of the oldest volcanic unit, the Fernow quartz latite, forming the Fernow caldera. The Rattlesnake Peak caldera formed next and was the largest of the three. This caldera is similar to the original 9-mi-diameter caldera proposed by Morris (1975). Finally, the Copperopolis Latite caldera (appendix I, map 2) overlapped the Rattlesnake Peak caldera but was somewhat smaller (table 2). The Copperopolis Latite caldera was then intruded by the Sunrise Peak monzonite porphyry and the younger Silver City quartz monzonite stock was intruded along the northwestern caldera wall.

The northwestern rim of the Copperopolis Latite caldera rim is neatly defined between exploration drill holes in the Southwest Tintic subdistrict. Hole SWT-23 cut Cambrian Tintic Quartzite outside the caldera at a depth of about 1260 ft (Welsh, 1976, 1985), while holes to the east and south, including SWT-30, -31, -36, and -37, each cut over 3000 ft of quartz latite tuffs and andesitic flows inside the caldera. Some of these holes inside the caldera cut volcanics containing large blocks of quartzite (Krahulec, 1996). None of the holes within this caldera have penetrated the base of the volcanic sequence, despite reaching depths of over 4000 ft.

Table 2. *Eocene-Oligocene volcanic and sedimentary strata in the East Tintic Mountains, modified from Moore (1993), Moore and others (2007), and Keith and others (2009).*

Age	Extrusive rocks	Maximum Thickness (ft)	Age*	Intrusive rocks	Calderas
Oligo-cene			34.4 Ma	Quartz monzonite porphyry	
	Laguna Springs Volcanic Group		33.3 Ma	Silver City quartz monzonite	
	Latite of Rock Canyon	1,500	33.7 Ma	Rhyolite of Keystone Springs	
Eocene	Latite Ridge Latite	500	34.6 Ma		Latite Ridge caldera?
	Volcaniclastic strata	500			
	Latite of Little Dog Canyon	250			
	Latite of Dry Herd Canyon	350			
	Upper biotite latite flows	350			
	Shoshonite of Buckhorn Mountain	500			
	Lower biotite latite flows	200		Biotite latite intrusions	
	Epiclastic strata	150			
	Upper lacustrine strata	50			
	Flows and agglomerates of Sunrise Peak	600	34.7 Ma	Sunrise Peak monzonite porphyry	
	Lower lacustrine strata	350			
	Tuff member of Copperopolis latite	900	35.1 Ma		Copperopolis Latite caldera
	Lava flows of Rattlesnake Peak	1,000	34.8 Ma		Rattlesnake Peak caldera
	Fernow quartz latite	1,500	34.9 Ma		Fernow caldera

*Ages are estimates, even some recent ages may be in conflict with the law of superposition and cross-cutting relations.

The proposed caldera interpretation is also supported by various corporate detailed aeromagnetic surveys which have a coincident magnetic low over much of the proposed Copperopolis Latite caldera margin, probably caused by hydrothermal alteration and destruction of magnetite along the caldera fault. Another line of supporting evidence for the larger caldera boundaries is based on exposure of Tintic Quartzite at about 6580 feet near Road Canyon outside the southwest flank of the caldera and a basement intersection at 3300 ft less than 1.5 miles to the east, in a deep drill hole in Burnt Hollow, inside the caldera (Morris, 1975).

LOCAL GEOLOGY

The Southwest Tintic subdistrict lies on the northwest flanks of both the Rattlesnake Peak and Copperopolis Latite calderas. The thick volcanic sequence is dominantly quartz-biotite latite crystal tuffs, andesite and latite flows and agglomerate, and lacustrine and epiclastic strata (table 2; Keith and others, 2009). Near the eastern margin of the Southwest Tintic subdistrict the northeast-trending Diamond fault reportedly dips about 65° NW (Welsh, 1976, 1985).

Age dates for the volcanic units range from about 39 to 30 Ma with recent dating clustering more tightly in the 35 to 33 Ma range. Broadly, the volcanic sequence is broken down into a (1) lower crystal tuff overlain by (2) andesitic to latitic flows, agglomerates, tuff-breccias, and tuffs and an (3) upper latitic air-fall tuff and tuffaceous sediment member (table 2). This volcanic section may be over 8000 ft thick. This sequence of volcanics is intruded by and coeval with the Sunrise Peak monzonite porphyry (table 2). Welsh (1976, 1985) believed that the Sunrise Peak stock is a resurgent vent facies of the andesitic sequence. The Silver City quartz monzonite stock is younger, intruded north of the proposed caldera margin, and has been dated at 33.8 Ma by Keith and others (1991). The Silver City stock is elongated north-northeast (appendix I, map 2). The Silver City stock is not seen as the source of Southwest Tintic's mineralization because it is relatively unaltered and boldly cut by veins, such as the 3500-ft long Sunbeam vein (appendix I, map 2; appendix II, photo 1-4), indicating it was fully crystallized and brittle during the later mineralization.

The youngest intrusive event is believed to be quartz monzonite porphyry intersected in the SWT porphyry drill holes. Kennecott drill logs from SWT-32 and SWT-33 describe this unit as gray, porphyritic quartz monzonite, coarse pink K-spar phenocrysts up to 2 inches, ½ inch rounded quartz phenocrysts, plagioclase altered to clay-sericite, coarse black primary biotite, with very fine-grained disseminated secondary biotite. The quartz monzonite porphyry was also intersected in STD-06 and possibly in SWT-30 and SWT-31. The most and thickest intersections of quartz monzonite porphyry were in SWT-32. There are at least two, and may be more, quartz monzonite porphyry phases — this uncertainty is a result of no one company having access to all of the SWT drill holes. A fresh quartz latite porphyry dike (appendix II, photo 5-6) similar to this description intrudes the Silver City stock (appendix II, photo 7-8) in a small area on the north side of Ruby Gulch (Krahulec, 1996).

There is some indication that the SWT porphyry Cu-Mo deposit is oriented north-northeast, similar to the Silver City stock (appendix I, map 2). Small outcrops of volcanic rocks above the SWT porphyry Cu-Mo deposit locally show steeper than average dips of up to 90°, apparently disrupted by the intrusion of the quartz monzonite porphyry.

The geometry of the quartz monzonite porphyry is uncertain and in this report it is interpreted to be mainly a steeply dipping dike swarm based on the relatively narrow individual drill intersections ranging from just a few feet to about 400 ft thick. These dikes are most common in hole SWT-32 and may be oriented north-northeast with steep westerly dips similar to other dikes in the Southwest Tintic zone of alteration. Kennecott reports (e.g. Welsh, 1976, 1985) referred to a Diamond Gulch quartz monzonite porphyry stock, which it may be in SWT-32.

MINERALIZATION

The SWT porphyry Cu-Mo system (U.S. Geological Survey [USGS] model 17 Porphyry Cu; Cox and Singer, 1986) and the Diamond Gulch chalcocite blanket both occur in a topographic embayment on the west side of the East Tintic Mountains and south of the east-west-trending Treasure Hill ridge. Treasure Hill primarily exposes strongly propylitized andesite porphyry flows and sills (appendix II, photo 12) cut by north-northeast-trending, narrow, high-sulfidation Au-Ag-Cu veins (USGS model 25E Epithermal quartz-alunite Au; Cox and Singer, 1986) that generally strike N 15° to 35° E and dip 75° to 85° W. Treasure Hill also has a few strongly altered but unmineralized magmatic-hydrothermal breccia pipes up to about 500 ft in diameter (appendix I, map 2; appendix II, photo 14-19).

Horseshoe Hill lies about a mile to the south of Treasure Hill and exposes argillically and phyllically altered crystal tuffs (appendix II, photo 13). Surficial oxidation of the high pyrite content in these unreactive tuffs has resulted in a nearly barren jarosite-goethite leached capping and minor turquoise developed locally (table 3; appendix II, photo 22). A couple of short adits on the north flank of Horseshoe Hill explore small north-northeast-trending oxidized pyrite veins. Tourmaline is found sparingly in veins and disseminations associated with argillic-phyllic alteration on Horseshoe Hill and in some of the nearby holes (SWT-01, SWT-18, SWT-19, SWT-26, SWT-28, SWT-30, STD-09, and STR-10). Limited geochemical sampling of the leached capping on Horseshoe Hill and a few scattered, isolated bedrock exposures to the west and south show minimal geochemical expression of the underlying Diamond Gulch chalcocite blanket or SWT porphyry Cu-Mo mineralization: 1 ppm Ag, 20 ppm As, 0.02 ppm Au, 15 ppm Bi, 150 ppm Cu, 1 ppm Hg, 3 ppm Mo, 70 ppb Pb, 5 ppm Sb, 20 ppm Sn, 1 ppm Te, 5 ppm W, and 50 ppb Zn.

The production of approximately 122,000 tons of ore are credited to the Southwest Tintic subdistrict, with an average recovered grade of 405 ppm Ag, 3.39 ppm Au, and 3.41% Pb, along with lesser amounts of Cu (table 4). The Southwest Tintic mines produced principally from veins cutting volcanic and intrusive rocks. The Swansea mine was the largest producer in the subdistrict, yielding 77,387 tons of Ag-Pb-Au ore. However, many of the other small mines (all less than 10,000 tons of ore production) in the area were dominantly Ag-Au-Cu producers (Cook, 1957). These mines were last operated in the early 1900s with some reopening briefly during the depths of the Great Depression in the mid-1930s. Most of the ore mined was oxide ore. The contact between oxide and sulfide ores lies near the modern water table and is generally quite sharp (Tower and Smith, 1900). The best, most concise description of these vein deposits is given by Morris (1968):

> **FISSURE VEINS:** Many of the ore bodies in the Tintic Quartzite, Opohonga Limestone, and the volcanic rocks, as well as the majority of those that cut the Silver City and Swansea stocks, commonly show little evidence of wall rock replacement and locally are classified as fissure veins. These veins have quite smooth, well-defined

Table 3. *Minerals of the Southwest Tintic mining district.*

Mineral	Formula	Mine
Actinolite	$Ca(Mg,Fe)_3(SiO_2)_4$	SWT
Alunite	$KAl_3(SO_4)_2(OH)_6$	Governor
Anglesite	$Pb(SO_4)$	Sunbeam, Swansea
Anhydrite	$Ca(SO_4)$	SWT, Homestake
Ankerite	$Ca(Fe,Mg,Mn)(CO_3)_2$	
Argentite	Ag_2S	
Aurichalcite	$(Zn,Cu)_5(CO_3)_2(OH)_6$	
Azurite	$Cu_3(CO_3)_2(OH)_2$	
Barite	$BaSO_4$	Alaska, Martha Washington, Molly Gibson, New State, Red Rose, Shoebridge-Bonanza, Treasure Hill, United Tintic
Biotite	$K(Mg,Fe)_3[AlSi_3O_{10}(OH,F)_2$	SWT
Bornite	Cu_5FeS_4	
Brochantite	$Cu_4(SO_4)(OH)_6$	
Calcite	$CaCO_3$	
Cerussite	$Pb(CO_3)$	Evelyn, Old Susan, Rising Sun, Ruby, Sunbeam, Sunrise Canyon, Swansea, Tintic Coalition, Volcano Ridge
Chalcanthite	$Cu(SO_4)•5(H_2O)$	
Chalcocite	Cu_2S	Diamond Gulch chalcocite blanket, Sunbeam
Chalcophyllite	$Cu_{18}Al_2(AsO_4)_3(SO_4)_3(OH)_{27}•36(H_2O)$	
Chalcopyrite	$CuFeS_2$	SWT, New State, Black Dragon, Swansea
Chlorargyrite	AgCl	
Chlorite	$(Fe,Mg,Al)_6(Si, Al)_4O_{10}(OH)_8$	
Chrysocolla	$(Cu,Al)_2H_{1.75}(Si_2O_5)(OH)_4•0.25(H_2O)$	Dragon
Clinoclase	$Cu_3(AsO_4)(OH)_3$	
Conichalcite	$CaCu(AsO_4)(OH)$	
Copper (native)	Cu	
Covellite	CuS	
Crandallite	$CaAl_3(PO_4)_2(OH)_5•(H_2O)$	Brooklyn
Cryptomelane	$KMn_6Mn_2O_{16}$	Burgin
Cuprite	Cu_2O	
Diaspore	AlO(OH)	Laclede, Shoebridge-Bonanza, Tesora
Dickite	$Al_2Si_2O_5(OH)_4$	Alaska, Molly Gibson, Swansea
Digenite	Cu_9S_5	
Dolomite	$CaMg(CO_3)_2$	
Enargite	Cu_3AsS_4	Homestake, Laclede, Little May, Martha Washington, Republic, Shoebridge, Swansea, Tesora, Treasure Hill
Epidote	$Ca_2Fe_{2.25}Al_{0.75}(SiO_4)_3(OH)$	
Famatinite	Cu_3SbS_4	Undine (?)

Table 3 continued

Mineral	Formula	Mine
Fluorite	CaF_2	
Galena	PbS	Alaska, Columbus Tunnel, Dragon, Homestake, Old Susan, Rising Sun, Shoebridge, Showers, Swansea
Gold (native)	Au	Ruby
Gypsum	$Ca(SO_4)\bullet 2(H_2O)$	
Halloysite	$Al_2Si_2O_5(OH)_4$	Alaska, Dragon, Shoebridge-Bonanza, South Iron Blossom, United Tintic
Hematite	Fe_2O_3	
Hemimorphite	$Zn_4Si_2O_7(OH)_2\bullet(H_2O)$	
Hydrozincite	$Zn_5(CO_3)_2(OH)_6$	
Illite	$K_{0.6}(H_3O)_{0.4}Al_{1.3}Mg_{0.3}Fe_{0.1}Si_{3.5}O_{10}(OH)_2\cdot(H_2O)$	Alaska, Laclede, South Iron Blossom, Swansea
Jarosite	$KFe_3(SO_4)_2(OH)_6$	Horseshoe Hill
Kaolinite	$Al_2Si_2O_5(OH)_4$	
Magnetite	Fe_3O_4	SWT, Old Susan
Malachite	$Cu_2(CO_3)(OH)_2$	Buckeye, Rising Sun, Ruby, Sunbeam, Sunrise Canyon, Tintic Coalition, Volcano Ridge
Manganite	MnO(OH)	
S	FeS_2	
Melantorite	$Fe(SO_4)\bullet 7(H_2O)$	Swansea
Mixite	$BiCu_6(AsO_4)_3(OH)_6\bullet 3(H_2O)$	Treasure Hill (?)
Molybdenite	MoS_2	SWT, Manhattan Tunnel
Orthoclase	$KAlSi_3O_8$	SWT
Pyrargyrite	Ag_3SbS_3	
Pyrite	FeS_2	SWT, Homestake, Laclede, Little May, Republic, Shoebridge, Swansea, Tesora, Treasure Hill
Pyrolusite	MnO_2	Sunrise Canyon prospects, White Cloud
Pyrophyllite	$Al_2Si_4O_{10}(OH)_2$	Homestake, Laclede
Scorodite	$FeAsO_4\bullet 2(H_2O)$	
Sericite	$KAl_3Si_3O_{10}(OH)_{1.8}F_{0.2}$	SWT, Hidden Shafts, Laclede, United Tintic
Silver (native)	Ag	Swansea
Smithsonite	$Zn(CO_3)$	Buckeye, Evelyn, Rising Sun, Ruby, Sunrise Canyon, Tintic Coalition, Volcano Ridge
Sphalerite	(Zn,Fe)S	Alaska, Old Susan, Swansea
Tennantite	$Cu_{11}FeAs_4S_{13}$	
Tenorite	CuO	Swansea
Tetrahedrite	$Cu_9Fe_3Sb_4S_{13}$	Little May, Golden Treasure, New State
Tourmaline	$(Na,Ca)(Mg,Li,Al,Fe)_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$	Horseshoe Hill
Turquoise	$CuAl_6(PO_4)_4(OH)_8\bullet 4(H_2O)$	Horseshoe Hill
Tyrolite	$CaCu_5(AsO_4)_2(CO_3)(OH)_4\bullet 6(H_2O)$	
Zunyite	$Al_{13}Si_5O_{20}(OH)_{16}F_2Cl$	Hidden Shafts?

Mineralogy primarily from Lindgren and Loughlin (1919), Bullock (1981), Krahulec and Briggs (2006), and Utah Mineral Occurrence System (UMOS).

Table 4. *Estimated production from the Southwest Tintic mines, modified from Cook (1957).*

	Production						Grade					
Mine	**Tons**	**Au oz**	**Ag oz**	**Cu tons**	**Pb tons**	**Zn tons***	**Au opt**	**Ag opt**	**Cu %**	**Pb %**	**Zn %**	**Comments**
Alaska	9,642	5,785.2	108,955	48.2	212.1	106.1	0.60	11.3	0.5	2.2	1.1	Largest Au and Zn producer
Beatrice D	212	-	4,770	1.7	1.9	-		22.5	0.8	0.9		
Boston and Tintic	15	-	546	0.0	1.0	-		36.4	0.1	6.9		
Brooklyn	1,923	-	27,884	28.8	5.8	-		14.5	1.5	0.3		
Butcher Boy	196	-	2,470	0.2	7.8	-		12.6	0.1	4.0		
Copper Queen	133	-	1,702	1.6	0.4	-		12.8	1.2	0.3		
Diamond Queen	6	-	46	0.1	2.4	-		7.7	1.1	39.4		
Golden Key	4,377	-	35,891	4.4	4.4	-		8.2	0.1	0.1		
Homestake	67	-	824	0.4	6.4	-		12.3	0.6	9.5		
Iron Duke	25	2.5	143	-	0.4	-	0.10	5.7		1.7		
Joe Daly	202	-	3,232	0.2	0.8	-		16.0	0.1	0.4		
King James	7	-	162	0.1	0.1	-		23.1	2.1	2.1		
Kingsley	31	-	251	0.0	3.1	-		8.1	0.1	9.9		
Laclede	3,254	-	80,374	247.3	26.0	-		24.7	7.6	0.8		Largest Cu producer
Lady Aspinwall	42	-	739	-	-	-		17.6				
Little May	424	-	3,180	6.8	2.5	-		7.5	1.6	0.6		
Monterey	100	10.0	1,660	2.5	3.7	-	0.10	16.6	2.5	3.7		
Niebauer	6	6.0	3,968	0.5	0.5	-	1.00	661.3	8.3	9.0		Doubtful Au and Ag grades
Picnic	365	3,102.5	9,855	12.0	5.5	-	8.50	27.0	3.3	1.5		Doubtful Au grade
Primrose	615	-	3,444	11.1	1.2	-		5.6	1.8	0.2		
Rabbits Foot	111	-	1,965	3.0	0.1	-		17.7	2.7	0.1		
Republic	475	-	4,133	20.4	-	-		8.7	4.3			
Shoebridge-Bonanza	926	-	6,389	17.6	30.6	-		6.9	1.9	3.3		
Showers-Bowers	8,123	-	94,227	40.6	243.7	-		11.6	0.5	3.0		
Sunbeam	7,371	737.1	38,329	22.1	103.2	-	0.10	5.2	0.3	1.4		
Swansea	77,387	2,321.6	944,121	77.4	3,405.0	-	0.03	12.2	0.1	4.4		Largest producer
Tesora	2,555	-	16,863	12.8	-	-		6.6	0.5			
Tintic Coalition	7	-	62	-	2.2	-		8.9		30.9		
Undine	2,681	-	39,679	21.4	67.0	-		14.8	0.8	2.5		
United Tintic	12	-	168	0.5	-	-		14.0	4.0			
West Morning Glory	33	3.3	175	2.0	-	-	0.10	5.3	6.1			
Yankee Girl Group	649	-	4,219	-	24.7	8.4		6.5		3.8	1.3	
Total	**121,972**	**11,968**	**1,440,424**	**584**	**4,163**	**114**	0.10	11.8	0.5	3.4	0.1	

* Most of the Southwest Tintic mines were productive in the late 1800s and early 1900s when Zn was generally considered a deleterious metal and not recovered. Consequently, Zn grades are not accurately reflected in these statistics. For example, ore samples from the Showers-Bowers mine report as much as 1.8% Zn.

contacts with the altered country rock and, unlike the replacement veins and ore bodies, are commonly crustified and banded. These fissure veins range in width from knife-edge seams to about 20 ft, averaging about 2 ft. Most are less than a few hundred feet long, although the Sunbeam vein is nearly continuous for about 4000 ft. The structures occupied by the veins seem to be small normal faults with an average strike of N 20° E; the average dip is 75° to 85° W, but some veins are vertical, and others dip east. They are widest and longest where they cut massive intrusive and sedimentary rocks, but they tend to form groups of short, subparallel veins or disappear entirely in altered tuffs and in incompetent argillaceous sedimentary units.

The banded veins that cut the Silver City and Swansea stocks consist of vertical layers of quartz, pyrite, galena, and other minerals that lie parallel to the fissure walls. Some of the bands characteristically contain central vugs that appear to lie along the original fractures; other bands are separated by vertical sheets of altered country rock. Locally, the intervening slabs of rock are progressively replaced by quartz, resulting in wide quartz bands without vugs or the typical crustified appearance.

Owing to heavy inflows of water at depths of 350 to 500 ft, only the Swansea vein was extensively mined below the water table. According to Lindgren and Loughlin (1919, p. 255 and pl. 3), the main Swansea ore shoot was stoped continuously from a point within 40 ft of the surface to a maximum depth of about 800 ft and through a maximum horizontal distance of 900 ft. The general shape of the stoped area is that of the letter T, the stem of which rakes 35° N. This ore body has an average width of about 3 ft but ranges from a narrow streak to 10 ft or more in thickness. A cross section of this vein observed on the 500-foot level by Tower and Smith (1899, p. 758) showed, from east to west, 18 inches of pyrite and quartz, 18 inches of galena and quartz, 30 inches of pyrite and quartz, 6.5 inches of galena, 3 inches of pyrite, and finally 3 inches of galena. The wall rocks adjacent to the vein are silicified, sericitized, and pyritized quartz monzonite of the Swansea stock [Fernow quartz latite]. Oxidation of the ore was nearly complete to the 250-foot level; above this horizon, the ores consisted chiefly of cerussite, anglesite, plumbojarosite, jarosite, argentojarosite, and cerargyrite in a matrix of iron-stained honeycombed quartz.

Many fissure veins cutting the igneous rocks undoubtedly contain unmined shoots of ore similar to the deep ore bodies of the Swansea mine. However, the small size of these ore bodies and the rather low-grade of the primary ores may not justify the expense of unitizing the small holdings or disposing of the excessive inflows of mine water.

Morris's (1968) description relies heavily on previous reports, maps, and sections from the Swansea Ag-Pb mine. Many of the mines near Treasure Hill are similar in most respects but are predominately Ag-Au-Cu±Pb±Zn. The primary vein minerals on Treasure Hill are quartz, coarse octahedral pyrite, enargite, and lesser galena and sphalerite (table 3). These mines include the Laclede, Little May, Picnic, Primrose, Republic, Tesora, Treasure Hill, United

Tintic, and West Morning Glory. These veins are primarily hosted in propylitized andesite porphyry. Although a perched water table was intersected in these mines (and drill holes) at a depth of just a few hundred feet, the water table in the Paleozoic rocks to the north in the Main Tintic subdistrict outside the calderas was at an elevation of about 4800 ft, roughly a thousand ft deeper (Evans, 1957).

An interesting feature of the Southwest Tintic subdistrict is the occurrence of three different crystal habits of pyrite in diverse geologic environments. Pyritohedral pyrite is often associated with the Ag-Pb-dominant veins, such as the Swansea mine (appendix II, photo 4). Octahedral pyrite is associated with the high-sulfidation, Ag-Cu-dominant veins on Treasure Hill, e.g. Homestake and Laclede mine (cover photo; appendix II, photos 20 and 21). Ordinary cubic pyrite is associated with zones of pervasive hydrothermal alteration, such as phyllic, argillic, and potassic alteration associated with the SWT porphyry Cu-Mo deposit.

Two geochemical vectors are recognized in these north-northeast-trending veins. The veins on Treasure Hill, which strike south-southwest toward the SWT porphyry Cu-Mo deposit, produced pyrite-enargite (Ag-Au-Cu) ores, e.g., Homestake mine (cover photo; appendix II, photo 20). The veins that lie farther to the east and west, whose projection would be essentially tangential to the SWT porphyry Cu-Mo deposit to the southwest yielded galena-rich ores, as at the Swansea mine to the west and the Showers and Bowers mines to the east.

The second vector is along the high-sulfidation pyrite-enargite veins themselves. Dump rock and production data (Cook, 1957; plate 3) along the veins shows a geochemical zoning from Cu-Ag-As near the SWT porphyry Cu-Mo deposit south of Treasure Hill (e.g., Laclede mine) to Cu-Pb-Zn-Au-Sb to the north (e.g., Alaska mine). Production from the seven-southernmost high-sulfidation deposits averaged 790 ppm Ag, 0.69 ppm Au, 6.9% Cu, and 0.9% Pb with negligible Zn. This contrasts with the four northernmost small mines along the same vein swarm, which averaged 343 ppm Ag, 13 ppm Au, 0.4% Cu, 1.5% Pb, and 0.8% Zn (Krahulec and Briggs, 2006).

PIMA (portable infrared mineral analyzer) analysis of the clay mineralogy associated with these veins indicated the southern, higher temperature veins were associated with sericite, pyrophyllite, and diaspore while the cooler, northern veins contained illite, dickite, and barite (table 3). These geochemical and mineralogical vectors support the spatial relationships presented by Corbett and Leach (1998, figure 6.4) for high -sulfidation veins near porphyry systems (Krahulec and Briggs, 2006).

Several small hydrothermal breccia pipes are associated with the veins near Treasure Hill (appendix I, map 2). Some of these pipes are shown as zones of intense silicification by Morris (1964a). The top of Treasure Hill itself (appendix II, photos 15–19) is characterized by a strongly silicified shingle breccia. The largest hydrothermal breccia pipe, measuring several hundred feet in diameter, forms a hill of texturally destructive silicification located about a half mile east of the top of Treasure Hill. One of the most prominently exposed breccia pipes is on the nose of the ridge, located immediately west of the Homestake shaft (Krahulec and Briggs, 2006).

Fluid inclusion homogenization temperatures for veins in the Southwest Tintic subdistrict peak at over 300°C with temperatures exceeding 350°C in the porphyry Cu deposit and fall off to about 200°C within two miles to the north (Ramboz, 1979). Homogenization temperatures then increase again, toward the Silver City stock in the Main Tintic subdistrict (Hildreth and Hannah, 1996).

Geophysical Surveys

Aeromagnetic surveys show a major magnetic high occurs over the outcropping Silver City monzonite stock and a much less distinct high associated with the Sunrise Peak monzonite (appendix I, map 5). This accentuates in a pronounced northeast-trending magnetic low extending from the SWT porphyry Cu-Mo deposit toward Ruby Hollow. This low essentially coincides with the northwestern margin of the Copperopolis Latite caldera (appendix I, map 2). The SWT porphyry Cu-Mo system partially underlies a small magnetic "ridge" within this linear low (Krahulec, 2006). This ridge may correlate with a zone of quartz-K-spar-magnetite veins seen in hole STD-06.

A wide variety of induced polarization (IP) surveys have been run over the Southwest Tintic subdistrict over the last fifty plus years (appendix I, map 6). These surveys broadly outline a north-northeast-trending chargeability high and resistivity low extending north-northeast through SWT, Diamond Gulch, Treasure Hill, and Ruby Hollow. This IP anomaly in part mimics the linear magnetic low described previously. The strongest IP chargeability response lies to the southwest over the known SWT porphyry Cu-Mo mineralization. This is verified by total sulfide plots on drill sections which show >10 wt.% pyrite. The sharp western termination of this anomaly has been interpreted to indicate that the system does not extend west of SWT-31, at least not to within 2500 ft of the surface, being truncated by the range front fault (Krahulec, 2006).

SWT Porphyry Cu-Mo

Southwest Tintic subdistrict pervasive hydrothermal alteration is, in part, crudely centered on and zoned around the known SWT porphyry Cu-Mo deposit (appendix I, map 7). The SWT system is elongate in a northerly direction and its shape can be compared to a partially overturned canoe (figure 2; appendix I, map 8) with a gently dipping west limb, a more steeply dipping east limb, and a plunge to the north. The relationship between the SWT porphyry system and the Diamond fault to the east is uncertain, but because the fault is locally mineralized (e.g., Tintic Coalition shaft) the porphyry Cu-Mo deposit is presumed to be younger than the fault.

The generalized alteration picture in plan view is depicted in table 5. The deepest core alteration assemblage drilled at SWT is a potassic zone with intense, locally texturally destructive K-spar, secondary biotite, chlorite, anhydrite, magnetite, and chalcopyrite (appendix II, photo 24, 26–32). At its most intense fine-grained biotite and microcrystalline K-spar completely replaces the rock. The secondary biotite zone is more strongly developed in the andesitic host rocks. At depth, drilling in this zone intersected massive, lavender anhydrite veins a foot-thick and getting thicker with depth (appendix II, photo 30). The biotite and pyrite content increase upward through the Cu zone at the expense of chlorite, K-spar, and magnetite. The biotite zone coincides with the best Cu grades and is believed to cover an area of about 7000 by 10,000 ft (appendix I, map 7 and 8). The pyrite halo overlies the Cu-rich potassic zone and is associated with phyllic alteration. The pyrite content ranges up to 20 wt.% and is virtually devoid of chalcopyrite. Drilling in the pyrite halo shows a central quartz-sericite-pyrite zone with an outer clay-sericite-pyrite zone. The phyllic assemblage is best developed in latitic crystal tuffs (Krahulec, 1996). There is virtually no mineralization, other than jarosite -goethite leached capping, developed at the surface on the oxidized pyrite halo over the SWT porphyry.

The propylitic zone, peripheral to the

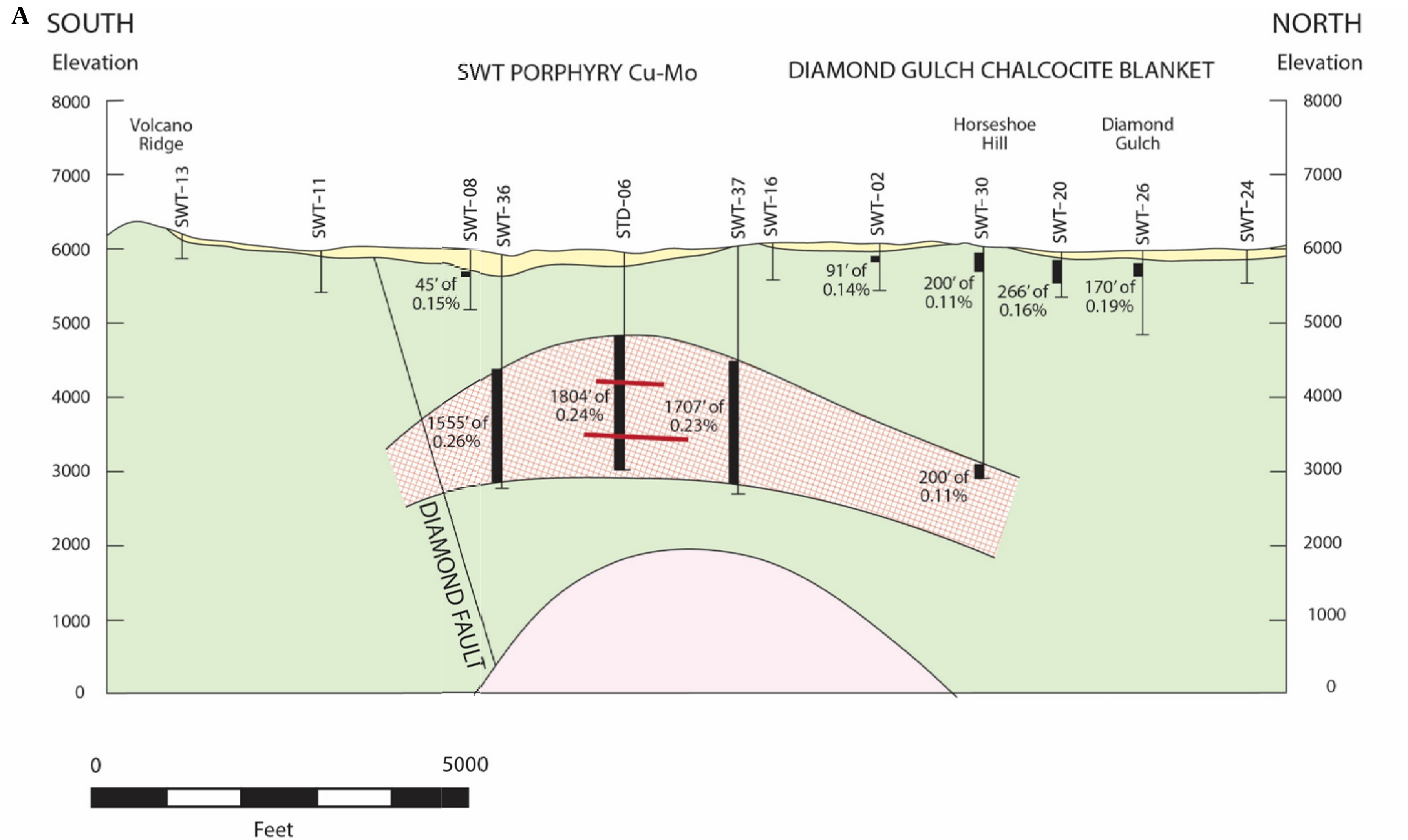


Figure 2. *Diagrammatic cross sections through the SWT porphyry Cu-Mo deposit and Diamond Gulch chalcocite blanket, see Plate 1 for section locations. A. Long section looking west-northwest.* #

B

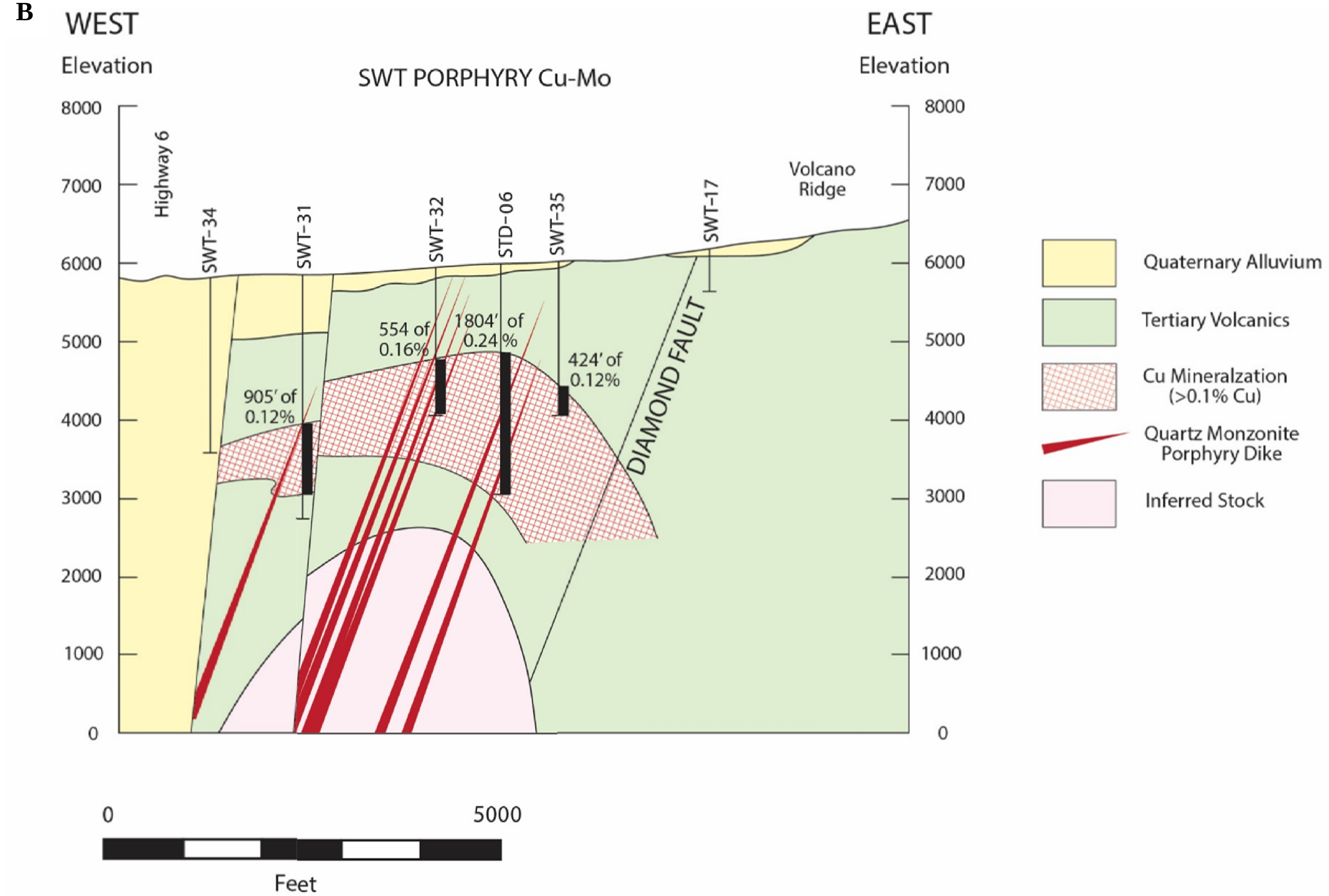
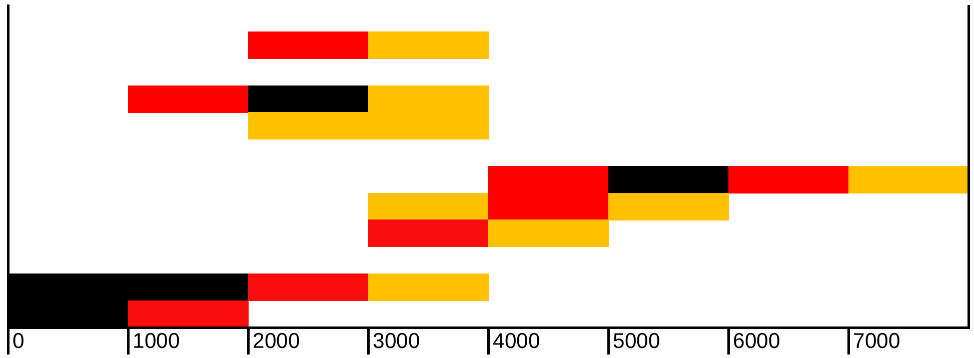


Figure 2 continued. *Diagrammatic cross sections through the SWT porphyry Cu-Mo deposit and Diamond Gulch chalcocite blanket, see Plate 1 for section locations. B. Cross section looking north-northeast.*

Table 5. *Idealized horizontal mineral zonation in the SWT porphyry Cu-Mo system (modified from Krahulec, 1996).*

Alteration	Minerals	Horizontal Range	Temperature*	Wt. % NaCl*
Argillic				
	Clay-Pyrite			
Phyllic				
	Quartz-Sericite-Pyrite		300° C	
	Tourmaline			
Propylitic				
	Chlorite		250° C	1.0
	Epidote		300° C	3.0
	Actinolite		350° C	3.5
Potassic				
	Biotite-Chalcopyrite-Pyrite		500° C	45.0
	K-spar-Magnetite-Chalcopyrite			



* Generalized from Ramboz (1979) and Norman and others (1991).

SWT porphyry Cu-Mo deposit, is divided into an inner actinolite facies, medial epidote facies, and distal chlorite-calcite facies (Norman, 1989; Norman and others, 1991). In outcrop, the narrow inner actinolite facies of propylitic alteration occurs just east of the SWT porphyry Cu-Mo center, and the intermediate epidote facies lies along the west facing slope further east (appendix I, map 4). In contrast, the intermediate epidote facies also extends north-northeastward over three miles beyond the Alaska mine, just north of Ruby Hollow. The outer chlorite-calcite facies of the propylitic zone is much more extensive and an outer boundary has not been mapped.

The epidote facies overlaps and is partially coincident with the previously described aeromagnetic low and IP chargeability high and resistivity low. Also, the geochemistry and mineralogy of the Treasure Hill veins along with the decreasing temperatures in the fluid inclusions suggest that the mineralizing fluids flowed north-northeast away from the SWT porphyry Cu-Mo deposit. However, the breccia pipes on Treasure Hill suggest a second, closer source for these magmatic-hydrothermal fluids, possibly indicating a second porphyry Cu system at depth nearby.

The SWT secondary biotite zone is preferentially developed in the andesite porphyry flows, sills, and agglomerates. The crystal tuff sequence is more readily altered to phyllic alteration. Consequently, the lower Fernow (?) quartz latite crystal tuff sequence intersected on the west half of the SWT porphyry Cu-Mo deposit is generally lower grade (less than 0.25% Cu) than the upper andesitic sequence (0.20 to 0.35% Cu) cut in the eastern half of the system. The lower Fernow (?) crystal tuff sequence was intersected in holes SWT-09, SWT-23, SWT-31, SWT-33, and SWT-38 (Welsh, 1976, 1985).

The primary porphyry Cu-Mo mineralization at SWT is under a shallow pediment (appendix II, photo 23) and cut by drill holes STD-06, SWT-30, SWT-31, SWT-32, SWT-35, SWT-36, and SWT-37. The apex of the system is near STD-06 which intersected 1804 ft averaging 0.24% Cu starting at a depth of 1155 ft (4785 ft elevation). The gently dipping west limb of the Cu shell is generally thinner and lower grade than the more steeply dipping east limb (figure 2). Where the Cu shell is cut by the quartz monzonite porphyry dikes the grades are diminished.

Calculating a mineral inventory on such widely spaced holes (the average drill hole spacing is about 1300 ft) is difficult because using a reasonable 500-ft radius leaves significant gaps between the holes and using a large enough radius, about 1500-ft, to fill most of the space between holes extends the resource out beyond the drill-identified footprint of the deposit. The UGS calculated a rough estimate for the resource by creating a hand-drawn, external polygon around holes intersecting the porphyry Cu-Mo. This inferred subeconomic resource is about 1.5 billion tons of 0.21% Cu and 0.01% Mo at a 0.1% Cu cutoff (table 6). Krahulec and Briggs (2006) report an approximate inferred subeconomic resource of over 400 million tons of 0.33% Cu, 0.012% Mo, and 0.07 ppm Au at a higher 0.3% Cu cutoff but by using a 1500-ft radius. For comparison, the average porphyry Cu-Mo deposit reportedly hosts about 550 million tons at 0.42% Cu and 0.016% Mo (Cox and Singer, 1986). Table 7 shows the drill intersections used in the definition of these resources.

The deep drilling at the SWT porphyry Cu-Mo deposit cuts down through pyrite to chalcopyrite mineralization to a deeper assemblage of chalcopyrite-molybdenite-magnetite. No primary copper-rich species like bornite or chalcocite have as yet been recognized in the deposit. The total weight percent sulfide at the bottom of STD-06 is

Table 6. *Southwest Tintic subdistrict mineral inventories.*

SW Tintic Porphyry Copper Deposit

Kennecott Copper Corporation - 1971

Cutoff % Cu	Tons	Grade % Cu	Grade % Mo
0.1	992,974,027	0.198	0.009
0.2	427,434,565	0.269	0.014
0.3	119,131,329	0.375	0.019
0.4	36,191,712	0.476	0.020

Notes on Grant (1971) in UGS files - uses holes SWT-09, SWT-30, SWT-31, SWT-32, SWT-33, SWT-35, SWT-36, and SWT-37. The mineralization in SWT-30 is supergene and should not be included in PCD resource which would reduce the 0.1% Cu cutoff tonnages by about 20 million tons; west side of 1000-ft polygons truncated by a fault.

Polygonal computer mineral inventory using maximum 1000-ft radius and individual assay intercepts (Grant [1971] notes in UGS files).

Cutoff % Cu	Tons	Grade % Cu	Grade % Mo
0.1	1,021,569,222	0.193	0.009
0.2	376,935,950	0.265	0.014
0.3	113,721,780	0.331	0.015
0.4	-	-	-

Note: there are no intervals with a 50-ft composite assay of greater than 0.4% Cu.

Polygonal computer mineral inventory using maximum 1000-ft radius and 50-ft composite assay intercepts (Grant [1971] notes in UGS files).

Cutoff % Cu	Tons	Grade % Cu	Grade % Mo
0.1	42,907,721	0.200	0.009
0.2	18,913,940	0.269	0.014
0.3	5,227,622	0.375	0.019
0.4	1,598,446	0.476	0.020

Polygonal computer mineral inventory using maximum 200-ft radius and individual assay intercepts (Grant [1971] notes in UGS files).

Centurion Mines Corporation - 1994

Cutoff % Cu	Tons	Grade % Cu	Grade % Mo
0.2	600,000,000	0.280	0.010

There is no accompanying information for this table, but later Centurion Mines reports suggest this estimate is flawed.

Geologic resource estimate (Krahulec, 1996).

Kennecott Exploration Company - 1994

Cutoff % Cu	Tons	Grade % Cu
0.1	2,860,000,000	0.210
0.2	1,380,000,000	0.270
0.3	437,000,000	0.330
0.4	-	-

This mineral inventory is based on holes STD-06, SWT-23, SWT-30, SWT-31, SWT, 32, SWT-34, SWT-35, SWT-36, and SWT-37. This inventory includes the deep mineralization in SWT-30 and newer information on STD-06. It also expands the maximum radius to 1500 feet to include most of the material between the widely spaced holes, but consequently may include too broad an area outside of the known mineralized holes.

Polygonal computer mineral inventory using maximum 1500-ft radius and 50-ft assay composites (Krahulec and Briggs, 2006).

Table 6 (continued)
SW Tintic Porphyry Copper Deposit (continued)

Utah Geological Survey - 2018

Cutoff		Grade	
% Cu	Tons	% Cu	% Mo
0.10	1,500,000,000	0.210	0.010

This inferred subeconomic resource is based on a hand-drawn polygon around holes intersecting the porphyry Cu-Mo, given a thickness defined by the average mineralized interval in the deep holes, using a tonnage factor of 12.5 ft^3/ton, and a grade of the weighted average of all the holes in the inventory.

This inferred subeconomic resource is based on holes STD-06, SWT-31, SWT, 32, SWT-35, SWT-36, and SWT-37. This inventory does include the deep, low-grade mineralization to the north in SWT-30.

Utah Geological Survey - 2018

Cutoff		Grade	
% Cu	Tons	% Cu	% Mo
0.10	400,000,000	0.238	0.012

This inferred subeconomic resource is based on a hand-drawn polygon around the three best holes intersecting the porphyry Cu-Mo, given a thickness defined by the average mineralized interval in the deep holes, using a tonnage factor of 12.5 ft^3/ton, and a grade of the weighted average of all the holes in the inventory.

This inferred subeconomic resource is based just on the three best, highest grade drill holes: STD-06, SWT-36, and SWT-37.

Diamond Gulch Chalcocite Blanket

Kennecott Copper Corporation - 1971

Cutoff		Grade
% Cu	Tons	% Cu
0.10	20,000,000	0.210

Mineral inventory using maximum 500-ft radius and composite assay intercepts (Grant [1971] notes in UGS files).

There is no accompanying information for this table.

Centurion Mines Corporation - 1985

Cutoff		Grade
% Cu	Tons	% Cu
0.08	83,500,000	0.123

Mineral inventory using maximum 500-ft radius and composite assay intercepts (Welsh [1985], notes in UGS files).

Includes holes SWT-02, SWT-18, SWT-20, SWT-22, SWT-26, SWT-27, SWT-28, SWT-29, SWT-30, and SWT-38. The cutoff grade is estimated because it is not actually listed in the text or table. Also the date is estimated based on the entire file.

Utah Geological Survey - 2017

Cutoff		Grade
% Cu	Tons	% Cu
0.10	88,000,000	0.156

This mineral estimate is based on a hand-drawn polygon around holes intersecting the chalcocite blanket, given a thickness defined by the average mineralized interval in these holes, using a tonnage factor of 12.5 ft^3/ton, and a grade of the weighted average of all the holes in the inventory.

Includes holes SWT-02, SWT-18, SWT-20, SWT-22, SWT-26, SWT-27, SWT-28, SWT-29, SWT-30, STD-09, and STR-12. It does not include supergene mineralization intersected in STR-10 and SWT-38, which are outside the boundary of the contiguous holes.

Table 7. *Drill intersections used to calculate mineral inventories.*

A. Drill intersections of greater than 0.1% Cu for the SWT porphyry Cu-Mo deposit.

Hole Number	Total Depth	From ft	To ft	Thick ft	Cu %	Mo %	Ag ppm	Au ppm	Collar Elevation	Elevation Top 0.1% Cu	Elevation Bottom 0.1% Cu	Elevation of TD
STD-06	2,959	1,155	2,959	1,804	0.24	0.013	1.4	0.06	5,940	4,785	2,981	2,981
SWT-30	3,100	2,980	3,100	120	0.11	0.001			6,002	3,022	2,902	2,902
SWT-31	3,055	1,930	2,835	905	0.12	0.004			5,810	3,880	2,975	2,755
SWT-32	1,741	1,180	1,630	450	0.18	0.010			5,875	4,695	4,245	4,134
SWT-35	1,994	1,570	1,994	424	0.12	0.004			5,965	4,395	3,971	3,971
SWT-36	3,148	1,520	3,075	1,555	0.25	0.015			5,784	4,264	2,709	2,636
SWT-37	3,387	1,507	3,214	1,707	0.23	0.011			5,972	4,465	2,758	2,758

B. Drill intersections of greater than 0.1% Cu for the Diamond Gulch chalcocite blanket. The table does not include intersections of weak Cu enrichment zones in STR-10, SWT-38, and a few other holes that are outside the boundary of the Diamond Gulch chalcocite blanket.

Hole Number	Total Depth	From ft	To ft	Thick ft	Cu %	Mo %	Ag ppm	Au ppm	Collar Elevation	Elevation Top 0.1% Cu	Elevation Bottom 0.1% Cu	Elevation of TD
STD-09*	1,708	155	205	50	0.09	0.000	0.25	0.01	6,000	5,845	5,795	4,292
STR-12	580	150	350	250	0.14				6,025	5,875	5,675	5,445
SWT-02	652	185	276	91	0.14				6,054	5,869	5,779	5,402
SWT-18	600	140	190	50	0.16				6,212	6,072	6,022	5,612
SWT-20	600	94	360	266	0.16				5,970	5,876	5,610	5,370
SWT-22	600	220	310	90	0.14				6,002	5,782	5,692	5,402
SWT-26	1,120	190	360	170	0.19	0.000			5,995	5,805	5,635	4,875
SWT-27	710	360	390	30	0.12				6,005	5,645	5,615	5,295
SWT-28	705	220	280	60	0.15				6,018	5,798	5,738	5,313
SWT-29	700	140	170	30	0.16				5,975	5,835	5,805	5,275
SWT-30	3,100	210	270	60	0.25		0.34	0.04	6,002	5,792	5,732	2,902

* STD-09 is within the defined boundary of the Diamond Gulch deposit, so this interval is included despite not reaching the 0.1% Cu cutoff.

less than 3 wt.% (table 8). The presence of a vast sulfide system, low-grade Cu shell, and lack of primary, Cu-rich species suggests that SWT is a high-sulfide/sulfate, low-Cu porphyry system.

The SWT porphyry Cu-Mo system contains a wide variety of vein types which frequently show complex and confusing relationships. Nonetheless, in general terms, they follow similar relationships to the veins at the El Salvador, Chile, porphyry Cu deposit, as described in an outstanding paper by Gustafson and Hunt (1975). To some extent, the veins, like the alteration assemblages, are controlled by host rock. For example, the relatively permeable tuffaceous sequences tend to have more disseminated and lesser vein mineralization. In contrast, the more massive flows and sills are generally less susceptible to dissemination and have a higher proportion of veins and fracture-controlled mineralization. For brevity, the recognized vein sequence at the SWT porphyry, as logged in STD-06, is presented in table 9 and will not be discussed in detail here.

The downhole geochemistry of the top of the primary deposit in STD-06 shows two mutually exclusive elemental suites: S-Fe-Ni-Co-Se and Cu-Au-Ag±Mo±Te. These two groups show a strong negative correlation to each other. The S-rich group represents the elements associated with the pyrite halo and the Cu-rich group represents the elements enriched in the underlying chalcopyrite shell (Krahulec, 2006).

The high-grade core of this system was intersected in holes SWT-37, STD-06, and SWT-36, from north to south (table 7). These holes are aligned in a north-northeast direction. The projection of this alignment to the northeast would go roughly through SWT -30 (the northernmost hole in the SWT porphyry Cu-Mo deposit), SWT-26 (the best hole in the Diamond Gulch chalcocite blanket), and the Treasure Hill-Republic vein system.

The quartz monzonite porphyry (appendix II, photo 25) was considered to be the magmatic source of the mineralization at SWT by Kennecott, partly because it is the only recognized intrusive with significant intersections in the drill holes (Welsh, 1976, 1985). However, where the quartz monzonite porphyry is cut by drill holes, it is typically less altered and lower grade than the adjoining volcanics. The main mineralizer at Bingham, the quartz monzonite porphyry (QMP), may be slightly lower than average grade.

Some of the quartz monzonite porphyry dikes are late mineral intrusives, similar to the late mineral quartz latite porphyry (QLP) at Bingham and not the primary causative stock. The Bingham QLP is both lower grade and less altered that the inclosing rock. Under this scenario, the causative intrusive source of the SWT mineralization may still lie at depth below the current drill holes. Additional definition drilling on SWT should focus on deep drilling on the east limb (figure 2b), east of SWT-32. From a block caving prospective, the east limb seems to have fewer quartz monzonite porphyry dikes, so would have less internal waste in a block cave scenario.

Under current technology, the presently defined SWT porphyry Cu-Mo deposit mineral inventories are not economically viable as an open pit due to the high stripping ratio, or as an underground mine due to the modest grades of 0.2 to 0.3% Cu. Additional drilling, currently underway by Freeport-McMoRan (January 2018), will probably define additional tonnages and may find higher grades. None the less, the UGS inferred subeconomic resource hosts over 6 billion pounds of Cu and nearly 300 million pounds of Mo with a current in place value of over $22 billion (at $3.20 per pound Cu and $7 per pound Mo).

Table 8. *Summary information for the bottom of the deep drill holes that intersect the SWT porphyry Cu-Mo deposit. The most prospective holes are those that bottom in the highest Cu and Mo grades and still have the highest estimated total wt.% sulfides. By this standard STD-06 and SWT-37 are the two most prospective deep holes. All elevations are in feet.*

					Bottom Hole							
	Collar		T.D.	Top >0.1% Cu			Calculated	Calculated	Estimated	Estimated	10 x Cp/Py	
Hole	Elevation	T.D.	Elevation	Elevation	Cu %	Mo %	Cp* wt.%	Moly* wt.%	Py* wt.%	Sulfide wt.%	Ratio	Comments
STD-06	5,940	2,959	2,981	4,785	0.24	0.007	0.69	0.01	2.00	2.70	3.47	K-spar, secondary biotite, anhydrite, and magnetite
SWT-30	6,002	3,100	2,902	3,020	0.01	0.001	0.03	0.00	3.00	3.04	0.11	K-spar, anhydrite, and secondary biotite
SWT-31	5,810	3,055	2,755	3,840	0.05	0.003	0.15	0.01	1.00	1.16	1.54	Secondary biotite, anhydrite, and sericite
SWT-32	5,875	1,741	4,134	4,780	0.14	0.002	0.42	0.00	2.00	2.42	2.08	Secondary biotite, chlorite, and magnetite
SWT-35	5,965	1,994	3,971	4,395	0.13	0.006	0.36	0.01	3.00	3.37	1.21	Secondary biotite and sericite
SWT-36	5,784	3,148	2,636	4,380	0.04	0.015	0.13	0.02	1.00	1.15	1.27	Chlorite, K-spar, anhydrite, and secondary biotite
SWT-37	5,972	3,214	2,758	4,780	0.25	0.014	0.72	0.02	2.00	2.74	3.61	Chlorite, anhydrite, and secondary biotite

* Cp is an abbreviation for chalcopyrite, Moly is an abbreviation for molybdenite, and Py is an abbreviation for pyrite.

Table 9. *Southwest Tintic porphyry copper system vein types (Krahulec, 1996).*

Type	Major component	Accessory minerals	Form	Alteration halo	Stage
	Granular quartz	Pyrite	Continuous veins	None?	Late barren
"D"	Pyrite (cubic or octahedral)	Quartz, en, sph, and gal	Continuous veins and fractures	Sericite and quartz	Late phyllic
"B"	Vuggy quartz planar veins	Cp, mo, and py	Continuous veins	None	Main ore
	Vuggy gypsum or anhydrite	Mo, cp, and py	Continuous, planer veins	Pyrite and chalcopyrite	Early ore
"A"	K-spar - quartz	Mag, chl, cp, and mo	Irregular, discontinuous veins	K-spar	Early potassic

This is a summary of the vein characteristics as seen in the core holes from the SWT porphyry copper system. The vein type nomenclature is styled after the veins described for the El Salvador, Chile, porphyry copper deposit as defined by Gustafson and Hunt (1975).

Diamond Gulch Chalcocite Blanket

A shallow, supergene chalcocite blanket is present under thin alluvium in Diamond Gulch and west of Horseshoe Hill (appendix I, map 7 and 9). The Diamond Gulch chalcocite deposit is in an area with a high primary pyrite content (pyrite halo to the adjoining SWT porphyry Cu-Mo deposit to the south-southwest and at depth) and strong jarosite-goethite leached capping developed on the west end of Horseshoe Hill. The chalcocite blanket resulted from the oxidation and leaching of the minor Cu present in the strong phyllic-argillic alteration, high pyrite content, and non-reactive host rocks, and precipitation of Cu on sulfides at the underlying redox boundary. In contrast to the porphyry Cu-Mo mineralization that is better grade in the more reactive andesites, the chalcocite blanket is better developed in the less reactive quartz-crystal tuffs. The leached capping is believed to be the result of just a single cycle of oxidation, leaching, and enrichment of the underlying primary sulfide zone (Welsh, 1976, 1985), multiple enrichment cycles are known to result in higher Cu grades. To some extent the primary Cu grade in the chalcocite blanket has been enhanced by scattered northerly trending, steeply dipping quartz-pyrite veins as seen in hole SWT-26.

The Diamond Gulch chalcocite blanket is cut by 11 holes (table 8) which average about 104 ft of 0.156% Cu, with the best intersection being 170 ft of 0.194% Cu in SWT-26. Various estimates have been made for the Diamond Gulch chalcocite resource (table 6), but no serious effort has been made to move toward the definition of a mineable reserve. A UGS estimate suggests an inferred subeconomic resource of 88 million tons at 0.156% Cu. The chalcocite blanket begins at a depth of 94 to 360 ft, enrichment ranges from 30 to 266 ft thick, and bottoms at a depth of 170 to 390 ft (table 8). An open pit mine would likely have a waste-to-ore stripping ratio of about 3:1 which could not be supported by the modest Cu grade currently defined. In the future, this resource, which contains an estimated 273 million lbs of Cu with a current in place value of about

$874 million (at $3.20 per pound Cu), could be a potential target for *in situ* leaching. Additional targeted drilling along the higher grade, north-northeast-trending corridor through SWT-26, SWT-30, and STR-12 on the west end of Horseshoe Hill could improve the grade of this resource.

Possible Exploration Targets

The most sought-after targets since the delineation of the SWT porphyry Cu-Mo deposit in 1969–70 is a higher grade portion of the known SWT system or a second, higher grade porphyry Cu deposit. Mapping of propylitic alteration in the Southwest Tintic subdistrict (Norman, 1989; Norman and others, 1991) shows that while the known actinolite facies is relatively limited to an area peripheral to the secondary biotite zone of the SWT porphyry Cu-Mo deposit, the epidote facies shows a pronounced elongation extending over 2.5 miles north-northeast of the known porphyry Cu-Mo deposit through Diamond Gulch, Treasure Hill, and Ruby Hollow, from south to north. This suggests that a second porphyry Cu deposit may still lie at depth somewhere under the extension of this epidote facies with its partly coincident magnetic low and IP chargeability high and resistivity low.

Kennecott (1970–82 and 1993–94) and Freeport-McMoRan (2010–11 and 2017–18) both directed holes to locate a second porphyry system. Kennecott drilled SWT-38 (1970) in Diamond Gulch looking for a second porphyry system. Kennecott's initial holes in 1993 tested for a second porphyry Cu deposit under Ruby Hollow, north of Treasure Hill (STD-01, STD-03, STR-11, and STR-13). They drilled STD-09 looking for evidence of a second porphyry system in Diamond Gulch. They completed STD-06 looking for a higher grade core to the known SWT porphyry Cu-Mo deposit. The Centurion-Kennecott joint venture also drilled a series of holes in the Dragon halloysite pit (1994) looking for a second porphyry system (STR-16, STR-17, STR-21, and STR-27). Kennecott also explored for a Lepanto-type volcanic-hosted Cu-Ag massive sulfide replacement target beneath the massive andesite porphyry flows on the Treasure Hill ridge (STD-02, STD-03, STD-07, and STD-08). Exxon drilled a series of ten shallow holes in the Treasure Hill area looking for high-grade Cu-Au-Ag veins and massive sulfides.

Freeport-McMoRan (2010–11) also drilled several holes in the Treasure Hill area looking for a second porphyry Cu system at depth (STFM-1, STFM-2, STFM-3, and STFM-5) and one hole (STFM-4) for a second porphyry system in Diamond Gulch. They are currently (2017–18) drilling three holes targeting a higher grade portion of the known system (SWT-17-1, SWT-17-2, and SWT-17-3). Less information is available on the results of these Freeport holes.

One suggestion for the location of a potential second porphyry Cu deposit at depth is along the north-northeast-trending Treasure Hill-SWT lineament in Diamond Gulch west of the Diamond cemetery, approximately in NW section 7, T. 11 S., R. 2 W. This proposed site lies within the:

- north-northeast-trending Treasure Hill-SWT lineament,
- epidote facies of propylitic alteration,
- IP chargeability high and resistivity low, and
- aeromagnetic trough.

This proposed drill test would likely be located on the south margin of the Weir fee tract. An adequate test of this site would require a 3000- to 4000-ft-deep-hole and if mineralization is encountered, the hole may be over 5000 ft deep.

Analysis of past drilling results suggest that the best place to explore for a higher grade portion of the known SWT porphyry

Cu-Mo deposit would be in the area of the two best deep holes STD-06 and SWT-37, which both bottomed in interesting mineralization (table 8). While STD-36 also intersected good mineralization, it was in low grade at the end of the hole. One of Freeport's current drill holes (SWT-17-01) is very well situated between STD-06 and SWT -37 and should be an excellent test for better grade mineralization at depth in the core of the SWT porphyry system. Alternately, hole STD-37 is reportedly still standing open and if it could be reentered, may be an inexpensive way to get additional information at depth.

Although the main problem for development of the SWT porphyry Cu-Mo deposit is its modest grade and moderate depth, the actual dimensions of the porphyry Cu-Mo deposit in plan view are still poorly defined despite all of the past drilling, in total there are about 13.5 miles of drill holes in the Southwest Tintic subdistrict. Basically, less than 40% of the inferred biotite zone is included in the recent UGS SWT porphyry Cu-Mo deposit inferred subeconomic resource, but it is possible that, given enough drilling, the entire biotite zone could be shown to be underlain by porphyry Cu mineralization. This interpretation suggests that the entire SWT porphyry Cu-Mo deposit could be in excess of 3 billion tons.

SITLA owns the mineral rights to **NW¼ section 13, T. 11 S., R. 3 W.** which lies in the northwest quadrant of the biotite zone of the SWT porphyry Cu-Mo deposit (appendix I, map 7 and 8). The main range front fault runs nearly due north through this quarter section about 850 ft from the west section line. Hole SWT-33 is in the southeastern corner of this tract, is 1595 ft deep, and does not reach porphyry mineralization. However, roughly the southeastern half of this SITLA tract lies within the projection of the secondary biotite alteration zone and may be underlain at depth by porphyry Cu-Mo mineralization, probably beginning at a depth of 2400 to 3600 ft, getting deeper to the northwest. The log for hole SWT-38, which is just northeast of this SITLA tract, could still hit the SWT deposit at depth, albeit probably at a depth of about 3700 ft.

The area around the western end of Horseshoe Hill contains a cluster of holes that contain phyllic-argillic alteration with minor, disseminated tourmaline, including SWT-01, SWT-18, SWT-19, SWT-26, SWT-28, SWT-30, STD-09, and STR-10 (appendix I, map 7). Two of these holes (SWT-26 and SWT-30) also have some of the best drill intersections of supergene Cu. Minor tourmaline also occurs in outcrop on Horseshoe Hill. Traces of tourmaline are also associated with some of the breccia pipes on Treasure Hill and are found in some of the holes there as well. The Horseshoe Hill cluster of tourmaline holes covers an area about 4500 by 3000 ft and is partially coincident with the Diamond Gulch chalcocite blanket. These holes are also partly coincident with an aeromagnetic low, IP anomaly, and quartz latite porphyry dike.

Tourmaline is commonly associated with magmatic-hydrothermal breccia pipes in porphyry Cu systems, and these pipes typically carry better than average grade mineralization. One of the premier porphyry Cu-related breccia pipes was the La Colorada pipe at Cananea, Mexico. This pipe produced approximately 7 million tons of 6% Cu and 2 ppm Au from an oval-shaped pipe with horizontal dimensions of just 2000 by 700 ft (Cananea field trip personal notes, 1994). The La Colorada pipe contained over $3 billion of Cu-Au at today's prices ($3.20/lb Cu and $1300/oz Au). A detailed magnetic and IP survey of the Horseshoe Hill tourmaline zone could prove useful exploring for a blind mineralized magmatic-hydrothermal breccia pipe.

SUMMARY AND CONCLUSIONS

The large, subeconomic resource at the SWT porphyry Cu-Mo deposit hosts over 6 billion pounds of Cu and nearly 300 million pounds of Mo with a current in-place value of just over $22 billion (at $3.20 per pound Cu and $7 per pound Mo). This resource contains significantly more metal than even the largest historical mines in the Tintic district, the Tintic Standard and Chief Consolidated. In addition, one suggested geological interpretation proposes that the entire SWT porphyry Cu-Mo deposit could be twice as big as currently recognized. The Diamond Gulch chalcocite blanket hosts an estimated 273 million pounds of Cu with an in-place value of about $875 million.

Nearly all of these resources are on federal land mostly open to mineral entry currently controlled by Freeport-McMoRan via unpatented mining claims. One federal tract of about 245 acres (S½NW¼ section 13, T. 11 S., R. 3 W. and NW¼ section 24, T. 11 S., R. 3 W.) and a smaller tract of 41 acres (SE¼SW¼ section 12, T. 11 S., R. 3 W.) are Bankhead-Jones lands that are also of interest. While these mineral resources are presently subeconomic, it is probable that future advances in mineral extraction technology combined with higher Cu-Mo prices could make these viable resources. SITLA should consider trading for all federal lands in sections 7, 8, 18, and NW¼ section 19, T. 11 S., R. 2 W. and sections 12, 13, and 24, T. 11 S., R. 3 W. This includes about 1818 acres of BLM and an additional 286 acres of Bankhead-Jones lands for a total of 2104 acres. Other potential porphyry and breccia pipes in this area still remain to be fully tested.

ACKNOWLEDGMENTS

In 2017, Tom Faddies, Assistant Director of Minerals for the Utah School and Institutional Trust Lands Administration, commissioned the UGS to evaluate the mineral potential of the Southwest Tintic subdistrict. The project was funded by SITLA and completed by the UGS under a Memorandum of Understanding between the two agencies during the fiscal year. The UGS has historical exploration files on the Southwest Tintic subdistrict from the Anaconda Collection of the International Archive of Economic Geology at the University of Wyoming and materials donated to the UGS by M. Dan Regan, John E. Welsh, James A. Marsh, Gary L. Ojala, and others. The figures and maps in this report were created by Taylor Boden and the text benefited greatly from a thorough editorial review by Stephanie Carney, both of the UGS.

REFERENCES

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

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

Cook, D.R., 1957, Geology of the East Tintic Mountains and ore deposits of the Tintic mining districts: Utah Geological Society Guidebook to the geology of Utah, no. 12, p. 176 p.

Corbett, G.J., and Leach, T.M., 1998, Southwest Pacific Rim gold-copper systems—structure, alteration, and mineralization: Society of Economic Geologists, Special Publication no. 6, 237 p.

Cox, D.P., and Singer, D.A., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, 379 p.

Evans, M.T., 1957, Ore deposits of the Chief mine, *in* Cook, D.R., editor, Geology of the East Tintic Mountains and ore deposits of the Tintic mining districts: Utah Geological Society Guidebook to the geology of Utah, no. 12, p. 80–93.

Grant, R.E., 1971, Southwest Tintic polygonal mineral inventory: unpublished in-house report prepared for Kennecott Copper Corporation, 9 p.

Gustafson, L.B., and Hunt, J.P., 1975, The porphyry copper deposit at El Salvador, Chile: Economic Geology, v. 70, no. 5, p. 875–912.

Hannah, J.L., Macbeth, A., and Stein, H.J., 1991, Field relations between Tertiary magmatism and Tintic-type ore deposits, East Tintic Mountains, Utah, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., editors, Geology and ore deposits of the Great Basin: Geological Society of Nevada Symposium Proceedings, v. 1, p. 485–489.

Hildreth, C.H., Jr., and Hannah, S.C., 1996, Fluid inclusion and sulfur isotope studies of the Tintic mining district, Utah—Implications for targeting fluid sources: Economic Geology, v. 91, p. 1270–1281.

Hintze, L.F., Willis, G.C., Laes, D.Y., Sprinkel, D.A., and Brown, K.D., 2000, Digital geological map of Utah: Utah Geological Survey Map 179DM, scale 1:500,000, CD.

James, L.P., 1984, The Tintic mining district: Utah Geological Survey, Survey Notes, v. 18, no. 2, p. 1–13.

Keith, J.D., Dallmeyer, R.D., Kim, C.S., and Kowallis, B.J., 1991, The volcanic history and magmatic sulfide mineralogy of latites of the central East Tintic Mountains, Utah, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., editors, Geology and ore deposits of the Great Basin: Geological of Nevada Society Symposium Proceedings, v. 1, p. 461–483.

Keith, J.D., Tingey, D.G., Hannah, J.L., Nelson, S.T., Moore, D.K., Cannan, T.M., MacBeth, A.P., Pulsifer, T., 2009, Provisional geologic map of the Tintic Mountain quadrangle, Juab and Utah Counties, Utah: Utah Geological Survey Open-file Report 545, 12 p., scale 1:24,000.

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

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

Lindgren, W., and Loughlin, G.F., 1919, Geology and ore deposits of the Tintic mining district, Utah: U.S. Geological Survey Professional Paper 107, 282 p.

Mabey, D.R., and Morris, H.T., 1967, Geologic interpretation of gravity and aeromagnetic maps on the Tintic Valley and adjacent areas, Tooele and Juab Counties, Utah: U.S. Geological Survey Professional Paper 516-D, l0 p.

Moore, D.K., 1993, Oligocene East Tintic volcanic field, Utah – geology and petrogenesis: Provo, Brigham Young University, M.S. thesis, 101 p.

Moore, D.K., Keith, J.D., Christiansen, E.H., Kim, C.S., Tingey, D.G., Nelson, S.T., and Flamm, D.S., 2007, Petrogenesis of the Oligocene East Tintic volcanic field, Utah, *in* Willis, G.C., Hylland, M.D., Clark, D.L., and Chidsey, T.C., Jr., editors, Central Utah—diverse geology of a dynamic landscape: Utah Geological

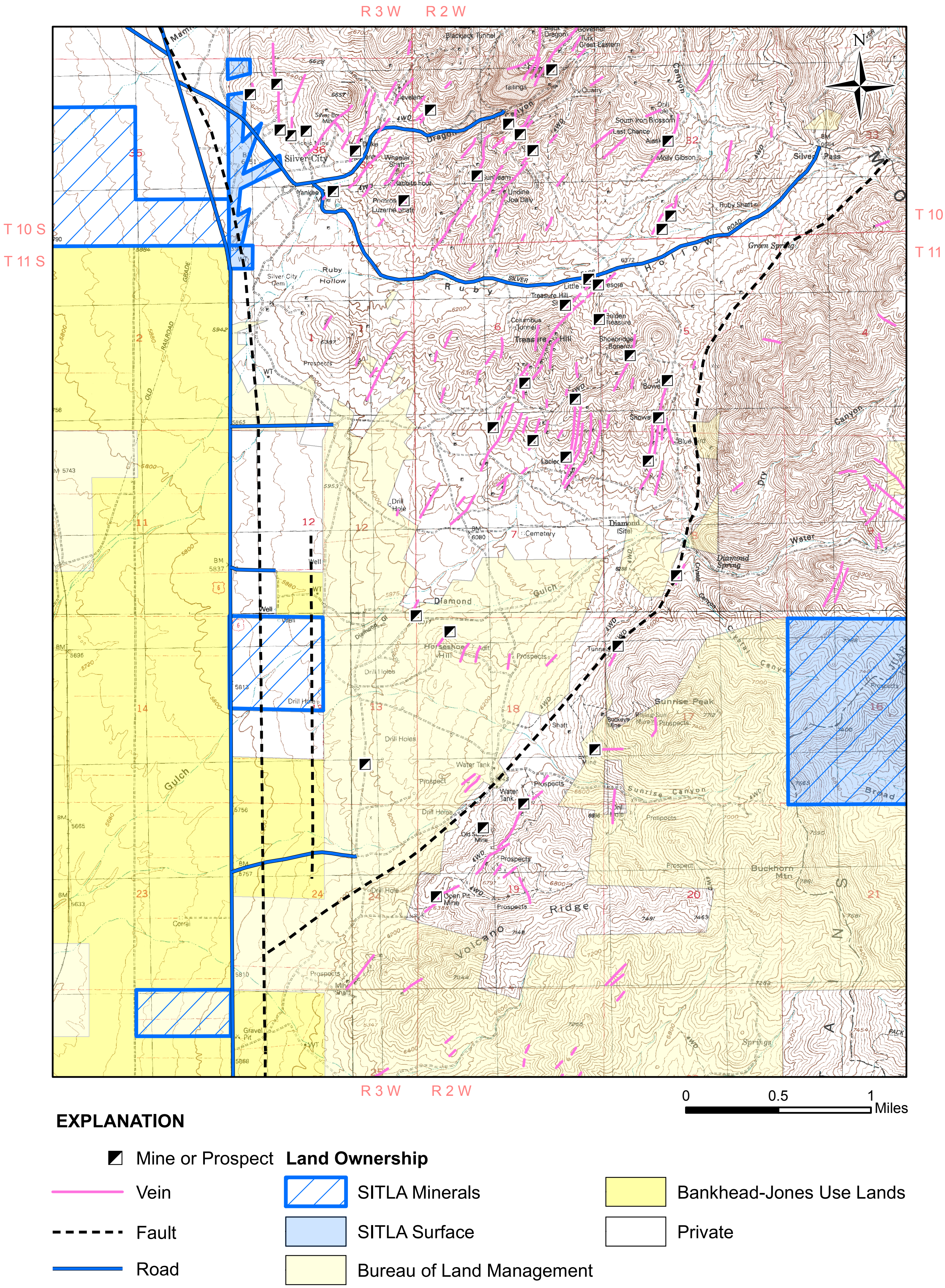
Association Publication 36, p. 163–180.
Morris, H.T., 1964a, Geology of the Eureka quadrangle, Utah and Juab Counties, Utah: U.S. Geological Survey Bulletin 1142-K, 29 p.
Morris, H.T., 1964b, Geology of the Tintic Junction quadrangle, Tooele, Juab, and Utah Counties, Utah: U.S. Geological Survey Bulletin 1142-L, 23 p.
Morris, H.T., 1968, The Main Tintic mining district, Utah, *in* Ridge J.D. editor, Ore deposits of the United States, 1933–1967, v. 2: American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., p. 1043–1073.
Morris, H.T., 1975, Geologic map and sections of the Tintic Mountain quadrangle and adjacent part of the McIntyre quadrangle, Juab and Utah Counties, Utah: U.S. Geological Survey Map I-883, scale 1:24,000.
Morris, H.T., 1985, Geology, ore bodies, and halloysite deposits of the Tintic mining district, Utah: Clays and Clay Minerals, p. 40–53.
Morris, H.T., and Mogensen, A.P., 1978, Tintic mining district, Utah: Provo, Utah, Brigham Young University, Geology Studies, v. 25, p. 33–45.
Norman, D.K., 1989, Petrology and geochemistry of alteration at Southwest Tintic, Utah: Salt Lake City, University of Utah unpublished M.S. thesis, 82 p.
Norman, D.K., Parry, W.T., and Bowman, J.R., 1991, Petrology and geochemistry of propylitic alteration at Southwest Tintic, Utah: Economic Geology, v. 86, p. 13–28.
Ramboz, C., 1979, A fluid inclusion study of the copper mineralization in Southwest Tintic (Utah): Bulletin Mineralogie, v. 102, p. 622–632.
Regan, M.D., 1961, Progress report, Southwest Tintic reconnaissance, Utah, November 1960 through December 1961: unpublished in-house report prepared for Bear Creek Mining Company, 36 p.
Shawe, D.R., 1972, Reconnaissance geology and mineral potential of Thomas, Keg, and Desert Calderas, central Juab County, Utah, *in* Geological Survey Research 1972, U.S. Geological Survey Professional Paper 800-B, p. B67–B77.
Sillitoe, R.H., 1995, Exploration and discovery of base- and precious-metal deposits in the circum-Pacific region during the last 25 years: Resource Geology Special Issue, no. 19, 119 p.
Tower, G.W., Jr., and Smith, G.O., 1899, Geology and mining industry of the Tintic district, Utah: U.S. Geological Survey 19th Annual Report (1897–1898), pt. 3, p. 601–767.
Tower, G.W., Jr., and Smith, G.O., 1900, Tintic special folio, Utah: U.S. Geological Survey Geologic Atlas of the United States, 8 p.
U.S. Climate Data, undated, Climate Delta, Utah: Online, https://www.usclimatedata.com/climate/delta/utah/united-states/usut0057, accessed January 2018.
Welsh, J.E., 1976, Southwest Tintic project based upon surface and subsurface reexamination: unpublished in-house report prepared for Kennecott Exploration Services, 31 p.
Welsh, J.E., 1985, Target evaluation and technical data review of the mineralization potential Southwest Tintic area, Tintic District, East Tintic Mountains, Juab County, Utah: unpublished in-house report prepared for Centurion Mines Inc., 23 p.

APPENDIX I

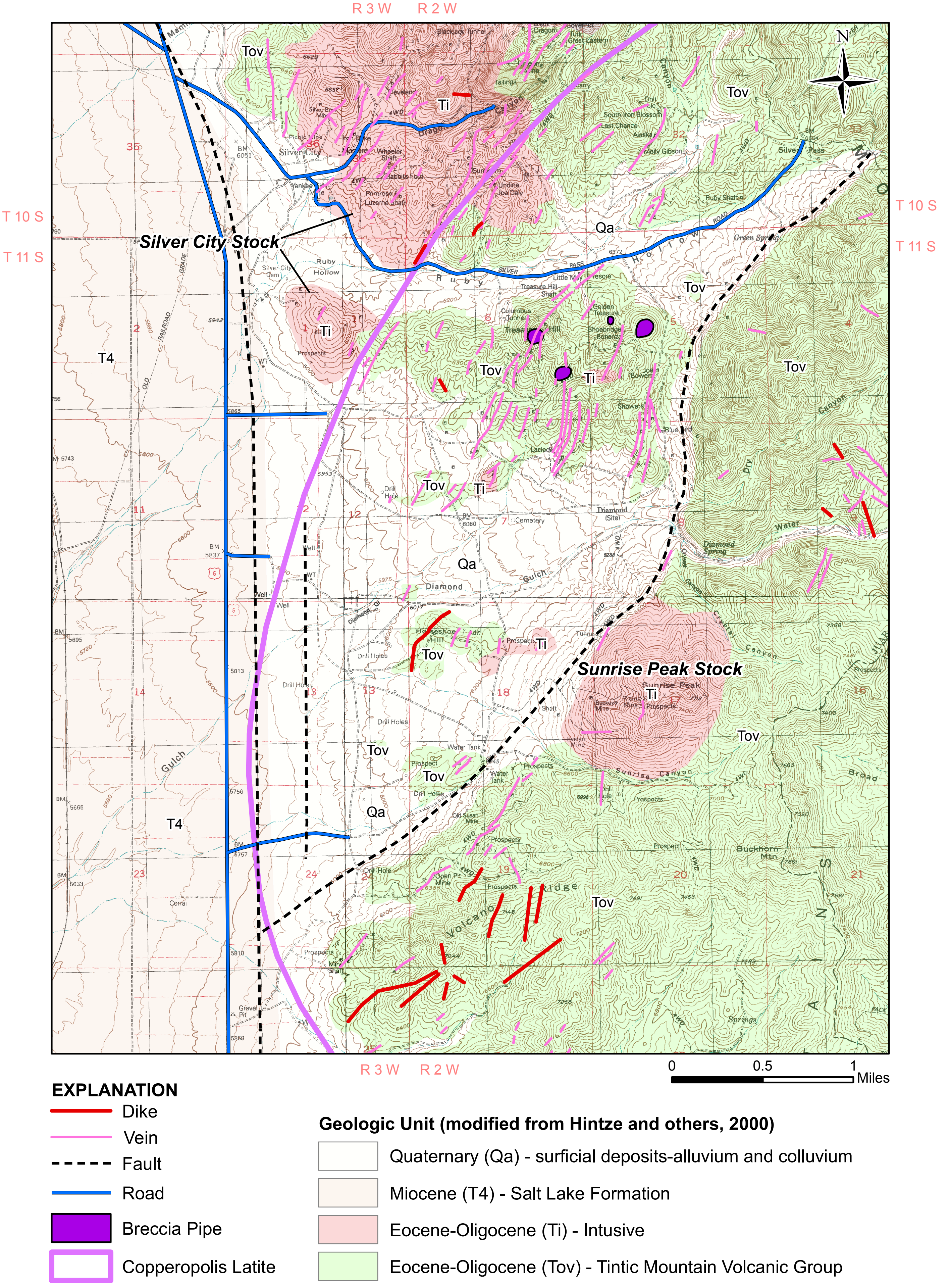
SOUTHWEST TINTIC DISTRICT MAPS

JUAB COUNTY, UTAH

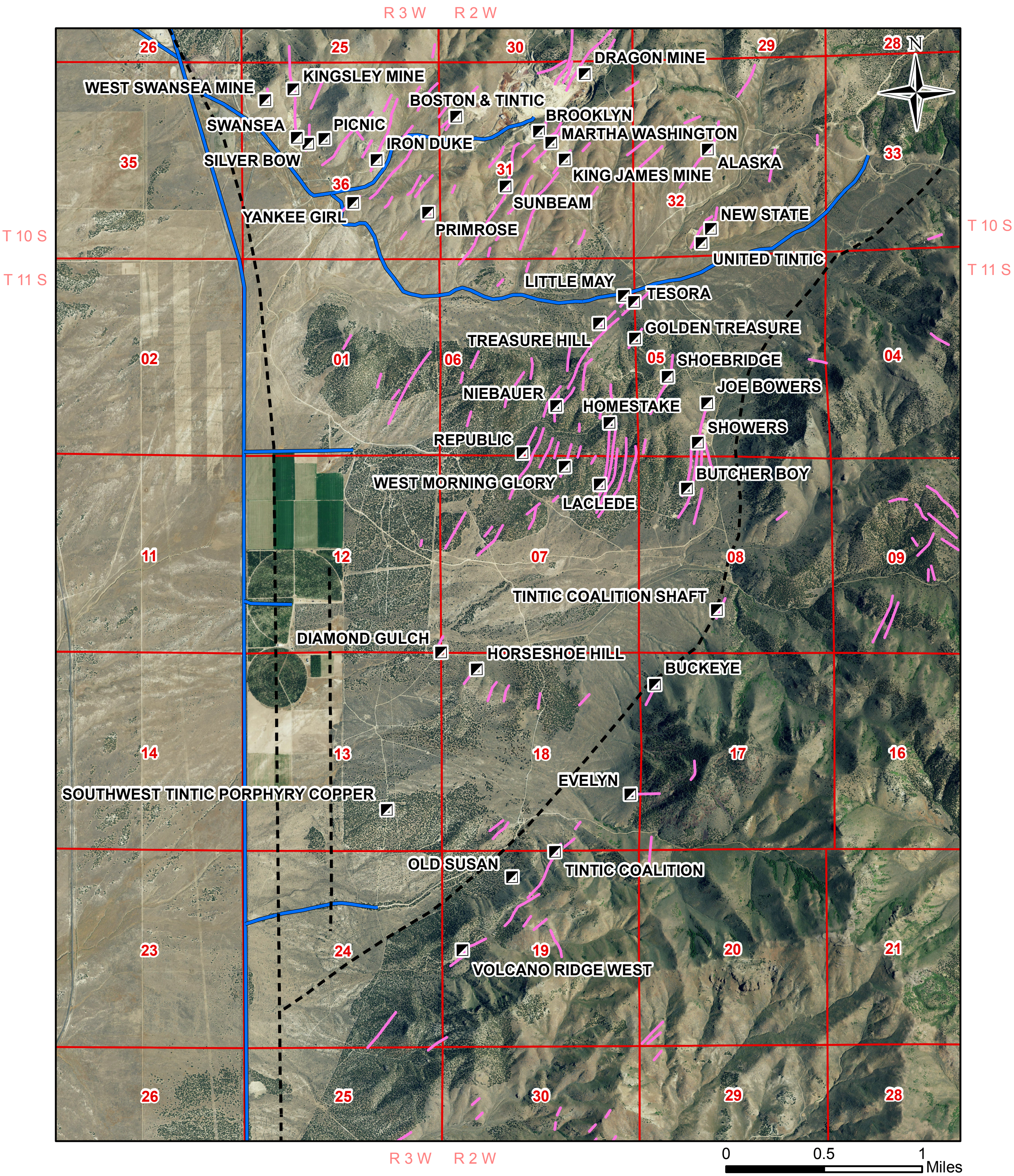
__Appendix I-1.__ Southwest Tintic area land ownership.



Appendix I-2. *Southwest Tintic area geology.*



Appendix I-3. *Southwest Tintic area mines on aerial photographic base.*



EXPLANATION

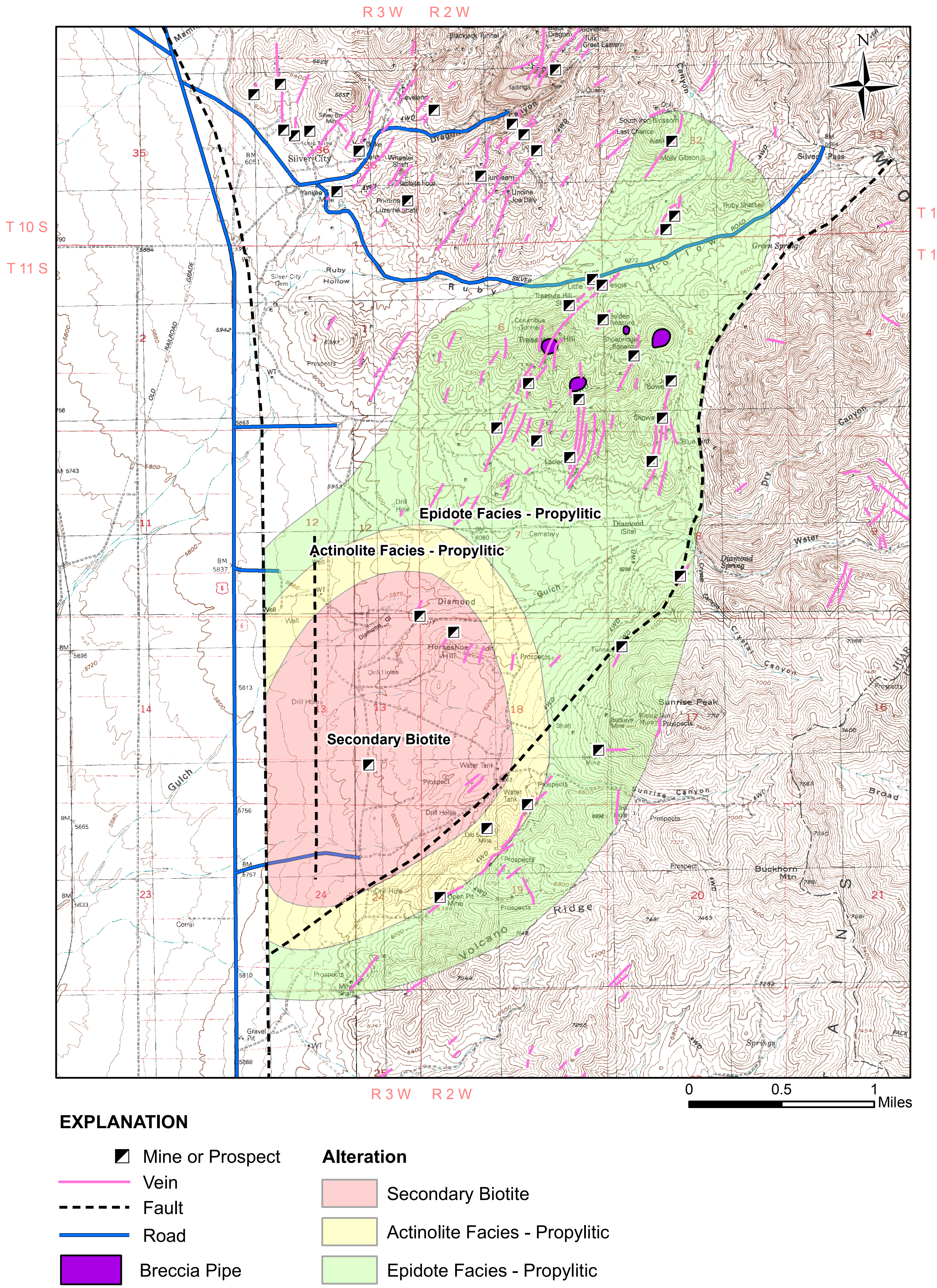
Mine or Prospect

Vein

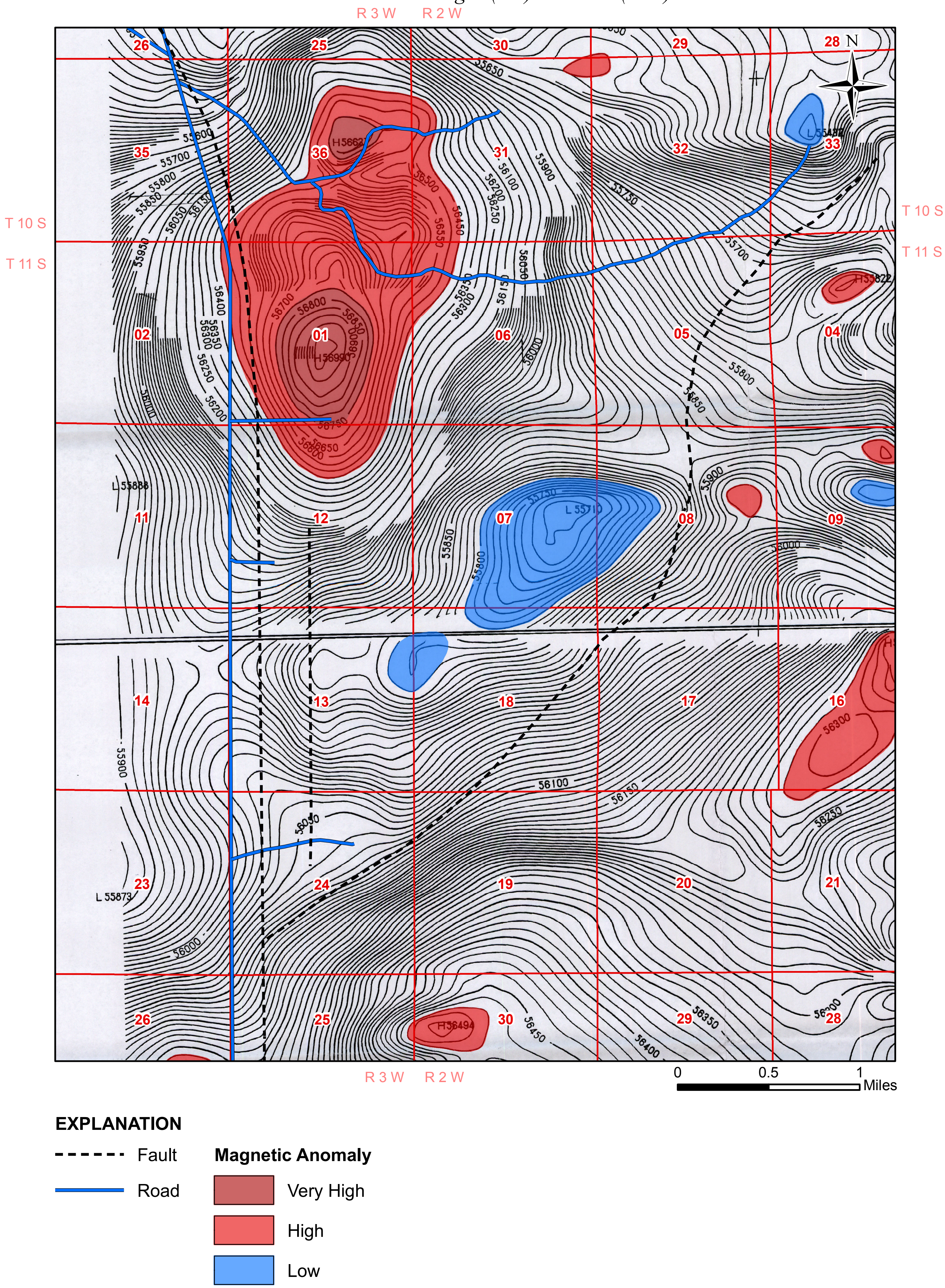
Fault

Road

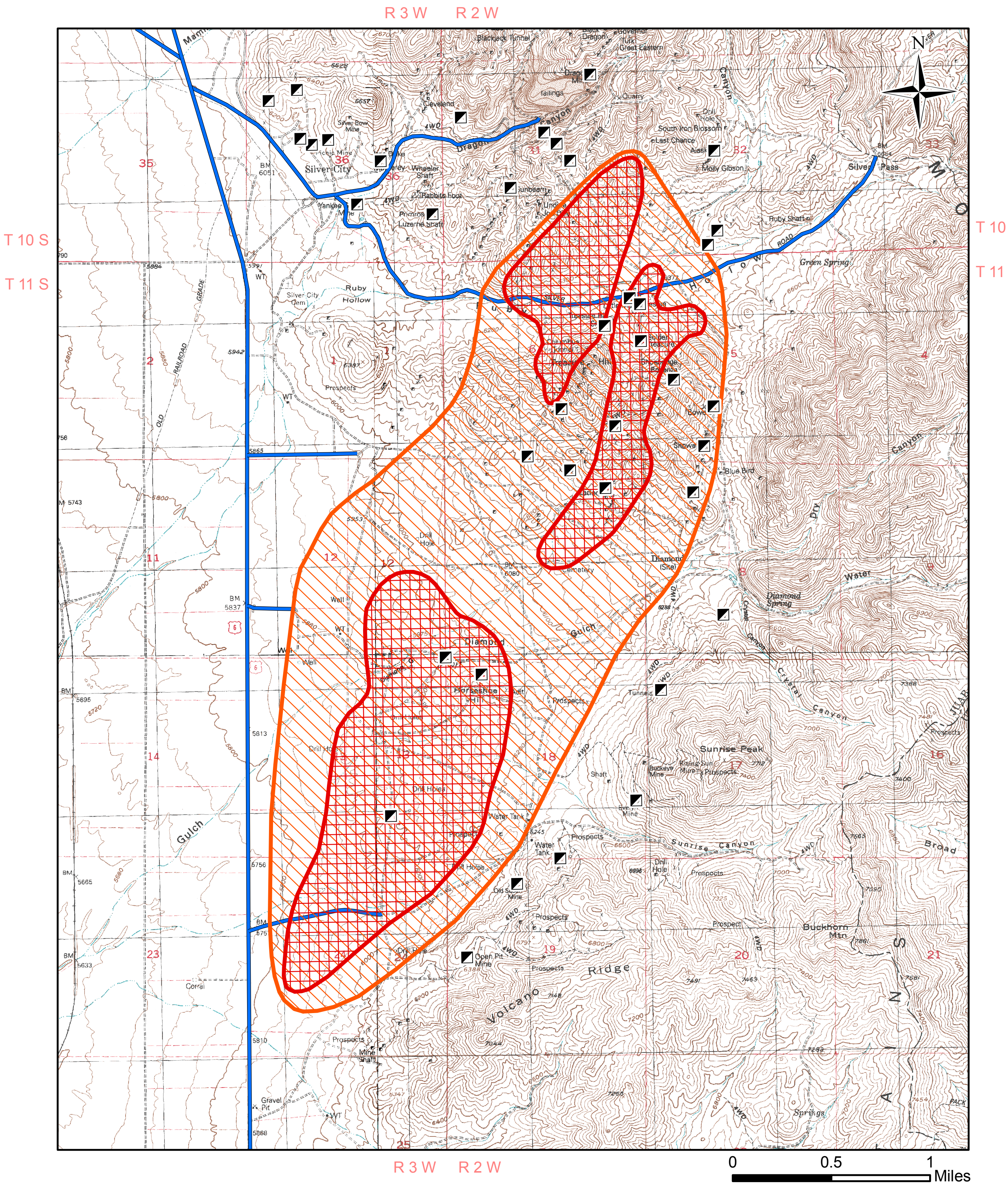
Appendix I-4. *Southwest Tintic area primary alteration, partially defined from subsurface drilling.*



Appendix I-5. *Southwest Tintic area total field aeromagnetic survey. Survey flown in 1980, draped at 750-ft terrain clearance, 1/6-mi north-south line spacing, and contoured on 10 gamma intervals. Some closed contours colored to accentuate highs (red) and lows (blue).*



Appendix I-6. *Southwest Tintic area induced polarization (IP) chargeability high and resistivity lows, compiled and generalized from several 1960-1980 era corporate IP surveys in UGS files.*



EXPLANATION

Mine or Prospect

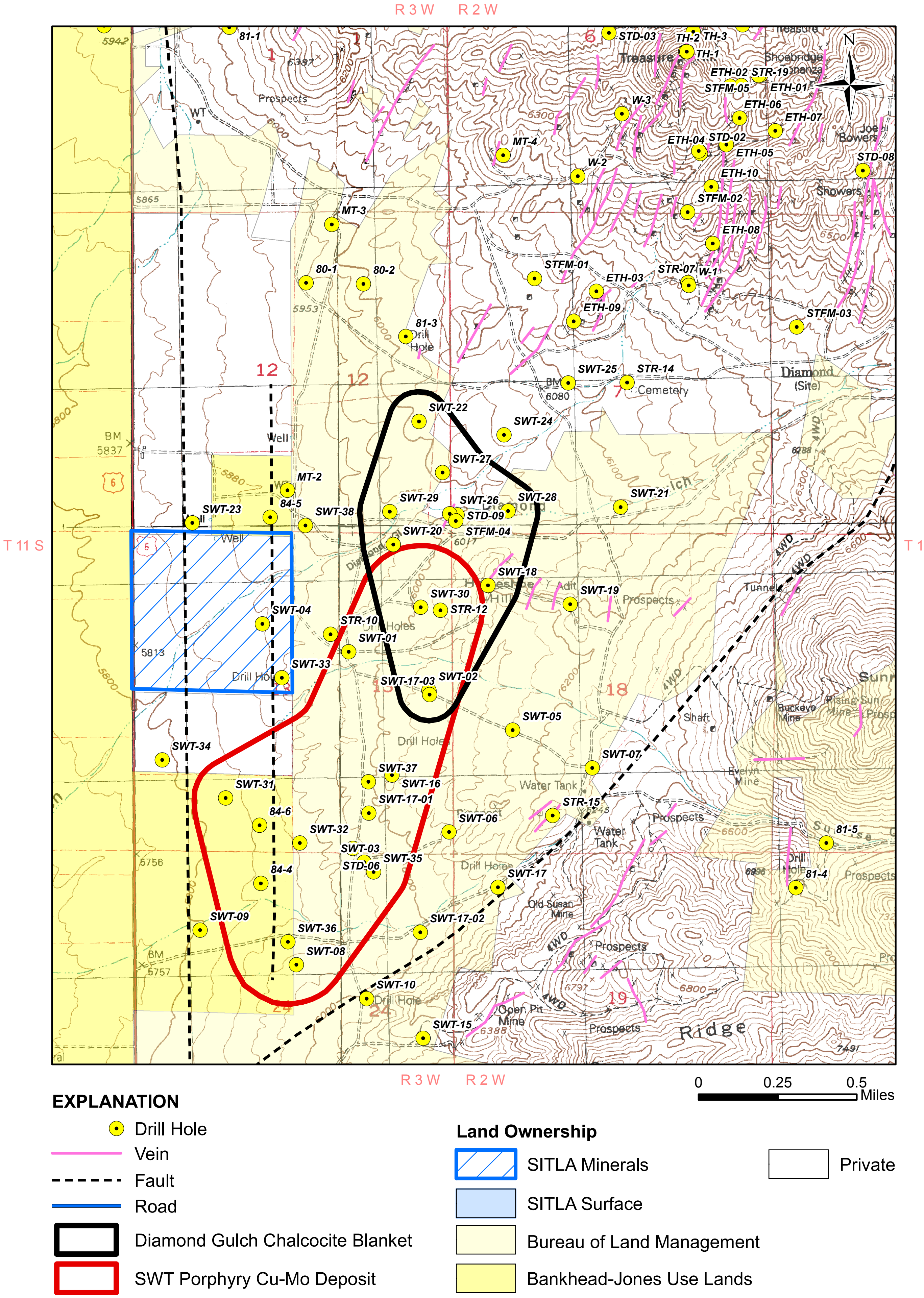
Road

Induced Polarization Anomaly

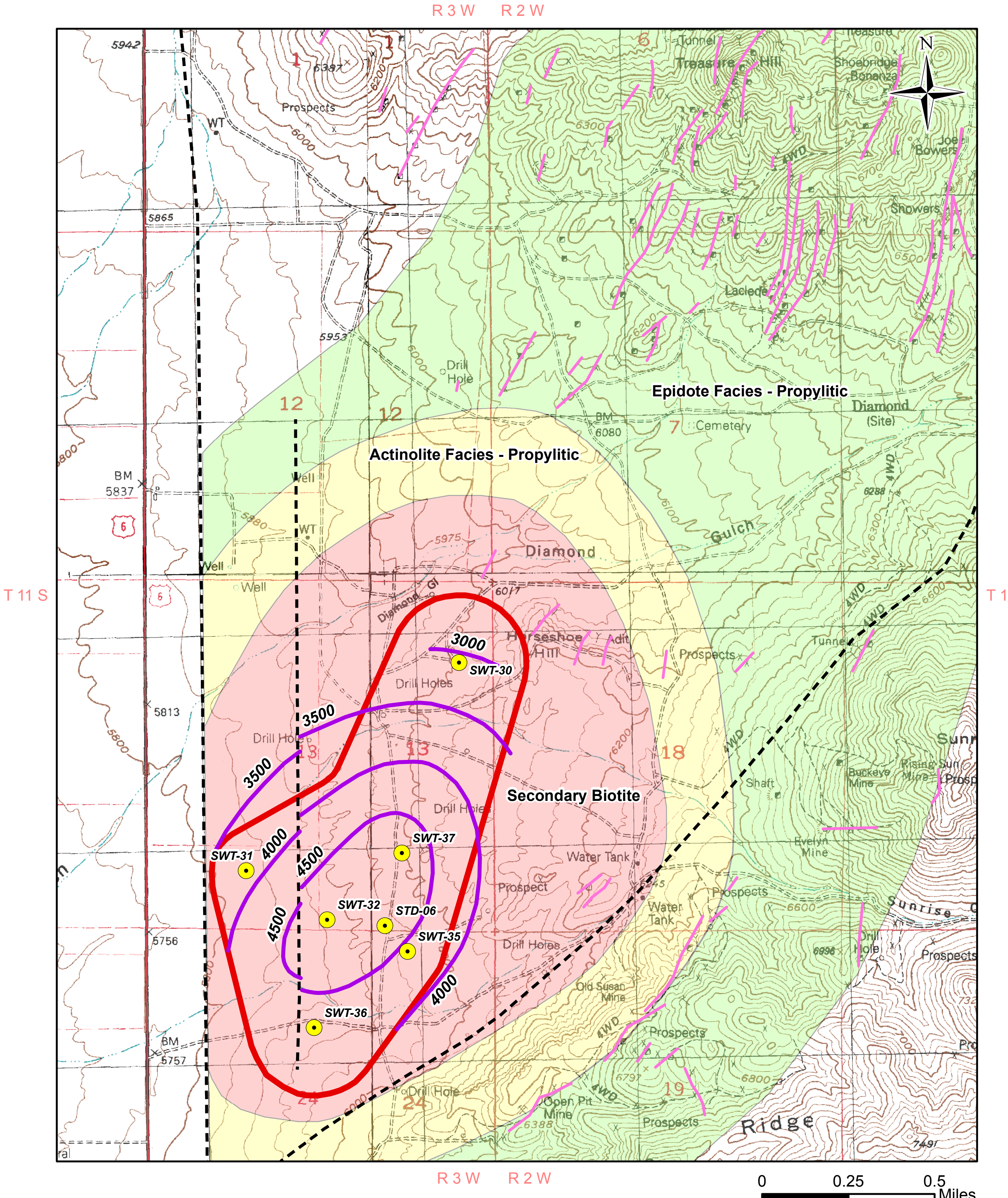
Very High

High

Appendix I-7. Horseshoe Hill and Diamond Gulch detail area ore deposit footprints, drill hole collars, and land ownership.



Appendix I-8. *Horseshoe Hill and Diamond Gulch detail area: SWT porphyry Cu-Mo footprint, drill holes, and elevation contours on top of >0.1% Cu drill intersections.*



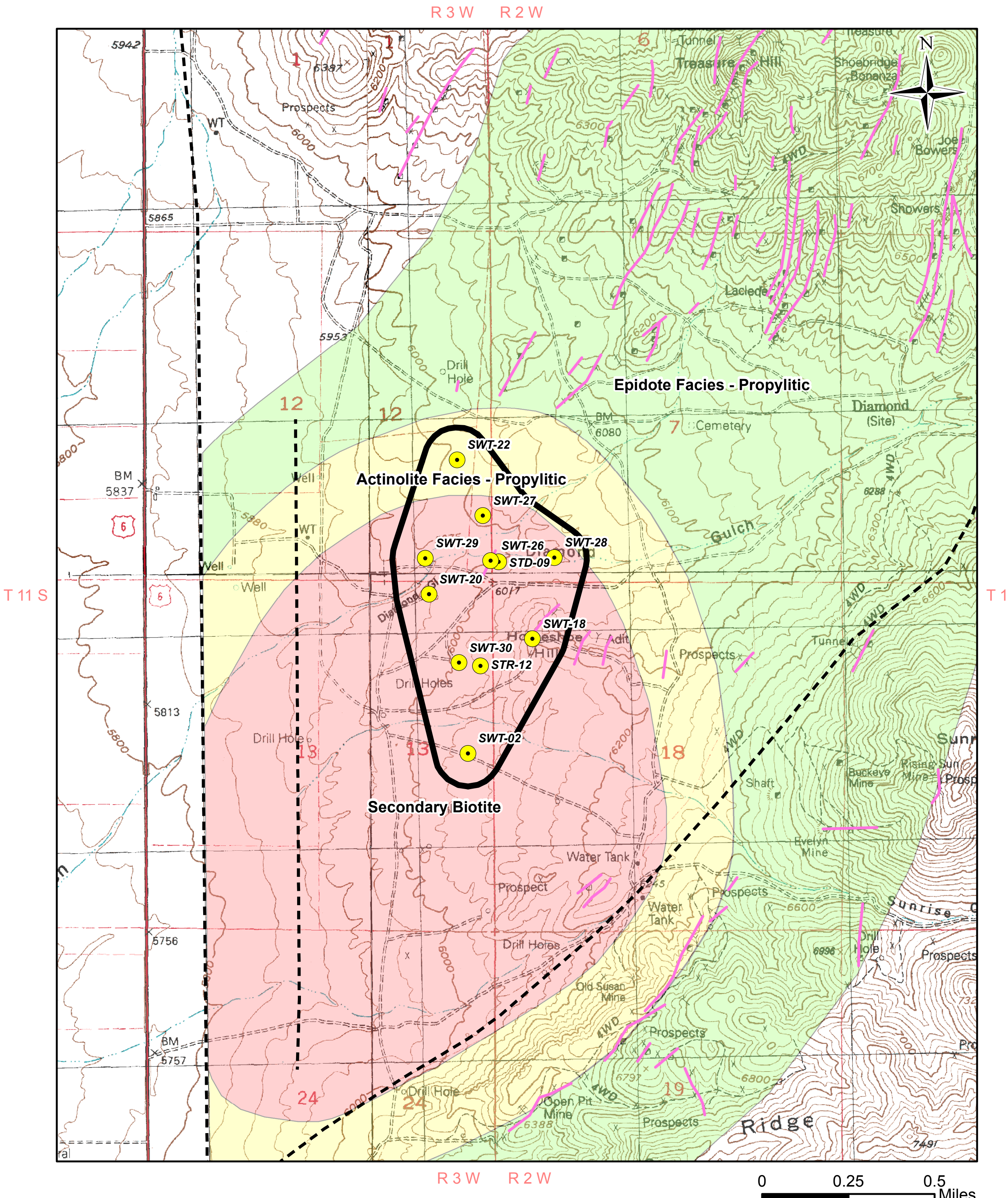
EXPLANATION

- Drill Hole
- Vein
- Fault
- Road
- SWT Porphyry Cu-Mo Deposit

Alteration

- Secondary Biotite
- Actinolite Facies - Propylitic
- Epidote Facies - Propylitic

Appendix I-9. *Horseshoe Hill and Diamond Gulch detail area: Diamond Gulch chalcocite blanket footprint and drill holes.*



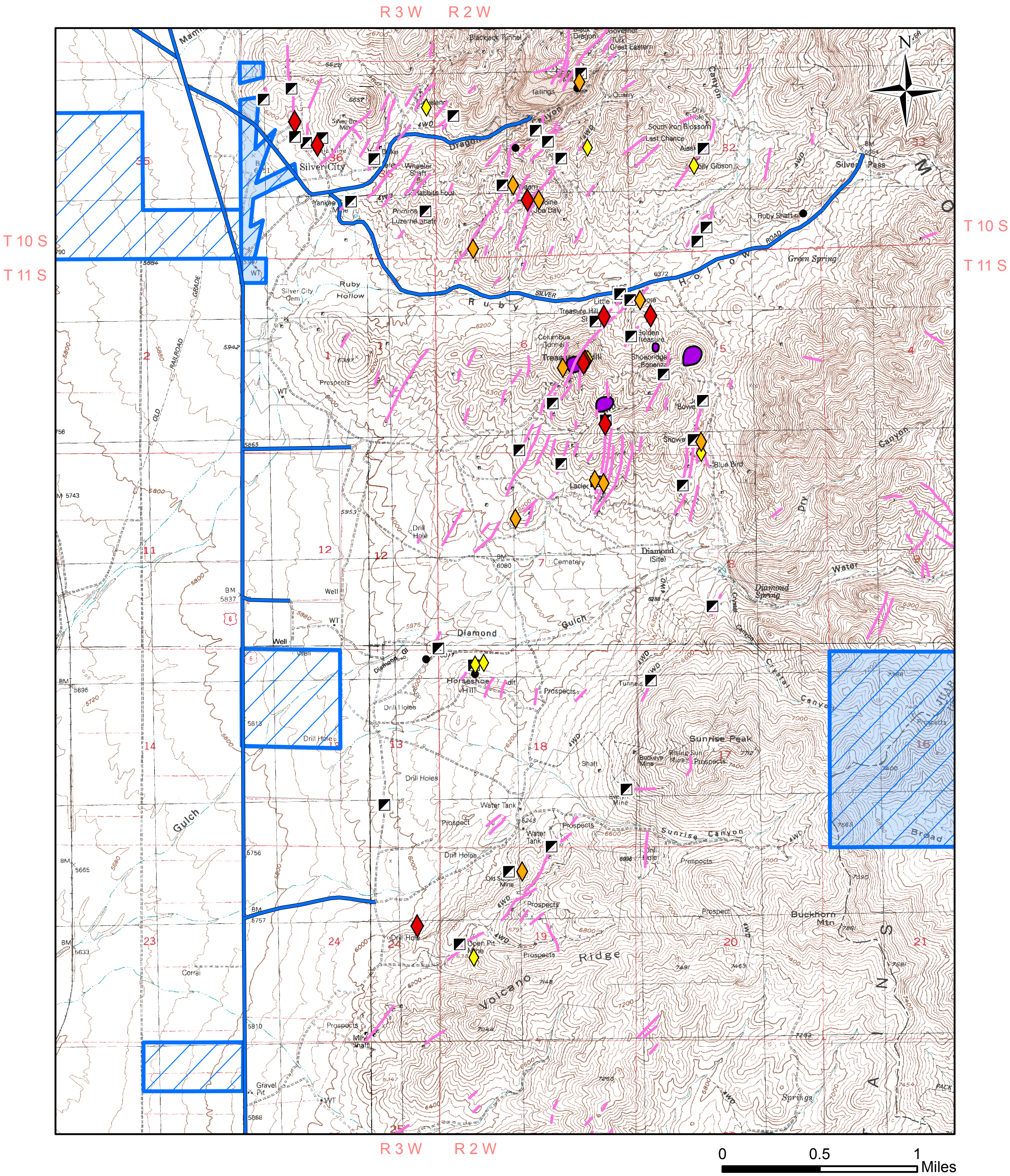
EXPLANATION

- Drill Hole
- Vein
- Fault
- Road
- Diamond Gulch Chalcocite Blanket

Alteration

- Secondary Biotite
- Actinolite Facies - Propylitic
- Epidote Facies - Propylitic

Appendix I-10. *Antimony (Sb) geochemistry in parts per million (ppm).*



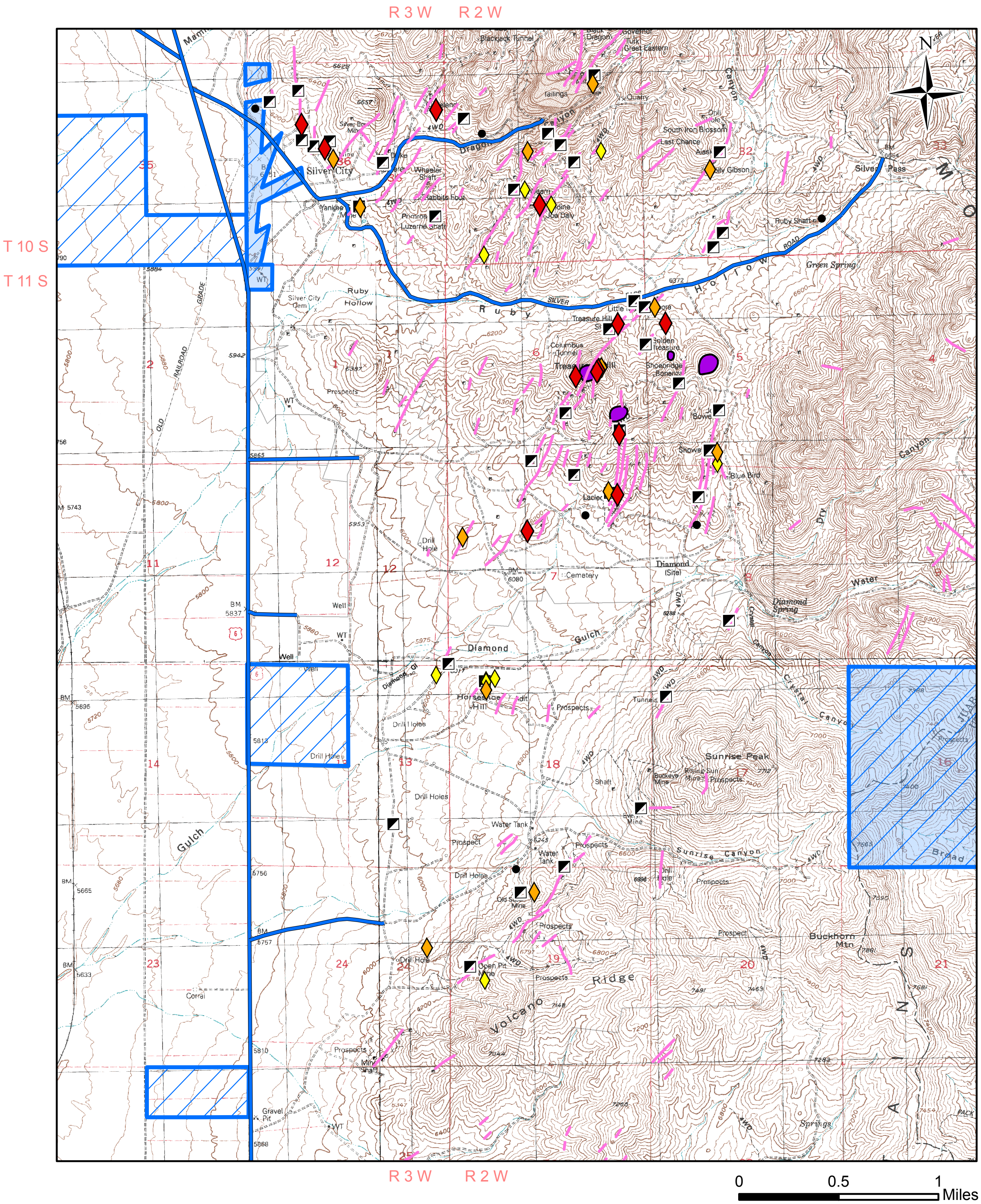
EXPLANATION

- 0 - 3 ppm
- >3 - 30 ppm
- >30 - 300 ppm
- >300 ppm
- Mine or Prospect
- Vein
- Road
- Breccia Pipe

Land Ownership

- SITLA Minerals
- SITLA Surface

Appendix I-11. *Arsenic (As) geochemistry in parts per million (ppm).*



EXPLANATION

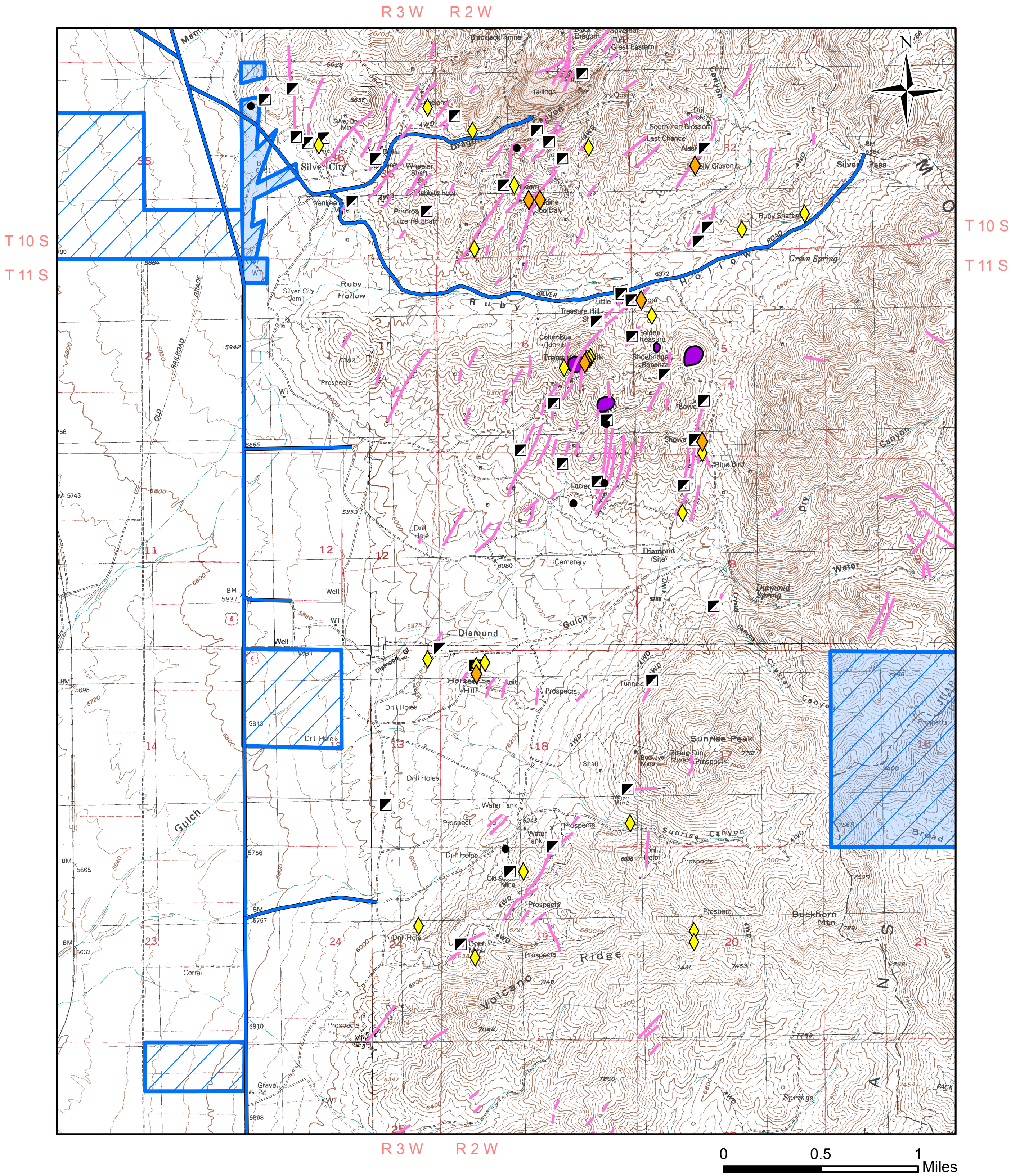
- 0 - 17 ppm
- >17 - 170 ppm
- >170 - 1700 ppm
- >1700 ppm

- Mine or Prospect
- Vein
- Road
- Breccia Pipe

Land Ownership

- SITLA Minerals
- SITLA Surface

Appendix I-12. *Barium (Ba) geochemistry in parts per million (ppm).*



EXPLANATION

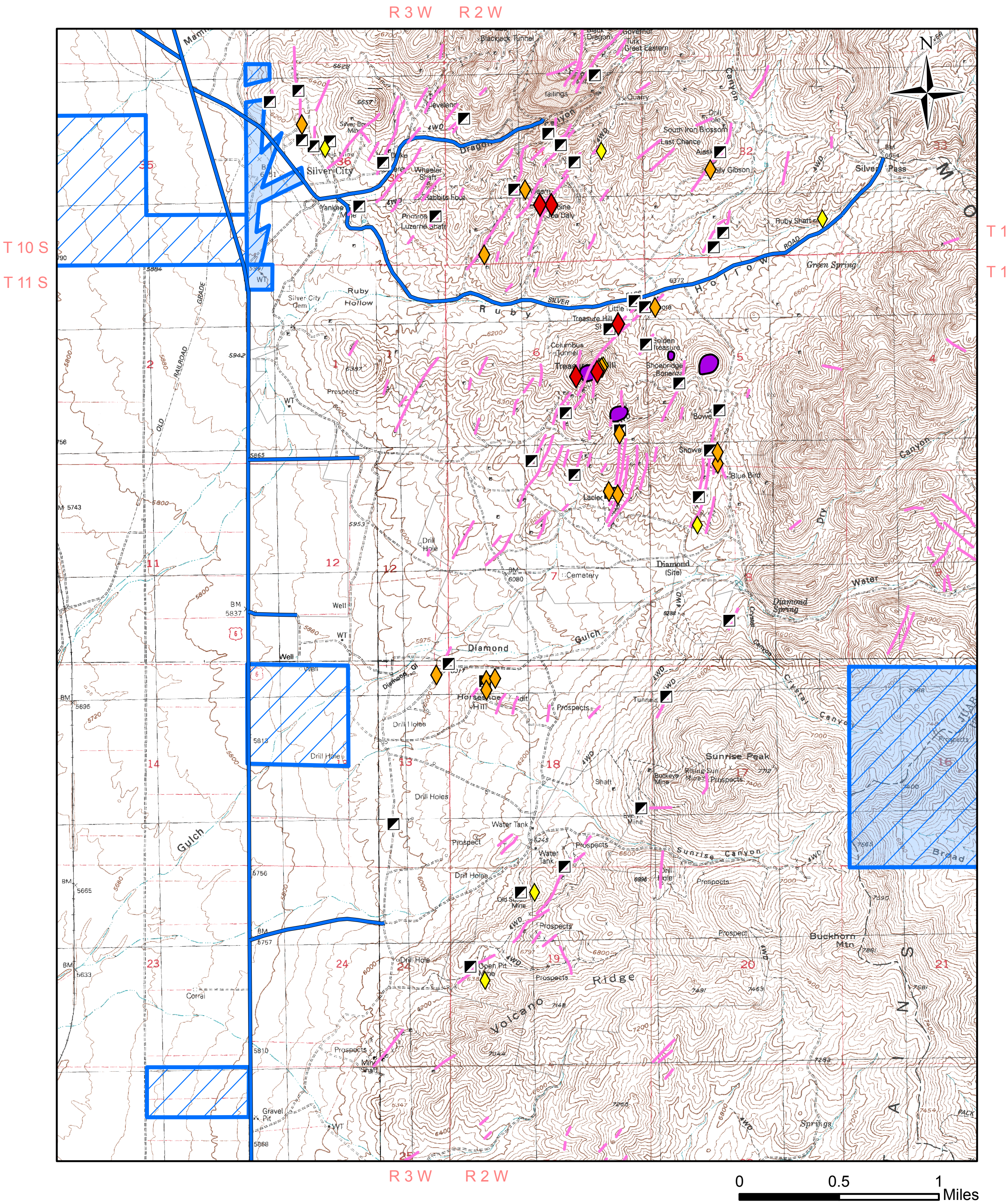
- 0 - 450 ppm
- >450 - 4500 ppm
- >4500 ppm

- Mine or Prospect
- Vein
- Road
- Breccia Pipe

Land Ownership

- SITLA Minerals
- SITLA Surface

Appendix I-13. *Bismuth (Bi) geochemistry in parts per million (ppm).*



EXPLANATION

- 0 - 0.85 ppm
- >0.85 - 8.5 ppm
- >8.5 - 85 ppm
- >85 ppm

Mine or Prospect

Vein

Road

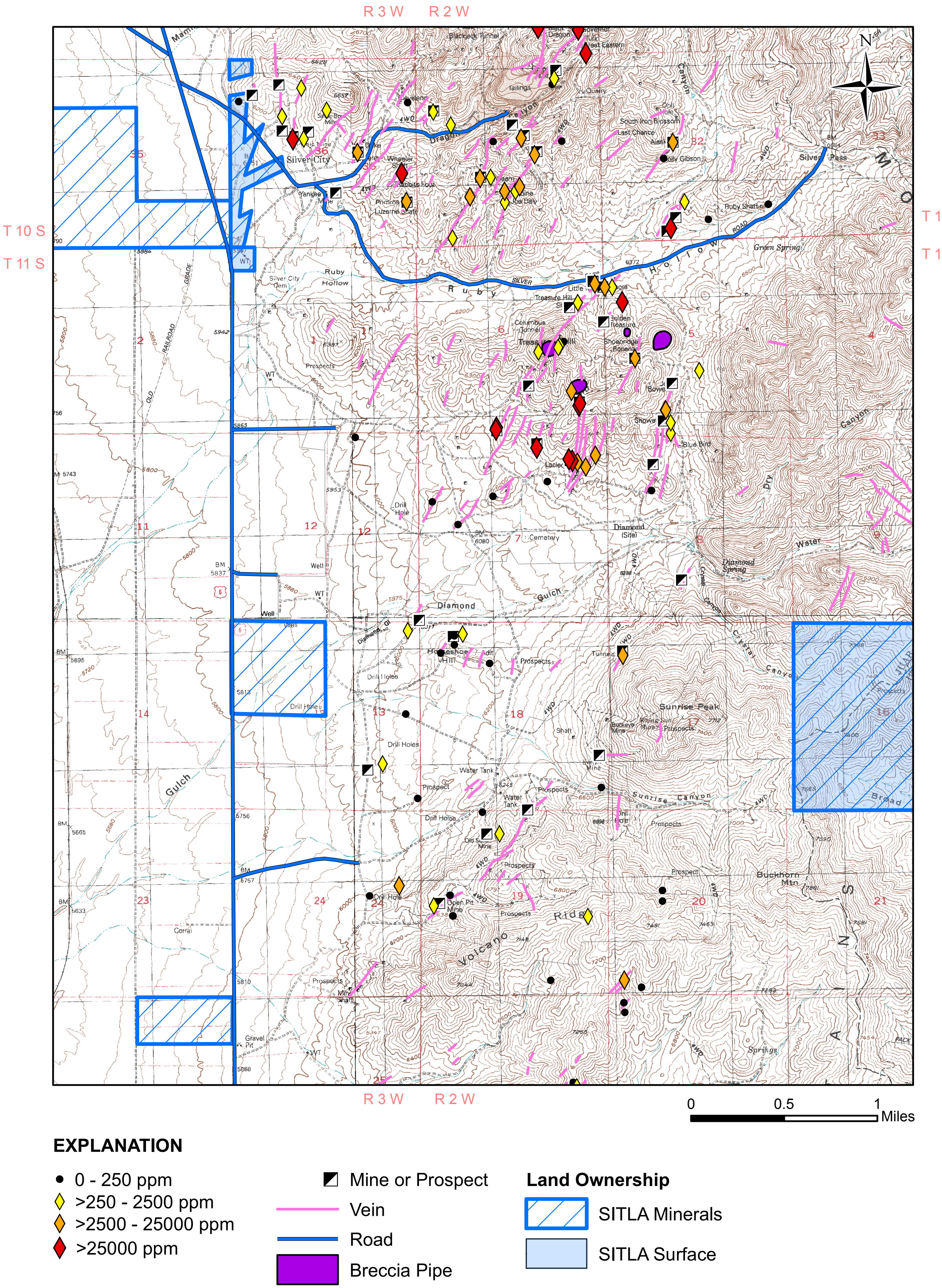
Breccia Pipe

Land Ownership

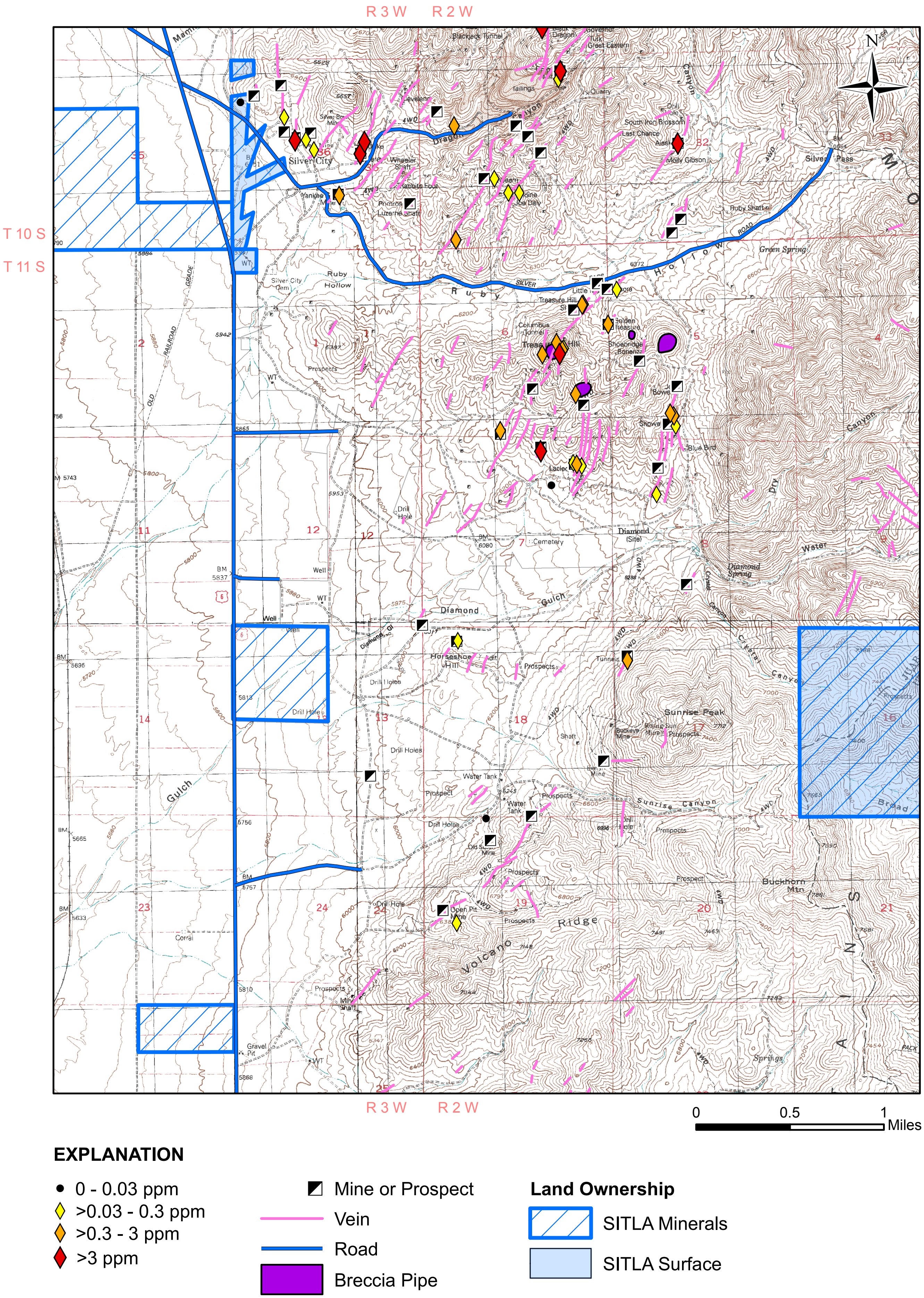
SITLA Minerals

SITLA Surface

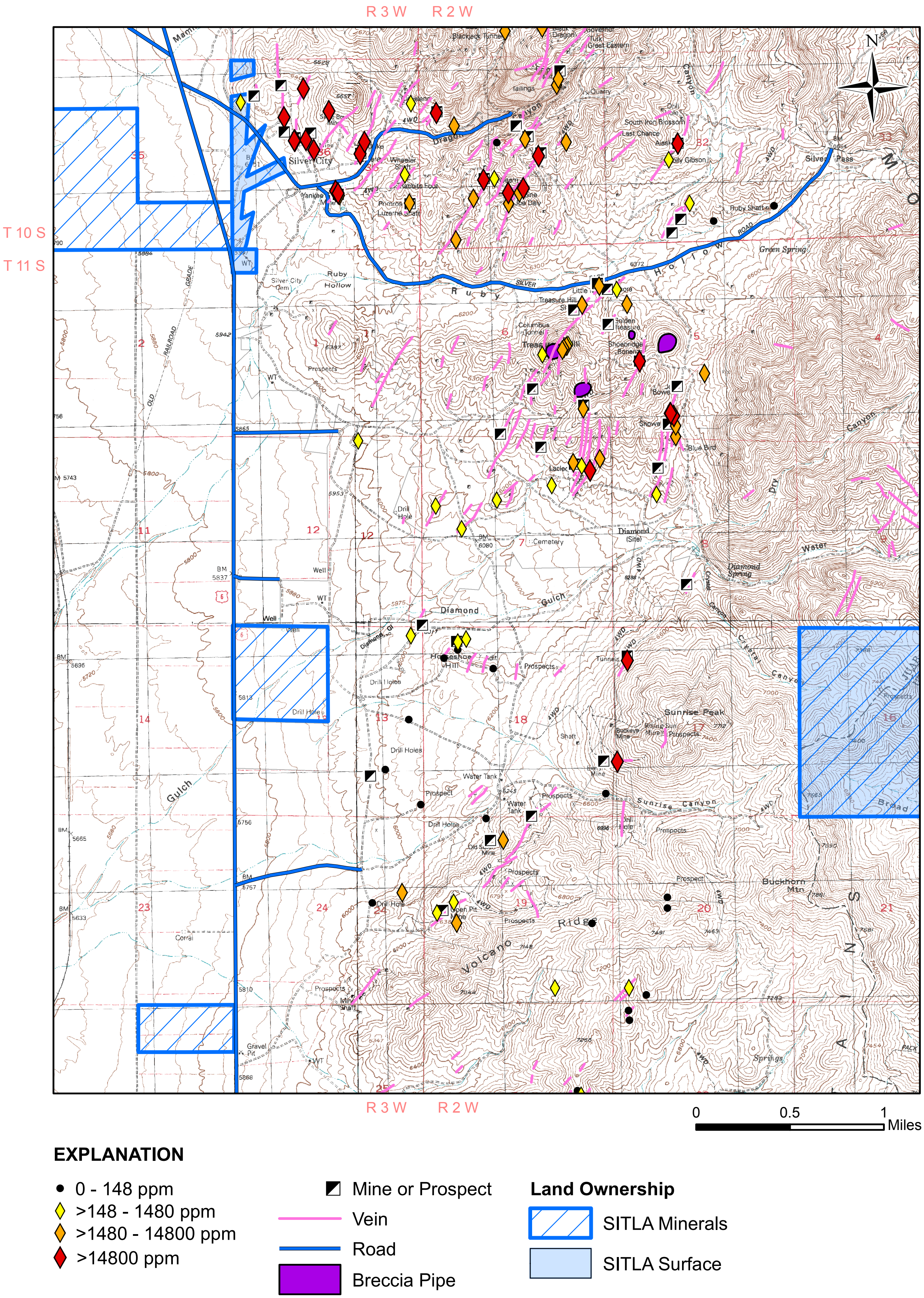
Appendix I-14. *Copper (Cu) geochemistry in parts per million (ppm).*



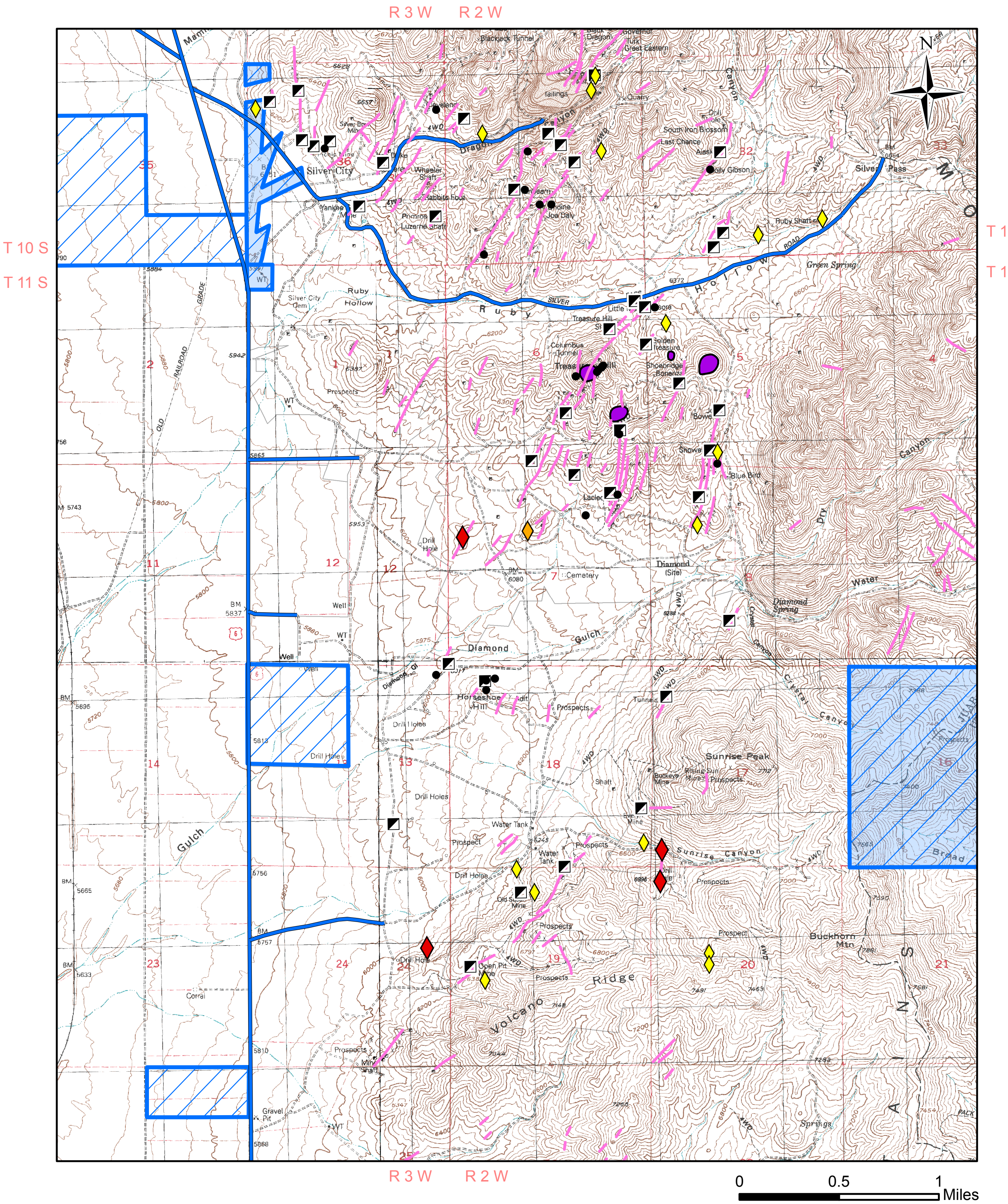
Appendix I-15. *Gold (Au) geochemistry in parts per million (ppm).*



Appendix I-16. *Lead (Pb) geochemistry in parts per million (ppm).*



Appendix I-17. *Manganese (Mn) geochemistry in parts per million (ppm).*



EXPLANATION

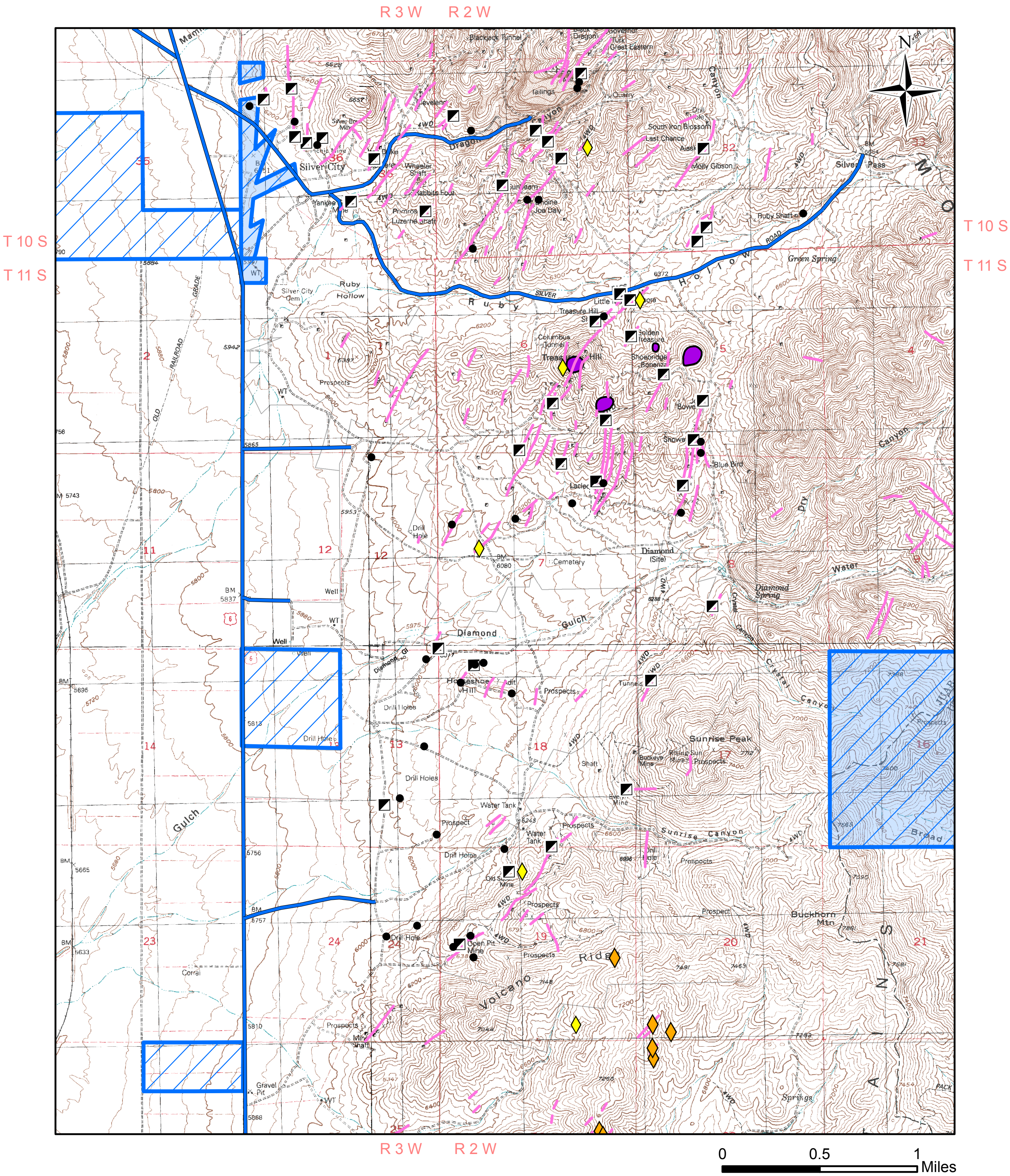
- 0 - 500 ppm
- >500 - 5000 ppm
- >5000 - 50000 ppm
- >50000 ppm

- Mine or Prospect
- Vein
- Road
- Breccia Pipe

Land Ownership

- SITLA Minerals
- SITLA Surface

Appendix I-18. Molybdenum (Mo) geochemistry in parts per million (ppm).



EXPLANATION

- ● 0 - 10 ppm
- ◇ >10 - 100 ppm
- ◇ >100 ppm

Mine or Prospect

Vein

Road

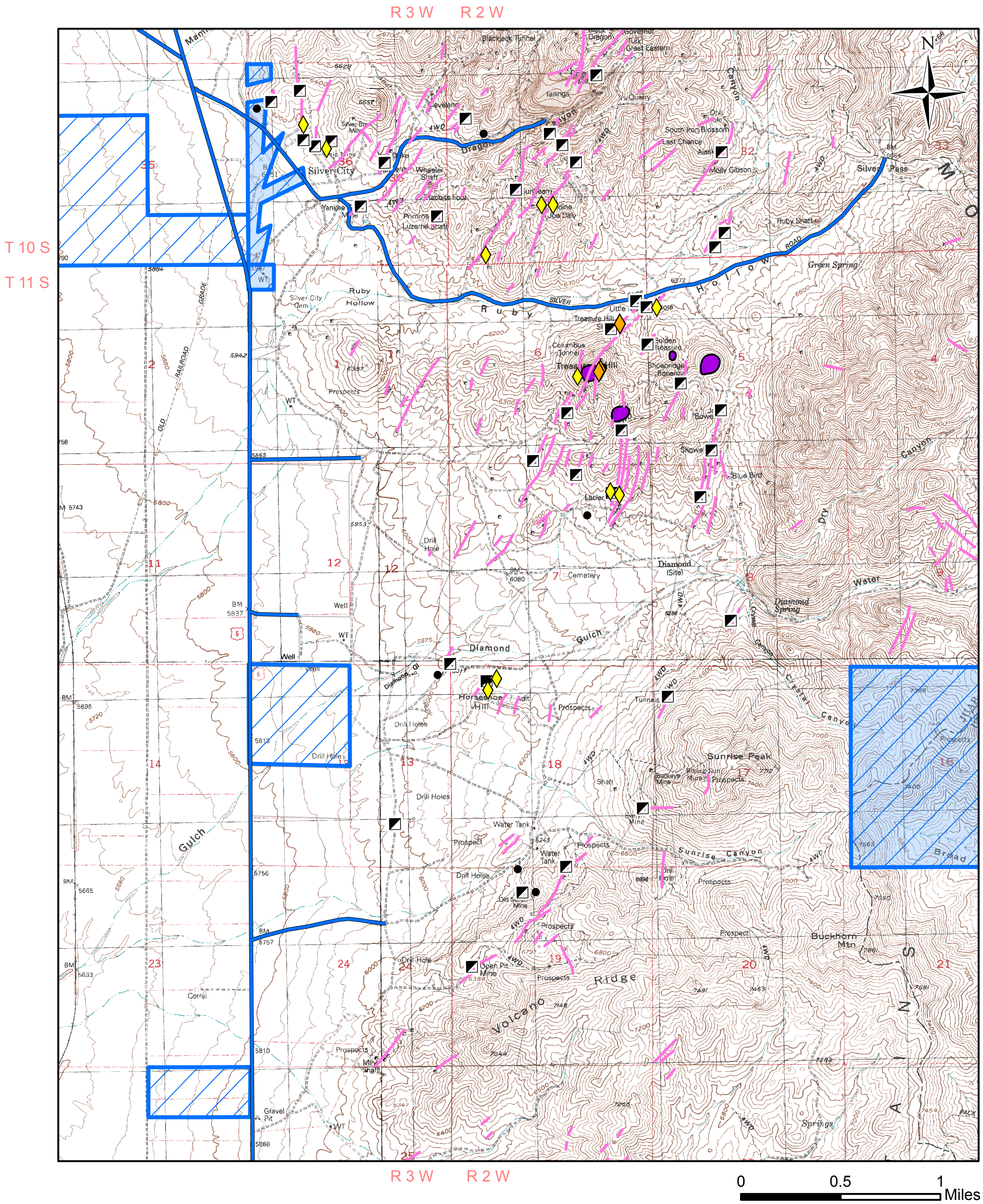
Breccia Pipe

Land Ownership

SITLA Minerals

SITLA Surface

Appendix I-19. *Tin (Sn) geochemistry in parts per million (ppm).*



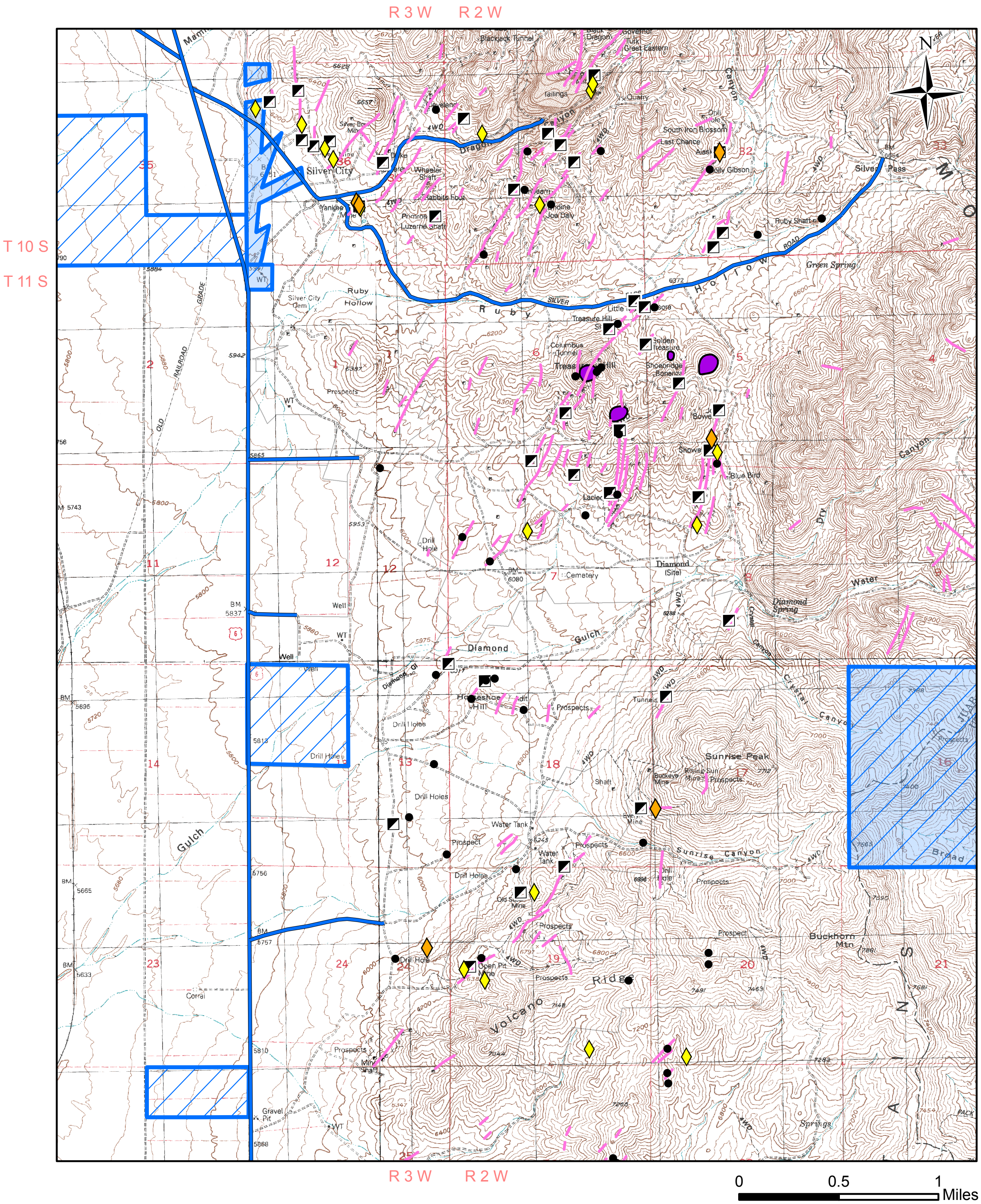
EXPLANATION

- 0 - 10 ppm
- >10 - 100 ppm
- >100 ppm
- Mine or Prospect
- Vein
- Road
- Breccia Pipe

Land Ownership

- SITLA Minerals
- SITLA Surface

Appendix I-20. *Zinc (Zn) geochemistry in parts per million (ppm).*



EXPLANATION

- 0 - 650 ppm
- >650 - 6500 ppm
- >6500 ppm

- Mine or Prospect
- Vein
- Road
- Breccia Pipe

Land Ownership

- SITLA Minerals
- SITLA Surface

Appendix II

Southwest Tintic District Photographs

Juab County, Utah


Photo 1. Sunbeam Ag-Pb-Cu shaft, view to the south, photo taken in 2005.

Photo 2. Reclaimed Sunbeam Ag-Pb-Cu shaft, view to the southeast, 2010, photo courtesy of Utah Division of Oil, Gas and Mining.


Photo 3. Sunbeam Ag-Pb-Cu mine dump, view to the north, 2005.


Photo 4. Sunbeam Ag-Pb-Cu mine, quartz vein pyritohedral pyrite, 2005.

Photo 5. Propylitized quartz latite porphyry in the Sunbeam Ag-Pb-Cu mine area, 2005.

Photo 6. Close-up of propylitized quartz latite porphyry in the Sunbeam Ag-Pb-Cu mine area showing biotite (black), clear quartz, and rounded, white orthoclase phenocrysts up to 2.5 inches, 2005.

Photo 7. Typical outcrop of Silver City monzonite stock, 2005.

Photo 8. Close-up of Silver City monzonite stock, 2005.


Photo 9. The Dragon halloysite open pit with headframe in bottom, about 1993.


Photo 10. View of the Swansea mine area looking northwest, 2005.


Photo 11. Similar view of the Swansea mine area, view to the northwest, 2017.


Photo 12. Propylitized andesite porphyry east of Treasure Hill, 2005.

Photo 13. Close-up of argillized crystal-lithic tuff member of the Copperopolis latite on Treasure Hill, 2005.

Photo 14. Treasure Hill, note rugged outcrop of silicified-argillized breccia pipe on top of hill, view to the southeast, 2008.

Photo 15. Treasure Hill angular to rounded, heterolithic, clast-supported breccia pipe, 2005.

Photo 16. Treasure Hill angular, homolithic, clast-supported shingle breccia, 2005.


Photo 17. Treasure Hill silicified, angular, clast-supported breccia pipe, 2005.


Photo 18. Treasure Hill angular, homolithic, clast-supported, shingle breccia, 2005.

Photo 19. Dr. Richard Sillitoe studying complex Treasure Hill breccia, 2006.

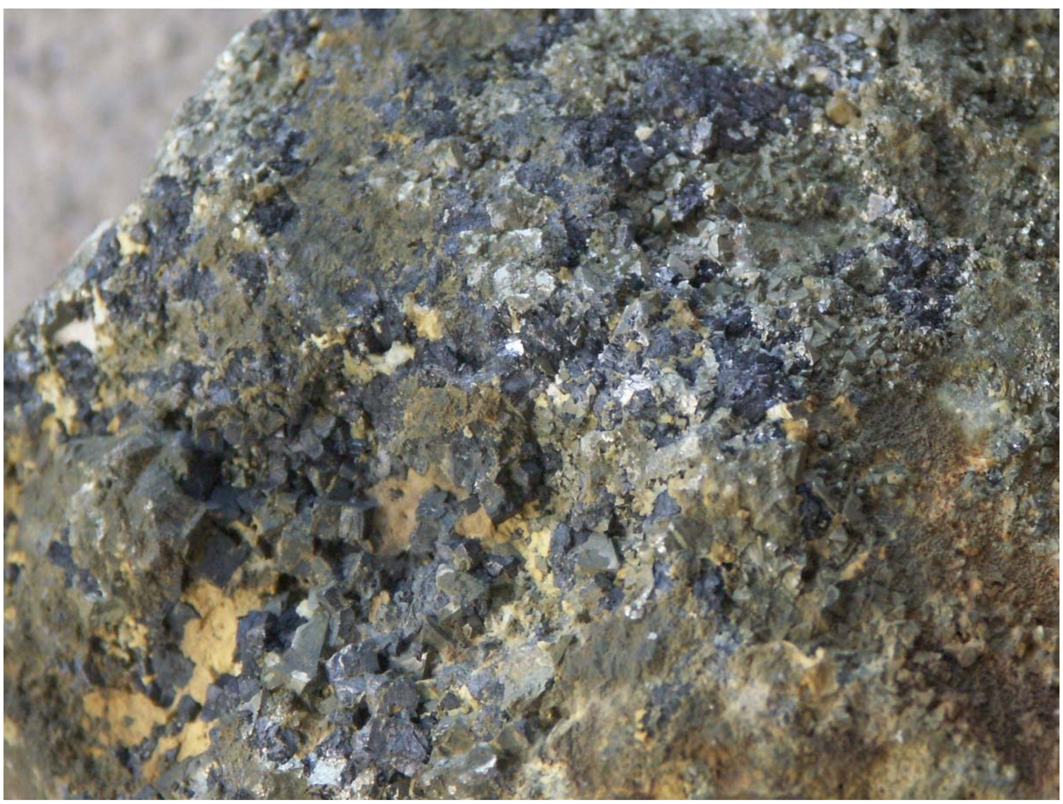


Photo 20. Close-up of Treasure Hill area enargite (black) and octahedral pyrite vein, 2005.

Photo 21. Close-up of coarse-grained octahedral pyrite from the Homestake Ag-Cu mine, 2005.

Photo 22. Close-up of turquoise vein fragment from prospect pit on top of Horseshoe Hill, 2017.

Photo 23. Hole STD-06 in progress in the pediment above the SWT porphyry Cu-Mo deposit, view to the north, 1994.

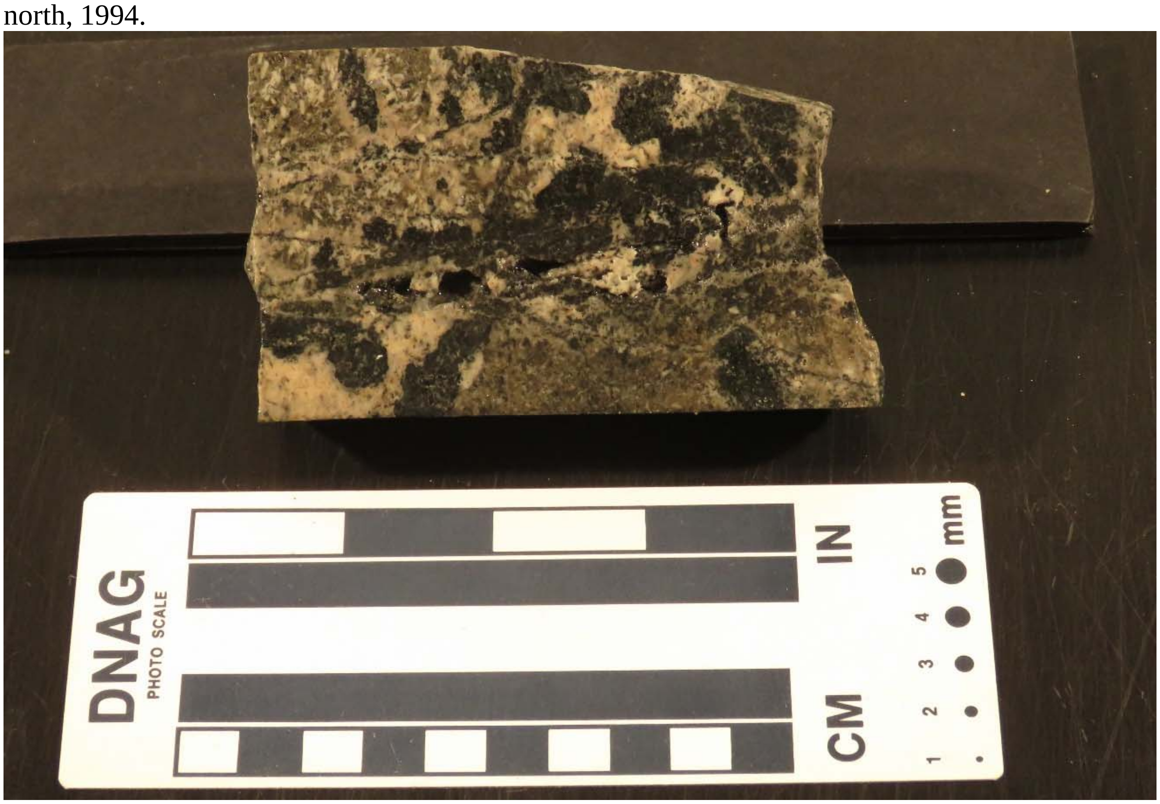


Photo 24. STD-06 core, 1552 ft, pink gray, porphyritic andesite, “mottled” K-spar-magnetite-biotite alteration, 3% sulfide, cut by pyrite vein with sericite selvage.

Photo 25. STD-06 core, 1922 ft, pink gray, Diamond Gulch quartz monzonite porphyry with large (2.5 inches) K-spar phenocrysts, very weak alteration, trace sulfide on pyritic fractures.

Photo 26. STD-06 core, 2003 ft, dark gray, crystal tuff (?), biotite-K-spar alteration, 2 vol.% sulfide, multitude of cross-cutting, quartz±K-spar±sulfide±magnetite vein sets.

Photo 27. STD-06 core, 2358 ft, gray, crystal tuff (?), biotite-K-spar alteration, 2 vol.% sulfide, chalcopyrite on late fracture.

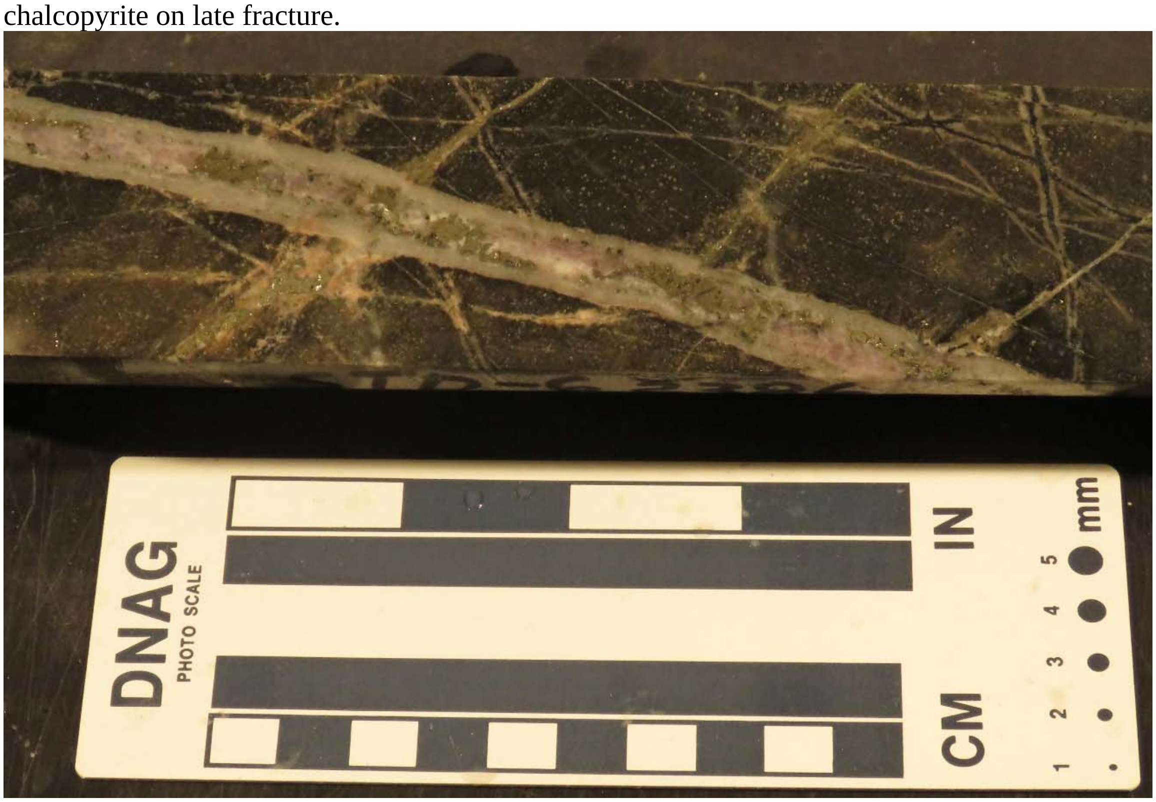


Photo 28. STD-06 core, 2386 ft, dark gray, andesite (?), strong biotite alteration, 2 vol.% sulfide, quartz-chlorite stockwork with bleached selvage cut by quartz-chalcopyrite vein cut by quartz-pyrite-molybdenite-anhydrite.

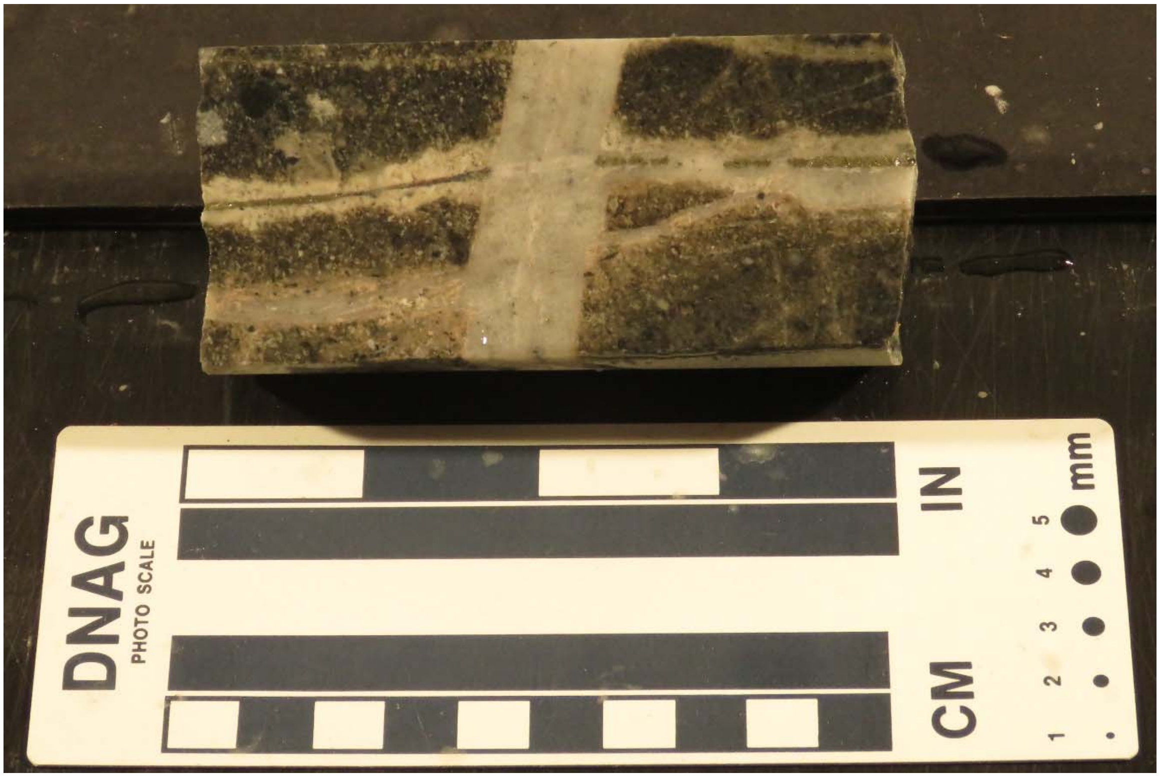


Photo 29. STD-06 core, 2585 ft, gray, andesite, biotite-K-spar alteration, 5 vol.% sulfide, quartz-molybdenite vein cut by pyrite-quartz vein with sericite selvage.

Photo 30. STD-06 core, 2615 ft, light gray, andesite, K-spar-biotite-magnetite alteration, 3 vol.% sulfide, thick lavender anhydrite-chalcopyrite vein.

Photo 31. STD-06 core, 2863-65 ft, 2-ft-long unbroken stick of gray, andesite porphyry, biotite-K-spar alteration, 3 vol.% sulfide, and multitude of quartz±K-spar±sulfide±magnetite vein sets. All of the fractures have been rehealed by veins. Unbroken 5–10-ft-long sticks of core were commonly recovered from the bottom of STD-06 with 100% RQD (rock-quality designation).

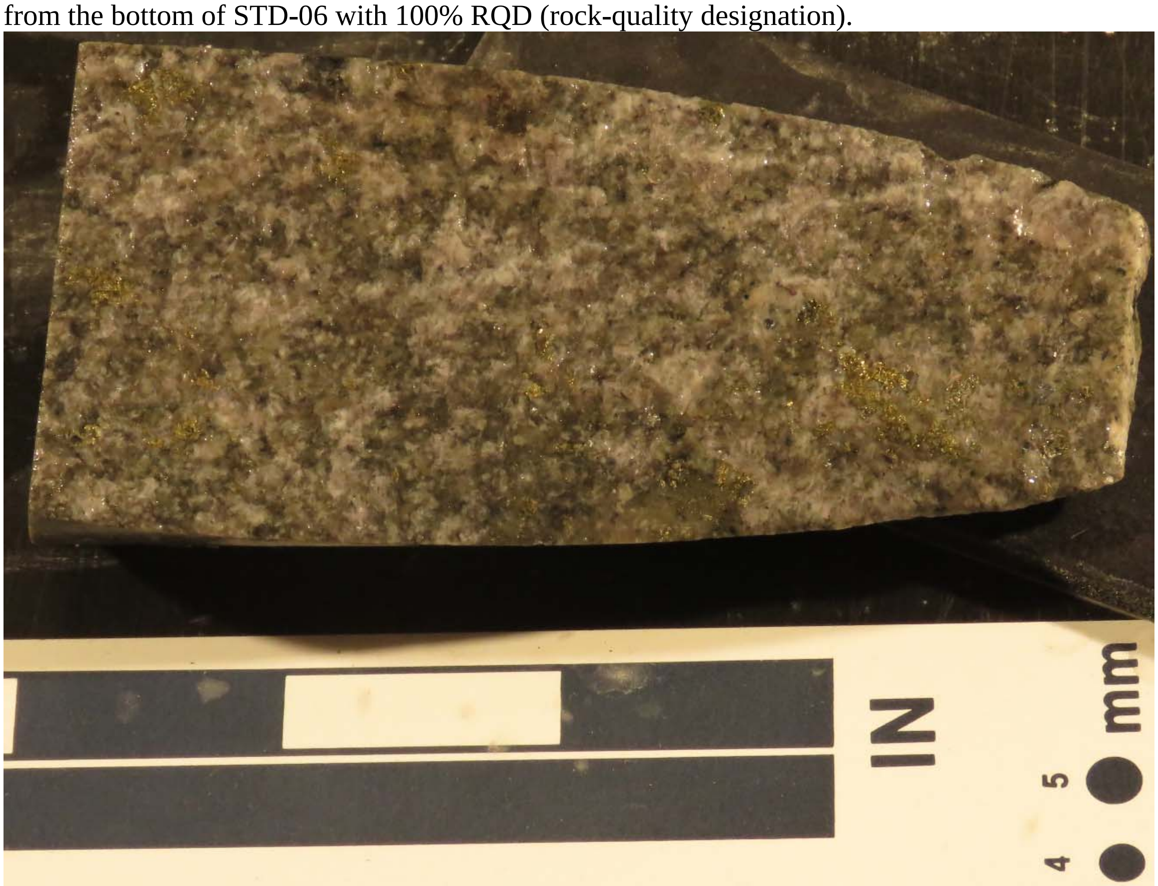


Photo 32. STD-06 core, 2940 ft, gray, andesite porphyry, biotite-K-spar alteration, 3 vol.% sulfide, late pyrite-chalcopyrite-molybdenite on late fracture.

APPENDIX III

SOUTHWEST TINTIC DISTRICT DRILL HOLE DATABASE

JUAB COUNTY, UTAH

Table A-1. Southwest Tintic drill hole database.

Hole_Number	Company	Azimuth	Inclination	Total_Depth	From_ft	To_ft	Thick_ft	Ag_ppm	Au_ppm	Cu_pct	Mo_pct	Pb_pct	Zn_pct
MT-1	Longyear JV	90	75	1,021									
MT-2	Longyear JV			1,066									
MT-3	Longyear JV	115	45	825	364	380	16	0.6				0.15	1.10
MT-4	Longyear JV			1,726	502	508	6						0.50
DDH	Cities Service		90	3,650	1,920	1,921	1		(0.03)	0.005	0.000	0.00	0.01
SWT-01	Bear Creek Mining			614	450	459	9			0.040			
SWT-02	Bear Creek Mining			652	185	276	91			0.140			
SWT-03	Bear Creek Mining			627	200	300	100			0.030			
SWT-04	Bear Creek Mining			527	507	520	13			0.100			
SWT-05	Bear Creek Mining			637	460	473	13			0.060		0.03	
SWT-06	Bear Creek Mining			713	100	110	10			0.080			
SWT-07	Bear Creek Mining			501	457	461	5			0.160			
SWT-08	Bear Creek Mining			756	340	385	45			0.150			
SWT-09	Bear Creek Mining			1,165	925	1,165	240			0.020	0.001		
SWT-10	Bear Creek Mining			811	448	455	8			0.095			
SWT-11	Bear Creek Mining			564	101	108	7			0.080			
SWT-12	Bear Creek Mining			673	661	670	9			0.030			
SWT-13	Bear Creek Mining			307	95	103	8			0.020			
SWT-14	Bear Creek Mining			221									
SWT-15	Bear Creek Mining			627	485	486	1					1.40	2.60
SWT-16	Bear Creek Mining			500	293	304	11			0.082			
SWT-17	Bear Creek Mining			508	280	290	10			0.120			
SWT-18	Bear Creek Mining			600	140	190	50			0.160			
SWT-19	Bear Creek Mining			600	590	600	10			0.040			
SWT-20	Bear Creek Mining			600	94	360	266			0.155			
SWT-21	Bear Creek Mining			600	589	600	11			0.010			
SWT-22	Bear Creek Mining			600	220	320	100			0.133			
SWT-23	Bear Creek Mining			2,010									
SWT-24	Bear Creek Mining			483	330	400	70			0.040	0.000		
SWT-25	Bear Creek Mining			525	360	370	10					0.07	0.11
SWT-26	Bear Creek Mining			1,120	190	360	170			0.194			
SWT-27	Bear Creek Mining			710	340	430	90			0.081			
SWT-28	Bear Creek Mining			705	210	310	100			0.113			
SWT-29	Bear Creek Mining			700	130	180	50			0.128			
SWT-30	Bear Creek Mining		90	3,100	80	280	200			0.113			
SWT-31	Bear Creek Mining			3,055	1,930	2,835	905			0.122	0.004		
SWT-32	Bear Creek Mining		90	1,741	1,180	1,734	554			0.163	0.010		
SWT-33	Bear Creek Mining			1,595	1,520	1,595	75			0.052	0.001		
SWT-34	Bear Creek Mining			2,269	2,540	2,610	70						
SWT-35	Bear Creek Mining		90	1,994	1,570	1,994	424			0.123	0.004		

Table A-1. Southwest Tintic drill hole database (continued).

Hole_Number	Company	Azimuth	Inclination	Total_Depth	From_ft	To_ft	Thick_ft	Ag_ppm	Au_ppm	Cu_pct	Mo_pct	Pb_pct	Zn_pct
SWT-36	Bear Creek Mining		90	3,148	1,520	3,075	1,555			0.250	0.015		
SWT-37	Bear Creek Mining		90	3,387	1,507	3,214	1,707			0.226	0.011		
SWT-38	Bear Creek Mining			1,430	300	400	100			0.100			
80-1	Centurion			900									
80-2	Centurion			200									
W-1	Bear Creek Mining	125	60	800									
W-2	Bear Creek Mining	125	60	1,000									
W-3	Bear Creek Mining	125	60	800									
81-1	Centurion		90	415									
81-2	Centurion			945									
81-3	Centurion			1,458									
81-4	Centurion			1,060									
81-5	Centurion			740									
82-5	Centurion			945									
84-1	Centurion			680									
84-2	Centurion			520									
84-3	Centurion			460									
84-4	Centurion			220									
84-5	Centurion			450									
84-6	Centurion			410									
ET-143	Bear Creek Mining			2,675									
ET-144	Bear Creek Mining			1,754									
ET-147	Bear Creek Mining			2,250									
ET-152	Bear Creek Mining			864									
ET-153	Bear Creek Mining			1,200									
ETH-01	Exxon			500									
ETH-02	Exxon			600									
ETH-03	Exxon			600									
ETH-04	Exxon			527									
ETH-05	Exxon			620									
ETH-06	Exxon			375									
ETH-07	Exxon			600									
ETH-08	Exxon			600									
ETH-09	Exxon			620									
ETH-10	Exxon			560									
STD-01	Kennecott JV		90	1,950	1,750	1,800	50	2.8	0.02	0.011	0.001	0.08	0.09
STD-02	Kennecott JV		90	2,222	1,950	2,000	50	1.0	0.01	0.023	0.002	0.04	0.06
STD-03	Kennecott JV		90	2,385	1,350	1,400	50	33.9	0.14	0.664	0.001	0.08	0.19
STR-04	Kennecott JV		90	1,500	550	600	50	48.0	0.06	0.026	0.001	0.51	0.71
STR-05	Kennecott JV		90	900	650	700	50	8.0	0.02	0.017	0.000	0.12	0.19

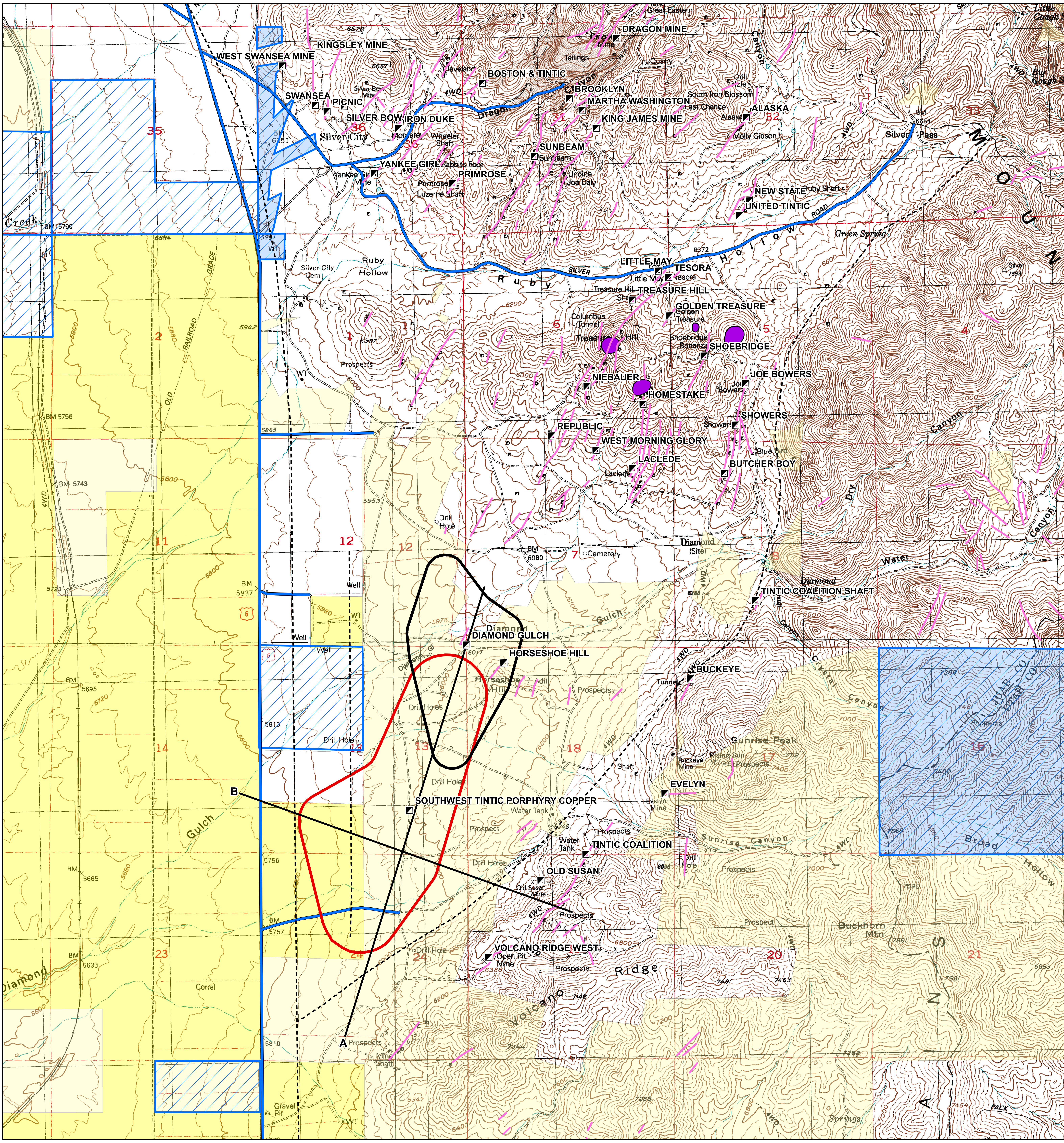
Table A-1. Southwest Tintic drill hole database (continued).

Hole_Number	Company	Azimuth	Inclination	Total_Depth	From_ft	To_ft	Thick_ft	Ag_ppm	Au_ppm	Cu_pct	Mo_pct	Pb_pct	Zn_pct
STD-06	Kennecott JV		90	2,959	1,155	2,959	1,804	1.3	0.06	0.240	0.010	0.00	0.00
STR-07	Kennecott JV		90	1,085	755	805	50	0.5	0.03	0.020	0.001	0.01	0.02
STD-08	Kennecott JV		90	1,614	855	1,105	250	32.5	0.13	0.132	0.000	0.07	0.06
STD-09	Kennecott JV		90	1,708	155	205	50	0.3	0.01	0.087	0.000	0.01	0.01
STR-10	Kennecott JV		90	595	205	305	100	0.3	0.05	0.154	0.000	0.01	0.01
STR-11	Kennecott JV		90	1,015	55	105	50	0.3	0.00	0.092	0.000	0.01	0.01
STR-12	Kennecott JV		90	580	100	350	250	(0.5)	0.01	0.153	0.000	0.01	0.01
STR-13	Kennecott JV		90	2,000									
STR-14	Centurion JV			840									
STR-15	Centurion JV		90	900									
STR-16	Centurion JV			875									
STR-17	Centurion JV			765									
STR-18	Centurion JV			600									
STR-19	Centurion JV			1,210	540	560	20			1.400			
STR-20	Centurion JV			645									
STR-21	Centurion JV			685									
STR-22	Centurion JV			745									

State of Utah
School & Institutional
Trust Lands Administration

UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources

Plate 1. Southwest Tintic Subdistrict.
UGS Contract Deliverable for SITLA
Mineral Resource Potential of the Southwest Tintic Mining District, Juab County, Utah



0 0.5 1 Miles

N

SOUTHWEST TINTIC SUBDISTRICT

by
Ken Krahulec
2018

Topographic base from U.S. Geological Survey Tintic Junction(1954), Eureka (1975), Tintic Mtn (1975), and Mc Intyre (1954) 7.5' quadrangles
Projection: UTM, Zone 12N
Units: Meters

Utah Geological Survey
1594 West North Temple, Suite 3110
P.O. Box 146100, Salt Lake City, UT 84114-6100
(801) 537-3300
geology.utah.gov

EXPLANATION

- Mine or Prospect
- Vein
- Fault
- A — Cross Section Line
- Road
- Breccia Pipe
- Diamond Gulch Chalcocite Blanket
- SWT Porphyry Cu-Mo Deposit

Land Ownership

- SITLA Minerals
- SITLA Surface
- Bureau of Land Management
- Bankhead-Jones Land Use Lands
- Private